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Measuring Globalization: Better Trade Statistics for Better Policy

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Editors

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Biases to Price, Output, and Productivity Statistics from Trade

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and
Michael Mandel
Editors

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Introduction

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Economic and trade liberalization in developing countries, coupled with technological advances that have greatly lowered trade and communication costs, have fueled an explosion in the volume of international trade since the 1990s. Trade liberalization and technological advances also have enabled a tremendous expansion in the types of international transactions, including trade in services and intangibles and the development of complex global supply chains. The accompanying expansion of multinational companies has blurred the boundaries of national economies, and the production of manufactured goods and some services increasingly has shifted to emerging economies. While international trade in goods and services has long been expanding, the speed and scope of recent changes have given rise to the term "globalization."

Among the most pressing policy questions in the United States and other advanced economies are those concerning the impact of globalization: Has globalization fostered productivity growth and well-being in advanced economies? Or have the forces of globalization weakened key national industries, resulted in widespread worker dislocation and wage stagnation, and worsened inequality? Understanding the impacts of globalization is critical to fashioning appropriate policies in a rapidly changing world. But understanding its impacts requires good data, and national statistical systems were not designed to measure many of the transactions occurring in today's global economy.

The chapters in this volume and its companion, *Measuring Globalization: Factoryless Manufacturing, Global Supply Chains, and Trade in Intangibles and Data,* identify biases and gaps in national statistics, examine the magnitude of the problems they pose, and propose solutions to address significant biases and fill key data gaps. The chapters originally were presented as papers at a research conference in 2013 funded by the Alfred P. Sloan Foundation, and their authors include researchers from academic institutions and statistics agencies in the United States and other countries.

Shifts in the location of production and associated trade patterns have been driven to a large degree by lower prices in emerging economies. The research in this volume focuses on biases in price indexes that may arise from the growth of globalization, building on work presented at an earlier Sloan-funded conference in 2009.[1] Price indexes likely fail to capture price drops that consumers and businesses enjoy when they shift purchases to lower-cost foreign suppliers—a general problem termed "sourcing substitution bias" that results in an understatement of real import growth and an overstatement of real gross domestic product (GDP) and multifactor productivity growth. Another source of bias arises from the fact that the use of imports in the economy is not tracked. Errors in the allocation of imports to industries and final consumption, which is required in the construction of key industry statistics, may have become more important as the volume and uses of imports in the United States and other advanced economies have grown. Such errors can lead to biases in input price indexes and associated biases in measures of real output and productivity growth. The decline of transportation costs also may have imparted a bias to price indexes for imports, particularly low-cost imported products.

Another source of bias to price indexes may arise when price changes associated with a new product or model are not observed. To avoid such biases for domestic product prices, the U.S. Bureau of Labor Statistics has used hedonic indexes to adjust prices for changes in product attributes, particularly for products experiencing rapid technological advances. With the growing volume of imports in technologically advanced product lines, the fact that hedonic indexes have not been used for imported products may be imparting a significant bias to import price indexes in certain product segments. At the same time, adjusting prices of domestically produced products for quality improvements has meant that price deflators in certain industries—in particular computers and semiconductors—are rapidly falling, and, correspondingly, their real value-added is rapidly increasing. As a result, relatively small industries (in nominal terms) drive measures of real GDP and productivity for aggregate manufacturing. One consequence of the use of hedonic indexes has been widespread misinterpretation of real output and productivity growth measures in U.S. manufacturing.

In addition to examining the theoretical nature of price-index biases that have been exacerbated by the growth of globalization, the chapters in this volume estimate the magnitude of various biases to price indexes and to real output and productivity growth in the United States and other countries. The findings point to a number of significant concerns, and the authors propose concrete solutions to address the biases, which include changes in the way some price indexes are constructed and the introduction of a new price survey.

The second conference volume extends the analysis to several other measurement issues arising from the growth of globalization. The fragmentation of production has given rise to so-called factoryless goods producers (FGPs): firms that design and market products but outsource the manufacturing of their products, often overseas. Several chapters consider the implications of a proposal to reclassify U.S. FGPs in the manufacturing sector. The growth of global supply chains often renders traditional international trade statistics misleading. Other chapters review new data on trade in value-added, which are designed to more accurately depict the volume of international trade and the stages of production performed in each country. Chapters in the second volume also examine the classification of output of multinational corporations in national statistics and, with the advent of the Internet, the explosion of international trade in data.

BIASES TO PRICE INDEXES: THEORY

In “Sourcing Substitution Bias and Related Price Index Biases,” Alice Nakamura, Erwin Diewert, John Greenlees, Leonard Nakamura, and Marshall Reinsdorf provide a thorough examination of biases to price indexes, with a special emphasis on biases resulting from the growth of international trade. A set of price index biases Nakamura et al. collectively label “sourcing substitution biases” arise from the methodology the U.S. Bureau of Labor Statistics and statistical agencies in other countries use in constructing price indexes. In particular, the BLS collects periodic price quotes for very specific products (e.g., a 10.75-ounce can of Campbell’s soup) sold by a specific retail outlet in the case of the Consumer Price Index (CPI), sold by a producer in the case of the Producer Price Index (PPI), or purchased by an importer in the case of the Import Price Index (MPI). The price changes reflected in the CPI, PPI, MPI, and other price indexes are essentially computed as weighted averages of the price changes of product-seller (or purchaser) observations (e.g., the price change of a 10.75-ounce can of Campbell's soup sold at the Walmart outlet in Kalamazoo, Michigan) as collected in BLS surveys.

As Nakamura et al. explain, this methodology implicitly assumes that the "law of one price" always holds: any observed difference in prices between apparently similar products is assumed to be the result of differences in product quality. Yet, the law of one price is routinely violated. Sourcing substitution bias arises when buyers shift from a high-cost supplier to a low-cost supplier of a good or service. Because price indexes are generally derived as weighted averages of price changes of specific products within the surveyed establishments, price drops that purchasers enjoy when shifting from a high- to a low-cost supplier are not captured. The rapid growth of low-priced big-box retailers such as Walmart and the decline of high-priced small retail stores raised concerns in the past that growth of the CPI was systematically overstated (see, for example, Reinsdorf [1993] and Diewert [1998]). So-called outlet substitution bias is one type of sourcing substitution bias.

The dramatic growth of emerging economies, most notably China, since 2000 and associated shifts in the location of production have raised concerns about other types of sourcing substitution biases. The growing share of U.S. imports coming from emerging economies reflects a shift in production away from high-cost suppliers in the United States and other advanced economies to low-cost suppliers in emerging economies. The cost savings enjoyed by consumers or businesses from these shifts to low-cost overseas suppliers is not captured in the import price index, resulting in an upward bias in this index. In addition, as emphasized in several chapters in this volume (Alterman; Fukao and Arai; Houseman, Bartik, and Sturgeon; and Nakamura et al.), the import price index is used to construct industry input price indexes, which in turn are used to compute the growth of industry real value-added. Upward bias to the import and input price indexes from shifts in sourcing from either high-cost domestic or foreign suppliers to low-cost foreign suppliers results in an upward bias to aggregate and industry real GDP growth and certain productivity measures. Nakamura et al. point out that price index biases arising from shifts in sourcing cannot be addressed simply by altering the formula used to construct the price indexes; the price drop associated with the shift to a low-cost supplier is not measured under current procedures, and no amount of reweighting of observed prices will fix the problem.

A closely related problem for price indexes arises from the introduction of new products or models, as is discussed in chapters by Nakamura et al., Brian Kovak and Ryan Michaels, and Mina Kim and Marshall Reinsdorf. In order to compute a price change for a specific product sold or purchased by a specific establishment, it must be in the sample for two periods. When new products or models are introduced into price samples, typically it is assumed that the price change for the new item is the same as that for closely related ongoing products—a procedure called "linking in." Often, however, price changes coincide with model changes. For example, a company may embed a price increase into a new model; to some degree the higher price of the new model may reflect higher product quality and to some degree a pure price increase. Because new models are likely to be subject to the linking procedure when they are added to price samples, the price increase in this example is missed, a problem called "product substitution bias" (Nakamura and Steinsson 2012).

Conversely, Kim and Reinsdorf point out that, particularly for products undergoing rapid technical improvements, the linking in procedure may result in a substantial overstatement of price index growth. Unlike in other BLS price indexes, hedonic methods to adjust for changes in product attributes, and thereby avoid linking in, are not used in the construction of import and export price indexes. Consequently, these indexes are especially subject to this type of bias.

Similarly, when businesses and consumers shift purchases to a lower-cost foreign product, the product typically is not identical to the one for which it is substituted. Indeed, the import price index, which is based on a survey of importers, treats country of origin as a product characteristic. This practice virtually assures that if an importer shifts its purchases of particular products, say, from Japan to China in response to lower Chinese prices, the Chinese products will be linked into the sample and the price drop for importers missed, no matter how close in specification the Chinese and Japanese products.

The common justification for the assumption that the law of one price always holds, which underlies current price index methodology, is that arbitrage eliminates any price differences. Building on earlier work in which they find large, systematic, and persistent cross-country price differences among semiconductor wafers with identical product specifications (Byrne, Kovak, and Michaels 2013), Kovak and Michaels argue that trading frictions may interfere with arbitrage. In "Assessing Price Indexes for Markets with Trading Frictions: A Quantitative Illustration," they develop a theoretical model describing the price dynamics of incumbent and new suppliers when buyers face high short-term costs in switching suppliers. Their theory is motivated by the stylized facts of semiconductor wafer production in which it is prohibitively expensive for wafer design firms to switch contract manufacturers for a specific design because of high manufacturing setup costs. In the short term, the incumbent supplier gouges firms that cannot switch. Over time, the prices of old and new suppliers converge. Importantly, their model can explain changes in relative prices when no change in the characteristics of the product or service provided by the suppliers has occurred.

Several chapters examine potential sources of bias to price indexes that are unrelated to sourcing substitution or to the introduction of new models or products. Benjamin Bridgman examines transportation costs for imported and exported goods and their implications for price indexes. Usually, the lower a good's price, the larger the share of its total price made up by transportation or specific trade costs. Most notably, with transportation costs generally falling over time, the price indexes of lower-priced goods from emerging economies like China will rise more slowly than those for higher-priced products from advanced economies, all else being the same. Falling transportation costs, therefore, will tend to result in an overstatement in the growth in real (quantity of) imports from emerging economies relative to advanced economies. The size of trade costs is particularly high in final goods prices, but Bridgman notes that as trade costs fall, this source of bias will become less important.

As discussed in chapters by Jon Samuels, Thomas Howells, Matthew Russell, and Erich Strassner and by Kyoji Fukao and Sonoe Arai, a different type of bias to the input price index may arise from the fact that statistics agencies generally do not track the destination of imports in the economy. Instead, agencies must make assumptions about how imported goods and services are allocated between final demand and intermediate uses in industries. Typically, statistics agencies assume an industry's use of an imported item is proportional to its overall use of the input in the economy—the so-called import comparability or import proportionality assumption. For instance, if an industry accounts for 10 percent of the use of a particular product, then it is assumed that it uses 10 percent of the imports of that product. Input price deflators are constructed for each industry as a weighted average of domestic and import prices. If the allocation of imported and domestic inputs to an industry is incorrect and if price trends of imported and domestic inputs differ, industry input price indexes could be significantly biased. Because input price indexes are used to compute an industry's real value-added and certain productivity growth measures, these statistics could be biased as well. As Fukao and Arai note, however, if one industry is using relatively more of an imported input, another industry will be using relatively less. As a result, the biases across industries will tend to cancel each other out and so have little effect on the accuracy of aggregate GDP or productivity measures.

EMPIRICAL EVIDENCE OF THE EFFECTS OF PRICE BIASES

The work in this volume significantly extends empirical research presented at the 2009 conference on the magnitude of biases to U.S. price index, real output, and multifactor productivity growth measures arising from the shift in sourcing to lower-priced foreign manufactured goods. In order to estimate these biases, researchers must make assumptions about the quality-adjusted price gaps for goods in advanced and emerging economies when shifts in sourcing occur. Reinsdorf and Yuskavage (2014) utilized apparent inconsistencies between, on the one hand, the Consumer Price Index—which the authors point out should be less prone to sourcing substitution bias—and, on the other hand, the Producer and Import Price Indexes to estimate the bias to the Import Price Index for manufactured goods. They find evidence of substantial upward biases to import price indexes in durable goods and selected nondurable goods. Although the implication of these biases for aggregate real GDP growth is modest, Reinsdorf and Yuskavage estimate that aggregate multifactor productivity growth was overstated by about 10 percent between 1997 and 2007.

Other prior research used case study evidence along with microdata on import prices to assess price differences between manufactured goods produced in emerging economies, in intermediate countries, and in the United States and other advanced economies. Under various assumptions about the price gap, Houseman et al. (2011) estimate that between 1997 and 2007, real value-added in U.S. manufacturing was overstated by 0.2 to 0.5 percentage points and multifactor productivity by 0.1 to 0.2 percentage points. Although the bias to real value-added growth was a relatively small share of measured growth in the computer and electronic products industry, it may have accounted for somewhere between a fifth and a half of the growth in the rest of manufacturing.

In this volume, authors use a variety of other evidence on price declines associated with the shift in sourcing to low-cost foreign suppliers in order to estimate biases to price indexes and to real output and productivity growth in the United States and other countries. The Japanese government collects unique data on the prices of products sold in Japan as compared to other countries, including the United States and China. In their chapter, “Biases to Manufacturing Statistics from Offshoring,” Fukao and Arai find substantial price gaps for inputs sold in developing countries and Japan, not only in products such as apparel and textiles but also in machinery. They estimate that large price gaps and growth of imported intermediates resulted in substantial underestimates of real input growth and overestimates of multifactor productivity growth, especially in Japan’s machinery sector.

In the appendix to “Measuring Manufacturing: How the Computer and Semiconductor Industries Affect the Numbers and Perceptions,” Timothy Bartik, Timothy Sturgeon, and I use prior estimates of the bias to real value-added growth for U.S. manufacturing (Houseman et al. 2011) to estimate the biases to manufacturing real value-added growth for each U.S. state. Over the decade ending in 2007, we find that adjusting for sourcing substitution bias lowers manufacturing real value-added growth rates by 0.1 to 0.7 percentage points, with the largest adjustments occurring in Michigan, Kentucky, Ohio, and Indiana.

The biases to manufacturing examined in our chapter could result from a shift in sourcing of intermediate inputs from high-priced domestic suppliers to low-priced foreign suppliers (offshoring) or from high-priced foreign suppliers to low-priced foreign suppliers (shifts in import sourcing). Two chapters in the volume—"Import Sourcing Bias in Manufacturing Productivity Growth" by Robert Inklaar and "Import Allocation across Industries, Import Prices across Countries, and Estimates of Industry Growth and Productivity" by Samuels et al.—focus solely on the latter source of bias.

Inklaar examines what he terms "import sourcing bias" in the manufacturing sector in all major trading countries from 1995 to 2008. To estimate cross-country price differentials for specific products, Inklaar computes unit values of imports from United Nations Comtrade data. He acknowledges that this approach has certain drawbacks. One is that, whereas the methodology used by statistics agencies assumes that all cross-country price differences are attributable to product quality differences, the use of unit values assumes the opposite extreme: None of the observed price differences reflect product quality differences. Moreover, because unit values are computed on fairly aggregated product categories, there is likely to be considerable heterogeneity in the products included in them. Despite these caveats, the average price differentials that Inklaar finds are generally in line with case study evidence, and they fall over the period studied. For the advanced European countries, the median price differential from importing a particular product from another advanced EU country versus a new EU country (the latter having been former Soviet bloc members) or from another emerging economy (such as China) was 30 to 35 percent in 1995. That price gap had fallen to 10 percent for new EU countries and to 20 percent for other emerging economies by 2008.

Inklaar estimates that annual multifactor productivity growth for manufacturing sectors in 20 advanced countries was, on average, overstated by 0.18 to 0.34 percentage points, representing 13 to 25 percent of MFP growth over the period. Evidence of import sourcing bias was considerably higher in advanced European countries than in the United States. Using Inklaar's methodology, Samuels et al. also report little import sourcing bias for U.S. manufacturing. Not surprisingly, Inklaar finds no evidence of import sourcing bias in emerging economies.

Although Inklaar's findings should be interpreted with caution, they suggest that import sourcing bias could be significant in many countries.

Using detailed data on prices and product characteristics for specific items, the chapters by Kovak and Michaels and by Kim and Reinsdorf are not subject to these concerns and also report large cross-country differences in prices, even after carefully controlling for differences in product quality. Kovak and Michaels use detailed proprietary transaction price data between firms that specialize in the design and marketing of semiconductor chips and foundries that specialize in fabricating chips for these firms. They find large cross-country differences in the transaction prices for chips with identical specifications, although the prices display some convergence over time. Nonetheless, the authors acknowledge that at least some part of the observed price differentials could be the result of differences in the services provided by the fabricators, such as the rate at which chips are rejected for quality reasons. In an industry such as semiconductors that is characterized by high switching costs in the short term, Kovak and Michaels argue that cross-country price differentials observed late in the product cycle reflect time-invariant quality differences. Adjusting for quality differences, their simulations suggest that semiconductor price indexes substantially understate the true price decline because price drops associated with switching to lower-cost providers in countries such as China are not captured.

In "The Impact of Globalization on Prices: A Test of Hedonic Price Indexes for Imports," Kim and Reinsdorf use hedonic price index methodology to control for cross-country differences in product attributes and to test for the existence of substantial biases in import price indexes. The authors note that both rapid technological change and shifts in sourcing across countries are likely to result in biased import price indexes. Products from different countries or products with substantially new attributes are treated as different products, and under the matched model procedures used in the construction of import price indexes, price changes associated with a shift in sourcing to a lower-cost country or with the introduction of a new product are missed. Hedonic price indexes adjust for quality differences between products, allowing price changes associated with the introduction of new products or shifts in product sourcing to be taken into account. While other BLS price indexes sometimes use hedonic adjustments to avoid these price index biases, hedonic indexes have not been used to adjust import prices.

The purpose of this chapter is to demonstrate the feasibility of hedonic indexes for import prices, using televisions and cameras as test cases.

Kim and Reinsdorf supplement information on product characteristics collected as part of the import price survey with information about these products available on the Web. They find evidence of significant biases in import price indexes for these product groups, both of which were characterized by substantial technical advances and shifts in country sourcing. For televisions, they estimate an upward bias in the import price index of 2.2 percentage points per year, of which 1.3 points derive from undermeasured gains from new technology and 0.9 points from unmeasured price declines from country substitution; for cameras they estimate an upward bias of 10.5 percentage points per year, with 5.8 points deriving from technology and 4.7 points from country sourcing changes.

The chapter by Kim and Reinsdorf underscores the importance of accounting not only for shifts in sourcing but also for technological change in those products when constructing price indexes. Failure to properly account for technological improvements in imported products could result in a significant understatement in the real growth of imports and correspondingly in an overstatement of measures of domestic real output and productivity growth. By implication, consistent use of hedonic price index methodology for domestic and imported products is critical.

The use of hedonic indexes raises other concerns, however, as is illustrated in my chapter with Bartik and Sturgeon. The U.S. CPI and PPI use hedonic indexes to adjust for quality improvements in products subject to rapid technological change, most notably computers and semiconductors. Although adjusting for improvements in product quality is appropriate, we argue that it has led to substantial misinterpretation of U.S. manufacturing statistics. In recent decades, measured real GDP growth in U.S. manufacturing has exceeded or kept pace with aggregate GDP, except during recessions, and many have pointed to these growth statistics as an indicator of manufacturing's strength in the United States. Virtually all of that growth, however, is attributable to the computer and semiconductor industries. Although these industries account for a small share of nominal manufacturing output, their prices, when adjusted for product improvements, are rapidly declining, and their real value-added growth substantially outpaces that in other industries, thus explaining the outsized effect these industries have on aggregate manufacturing statistics. Hedonic price indexes are highly sensitive to methodology used. Moreover, using proprietary data on global production of computers and semiconductors, we show that the United States was declining as a location of production for these products, even while they were driving the apparent robust growth in U.S. manufacturing.

Other problems may arise from the fact that countries generally do not track the destination of imports in the economy. The chapters by Samuels et al. and Fukao and Arai examine possible biases to input price indexes, real value-added, and multifactor productivity resulting from inaccuracies in the allocation of imported inputs to final demand and to industries as intermediate inputs. Samuels et al. find that, compared to the standard import comparability assumption, allocating imports to final and intermediate uses based on broad economic categories—as proposed by Timmer (2012)—does result in a substantially different allocation of imports to intermediate uses for some product categories. This alternative allocation does not incorporate any new information about import uses in the economy but instead simply varies the assumption about their use. In contrast, Japan collects information on the destination of imports in the economy. Fukao and Arai exploit this information to test how real input and multifactor productivity growth for Japanese industries vary under import allocations based on survey data, as compared to allocations based on the import comparability assumption, which is used in most countries. They find substantial over- and underestimates of real input and productivity growth at the detailed industry level, although they note that, by construction, these errors will tend to cancel each other out in the aggregate economy.

It is important to note that errors in the allocation of imports at the industry level have potentially important implications for economic impact analyses commonly conducted with these data. Analysts often use industry data to predict the effects of increases or declines in an industry's output on employment and income at the local, regional, or national level. These effects depend critically on industry input-output relationships, which govern the spillover effects on employment and income in supplier industries. The employment and income effects of policies targeting a particular industry, for instance, will be lower as the imported inputs used by the industry become greater.

SOLUTIONS

To address biases that rapid technological progress and globalization have likely exacerbated, several chapters propose fundamental changes to the way various price indexes are constructed. Nakamura et al. recommend that in many circumstances the BLS depart from its standard practice of collecting single-point-in-time price quotes for specific products from specific establishments. They point out that the advent of UPC codes and electronic communications enables firms to easily supply the universe of transaction prices on specific items over the course of the month. Averaging these transaction prices within establishments would eliminate biases to price indexes that result from sales promotions. Averaging UPC transaction prices across establishments would be necessary to address outlet substitution bias in the CPI, the form of sourcing substitution bias that occurs when buyers shift purchases to stores offering lower prices. Some have argued that pure transaction price data do not reflect auxiliary attributes that products acquire as a result of where the products are sold; for example, some consumers may find shopping at a small but higher-priced store less time consuming or otherwise more pleasant than at a low-priced big-box store. As the authors point out, however, international guidelines explicitly state that the unpaid time consumers take in shopping should not be taken into consideration in constructing price indexes.

While the averaging of transaction prices for UPC codes would help address outlet substitution bias in the CPI, it would not deal with other types of sourcing substitution bias, including biases stemming from shifts in purchases to low-cost foreign suppliers. This is because no matter how similar the products, UPC codes are unique to a producer—domestic or foreign. To address biases in import price indexes, Kim and Reinsdorf propose using hedonic indexes in lieu of matched model indexes, which miss price changes that occur whenever new models are introduced or importers shift to lower-cost foreign suppliers. The authors demonstrate that information already collected as part of the BLS import prices program, when supplemented with publicly available information on the Internet, is sufficient to implement hedonic indexes, and that biases in matched model indexes can be sizable.

The use of hedonic indexes in computing import price indexes would only address sourcing substitution biases associated with shifts from a high- to a low-cost foreign supplier. To more completely address sourcing substitution bias in input price indexes, William Alterman, the former BLS assistant commissioner for international prices, proposes a new price index that would be based on a survey of input purchasers. As noted, input price indexes miss price declines whenever firms shift from high- to low-cost suppliers of intermediate inputs; these shifts could be from a high- to a low-cost domestic supplier, from a high-cost domestic supplier to a low-cost foreign supplier, or from a high-cost foreign supplier to a low-cost foreign supplier. When such price drops are not captured, the growth of the industry's input price index, real value-added, and certain productivity measures are overstated. In theory, input purchasers could report a price change, even when they source the input from a new supplier. In "Producing an Input Price Index," Alterman reports findings from an initial examination of the feasibility of constructing an input price index for materials inputs. Although some technical issues along with budget constraints pose significant challenges to the introduction of a new price survey, Alterman concludes that fielding a sample of materials purchasers is possible and that, in general, businesses can periodically report prices on input purchases. Nakamura et al. and Kim and Reinsdorf point out that, if implemented, such a survey would need to collect data on product characteristics so that prices could be adjusted for changes in product attributes whenever models or suppliers change.

Alterman acknowledges that the proposed input price bias is not a panacea. It would not, for instance, capture price declines when firms outsource or offshore work previously done in-house. This is because data on the price for work previously done in-house would not exist and so could not be compared to the price from an arm's-length transaction. Moreover, because in official statistics aggregate GDP is computed from the expenditure side as the sum of final consumption, investment, government purchases, and net exports—not as the sum of value-added across industries—a fully implemented input price index would address biases from sourcing substitution to real GDP and productivity measures for industries, but not for the aggregate economy. The use of hedonic indexes for import prices, as proposed by Kim and Reinsdorf, would address some of the bias to both aggregate and industry real GDP measures from sourcing substitution. Information from biases to the input price index or from discrepancies between movements in the CPI, PPI, and MPI, as discussed in Reinsdorf and Yuskavage, potentially could be used to better address biases to aggregate output and productivity measures.

Adjusting prices for changes in product quality, however, also may mean that products experiencing rapid technological change will dominate movements in aggregate statistics, as Bartik, Sturgeon, and I illustrate with the outsized effect that the computer and semiconductor industries have on real GDP growth in U.S. manufacturing. To mitigate confusion and misinterpretation of the data, we argue that statistical agencies should make clear the influence certain industries have on aggregate statistics—for example, by also publishing subaggregates without these industries.

The case of U.S. manufacturing raises broader questions about how to measure competitiveness in a global economy and in an era of rapid technological change. Traditionally, economists and policymakers have looked to real output and productivity measures to assess an industry's competitiveness. Yet the United States was declining as a location for production of computers and semiconductors even while these industries accounted for the robust output and productivity growth in U.S. manufacturing. My coauthors and I argue that international data on the location of production are necessary to assess the global competitiveness of a particular industry or sector in a country.

In addition, the fragmentation of production raises difficult classification issues. For example, although the competitiveness of the United States as a location for the production of computers and semiconductors has declined, much of the product design work and marketing remains in the United States. These activities usually are counted in the research or wholesale trade sectors, though they traditionally are integral parts of manufacturing. These developments arguably necessitate a rethinking about how activities in the economy are classified.

The companion to this volume examines these issues in greater depth. Several chapters focus on a recent proposal to classify so-called factoryless goods producers in manufacturing, explaining the rationale for the proposal, the current prevalence of FGP activities in the United

States, and the likely effect of such a change in classification on manufacturing statistics. The second volume also reports on recent efforts to develop data sets measuring trade in value-added. Value-added of a product produced in a global supply chain may be counted multiple times in international trade statistics, which measure gross flows of imports and exports. Electronic components, for example, produced in Japan may be exported to China for assembly into final consumer goods. The value-added of the electronic components will be counted once in Japan's exports and again in the Chinese exports of consumer electronics. Similarly, bilateral trade statistics can be misleading: Imports from a particular country may contain substantial amounts of value-added from other countries, and the import content of a country's exports may be sizable. Data on trade in value-added are needed to understand what is made where and, ultimately, to assess the competitiveness of national industries and activities in the supply chain. Advances in technology and communications that have allowed the explosion of trade in manufactured products have permitted the rapid expansion of multinational companies and of trade in services and intangibles, many of which were previously regarded as "untradeable." Chapters in the second volume also examine the thorny issue of attributing output from multinational companies to the countries in which they operate as well as evidence that trade statistics greatly understate cross-border flows of data, raising concerns about recent policies in some countries to discourage these flows.

Note

1. The conference "Measurement Issues Arising from the Growth of Globalization" was held November 6–7, 2009. Summaries of the conference research and of its research papers are available at http://research.upjohn.org/externalpapers/7/ and http://research.upjohn.org/reports/130/, respectively.

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Part 1

Trade-Related Biases to Price Indexes: Theory

2
Sourcing Substitution and Related Price Index Biases

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Price indexes are fundamentally important for understanding what is happening to national economies. Unfortunately, for reasons we will explain, price-index bias problems seem likely to have grown with the evolution of information technologies and accompanying changes in business price setting and product-variant development practices, as well as with the growth in the amount and timeliness of price information available to potential buyers. We argue, however, that specific changes to statistical agency practices and data-handling capabilities can greatly reduce the bias problems we focus on.

We recommend hybrid alternatives to the conventional price indexes. Our hybrid indexes use unit values to combine price information for transactions that take place at different prices for homogenous product items. The hybrid indexes reduce to the conventional price indexes when there is truly just one price per product each time period. This recommendation is in line with the advice provided in several international price index manuals such as ILO et al. (2004a,b, 2009). For example, in the manual for the Producer Price Index (PPI) it is stated that "having specified the [product] to be priced . . . , data should be collected on both the value of the total sales in a particular month and the total quantities sold in order to derive a unit value to be used as the price . . ." (ILO et al. 2004a, p. 22).

Some of the prices used in a typical U.S. Bureau of Labor Statistics PPI are calculated now in this way. Yet, as a rule, the conventional statistics agency practice does not measure prices as unit values.[1] The conventional practice of national statistics agencies is to collect the price of a precisely defined product at a particular establishment and designated point in time, with this collection process being designed to yield a unique price each period for the given product-establishment combination. (See, for example, BLS [2007a,b,c,d].)

Throughout the chapter, a short list of terms is used in distinct ways that are important to bear in mind: product unit (or "product" for short), product unit item (or "product item," or simply "item"), product content, index basket product unit (or simply "index basket product"), the unit value (or, equivalently, the "unit value price," or "unit price"), and the product content unit value. Our usage of, and need for, these terms are most easily conveyed in a specific context. We will use the example of Campbell's tomato soup, which is most often sold in a 10.75-ounce can, but it is also available in a variety of other can sizes, including a 15.2-ounce can.

We define a product by the brand and the company that owns the brand, or at any rate that is responsible for the product (if, say, it is not marketed under a brand name), and by the precise nature of the product content as well as by the specific sort and size of packaging the product is sold in. A commercial product is assigned a Universal Product Code (UPC) by the company responsible for the product. The rules for how UPCs are to be assigned are maintained by (and conformity with them is monitored by) an international governing body (as we explain subsequently), to which a company must belong in order to be able to assign UPCs to the company's products.

Products of different companies have different UPCs. The rules for assigning UPCs also dictate that if either the content or the nature or size of the packaging format differs for products produced by a company, then separate UPCs must be assigned. The way in which we use the term “product unit” or “product” is consistent with how commercial products are defined for UPC assignment. Hence a 10.75-ounce can of Campbell’s tomato soup, which is the most common can size, is a separate product from a 15.2-ounce can of Campbell’s tomato soup.

Each can of the 10.75-ounce size for Campbell’s tomato soup is referred to as a “product item” or simply an “item.” No matter how short the time period, different items of a product may sometimes be sold by different merchants or even the same merchant at different prices. For example, the same grocery outlet on the same day could sell 10.75-ounce cans of Campbell’s soup at different prices because a promotional sale began partway through the day, or because some cans had stickers on them for a lower price owing to an earlier promotional sale, or because of arrangements such as discounts for customers who have coupons. The average of the prices for which items of a product are transacted in a stated time period and market area is the unit value (or unit price).

The product content is what is inside a can of Campbell’s tomato soup, and that content is the same whether it is a 10.75-ounce can or a 15.2-ounce can. In many jurisdictions in the United States, a grocer is required by law to display for each product not only the per-item price for the product, but also the price being charged for a stated unit of quantity of the product content, such as a fluid ounce. The latter sort of standardized prices are sometimes referred to as “unit value prices,” but they do not result from any sort of averaging of the realized prices in different transactions, and this is not what we mean (nor what is meant in the index number literature) by the term “unit price” or “unit value.”

Price indexes are defined for baskets of products. The basket for, say, the U.S. Consumer Price Index (CPI) consists of product categories. At each retail outlet selected for price collection for the CPI program, when price collection is initiated there, the price collector chooses, based on outlet information about product sales at that outlet, a specific product unit for each CPI product category for which prices are to be collected there. Each selected product then becomes an index basket product for which a price collector attempts to collect a price each pricing period.

Suppose now that a 10.75-ounce can of Campbell’s tomato soup has been selected as an index basket product to be priced, period after period, at a specific establishment. And suppose that the establishment subsequently ceases to sell the 10.75-ounce cans and switches to instead selling the 15.2-ounce can format for Campbell's tomato soup. In this situation, the decision could be made to "quality-adjust" the price for the 15.2-ounce can so that the observed price for that product item could be used as a proxy for the missing price for the 10.75-ounce Campbell's tomato soup index basket product. The simplest such adjustment would be to compute the per-ounce price for the soup sold in the 15.2-ounce can and then to multiply that times 10.75, with the resulting value being used as a proxy price for Campbell's tomato soup in a 10.75-ounce can.[2]

The chapter's second section, titled "Background Material," introduces the issues. Section Three, "Basic, Hybrid, and Conventional Versions of Laspeyres, Paasche, and Fisher Price Indexes," provides notation and definitions used in the rest of the chapter. The Laspeyres, Paasche, and Fisher price index formulas are introduced in the basic forms in which these are usually presented in textbooks and in the economics, accounting, and price-index scholarly literatures. Next we develop hybrid price-index formulas that explicitly allow for possible price differences in a given time period for homogeneous units of each product. We proceed to develop grouped transaction variants of the conventional and hybrid price index formulas that allow us to conveniently represent various bias problems for the conventional indexes.

In the fourth section, "Different Sorts of Price Index Selection Bias," we use our bias formula for a Laspeyres-type price index to characterize certain ways in which bias can arise. The biases discussed include the recognized problem of Consumer Price Index (CPI) outlet substitution bias,[3] the CPI promotions bias defined in this chapter, and what Diewert and Nakamura (2010) define as "sourcing substitution bias" in the PPI and Import Price Index (MPI).[4] We deal briefly as well with sourcing substitution bias in the proposed new Input Price Index (IPI).

The U.S. Bureau of Labor Statistics (BLS) produces the price indexes we focus on in this chapter. The BLS largely abandoned the use of unit values in price index compilation because of advice from experts, including the 1961 report of the Stigler Committee (Price Statistics Review Committee 1961), and research by its own staff (exemplified by Alterman [1991]).[5] In the fifth section, "Five Sorts of Barriers to Adoption of Unit Values for Official Statistics Purposes," we examine the problems with unit values that are highlighted in the Stigler

Committee report and also by Alterman (1991). We explain why the main basis of condemnation in those historical reports does not pertain to our present unit-value recommendation.

Nevertheless, there are formidable practical challenges to implementing unit values as we recommend. Producers give their products identifying names and Universal Product Codes (UPCs). UPCs have come to play ubiquitous roles in business information systems for managing all aspects of the handling of products and their associated cost and sales financial flows. Once a 10.75-ounce can of Campbell's tomato soup is shipped out from the production facility carrying the UPC that Campbell's has assigned to that product, then that UPC stays with that soup can wherever it goes.

However, along the way from the original producer to the final purchaser, a unit of a product can take on auxiliary attributes that may matter to the final purchaser, or to the final user, or both, and that may be associated with price differences. For example, some of the cans of tomato soup may be shipped by the producer to convenience stores, and some may be shipped to superstores.[6]

Separate UPCs are sometimes defined for products that most users might regard as differing only in ways that make no difference to them. This issue can arise, for example, with products that differ in ways that are necessary for avoidance of a patent infringement ruling but that are intentionally the same in terms of all attributes of concern to most users. Or a producer might bring out a slightly reformulated product with a different UPC and with a price that yields a higher profit margin.[7] When a producer brings out a new product and discontinues an older one, if the product change is trivial, a statistics agency may decide that the reformulated version of the product should be treated as a continuation of the original version so that the price increase can be captured. We discuss operational issues that arise in situations like these in the subsections below that deal with what we refer to as "Impediment 3" and "Impediment 4" (see also Reinsdorf [1999]).

How, then, can we best measure price change over time when units of precisely defined and interchangeable product items are sold at different prices in the same time period and market area? And when is it best to treat highly similar but commercially distinguishable products as separate products for inflation measurement purposes? Consideration of these questions requires an understanding of the role of measures of inflation in the compilation of other key economic performance measures for nations: the topic of Section Six, titled “Inflation Measurement Effects on Other Economic Performance Measures.” Finally, in the seventh section, “Possible Price Measurement Practice Reforms,” we suggest possible changes to conventional price-index-making practices.

Two brief appendices provide additional materials that some readers may find helpful. In Appendix 2A, we show with a numerical example that the featured bias problem in the example cannot be fixed simply by adopting a superlative price index formula like the Fisher.[8] Appendix 2B demonstrates why, ideally, the same product definitions should be used both for price quote collection and for the collection of the data needed to compute value-share weights.

This chapter is written with three different groups of readers in mind. One group consists of those who view the averaging of observable prices for different items of the same product to form unit values as an inferior practice. We hope to persuade these readers that for a wide class of price index uses, including the deflation of gross domestic product (GDP) components, it is important that the price quotes utilized be representative of the prices for the transactions that make up the associated value aggregates.

A second group we hope will benefit from this chapter are those who were already convinced by what early contributors to the price index literature—Walsh (1901, p. 96; 1921, p. 88), Davies (1924, p. 183; 1932, p. 59), and Fisher (1922, p. 318) in particular—wrote long ago on the use of unit values in price indexes. These are experts who hold the view that there is no need to elaborate on the issues we deal with in this chapter. We hope to persuade these readers that there is considerable value in having a more explicit exposition of these issues. We hope too that these readers will turn their research efforts toward helping to develop feasible implementation strategies for the sort of approach that we recommend.

A third group of readers that we hope to engage with this chapter are those not previously acquainted with some of the price index bias problems that we focus on, including the sourcing substitution bias problems defined by Diewert and Nakamura (2010) and for which Houseman et al. (2011) provide the first empirical results. We hope to provide these readers with a readily understandable exposition of these biases. We feel it is crucial for economists at large to understand how these inflation measurement distortions arise and why they have likely become more serious in recent years.

BACKGROUND MATERIAL

In this chapter, we focus mostly on three main price indexes produced by the BLS: the Consumer Price Index (CPI), the Producer Price Index (PPI), and the Import Price Index (MPI). We focus on one aspect of conventional official statistics price-index-making and abstract from many other important issues in the process. It should also be noted that although our discussion will focus on the handling of prices for physical products with associated UPC codes, the major price indexes include services as well as goods categories.

Knowing some specifics of how price indexes are produced is helpful for considering price index bias problems. The official price indexes used to measure inflation first aggregate price relatives into elementary indexes for narrow categories of products, such as men's suits or crude petroleum. They then aggregate the elementary indexes, in most cases employing a Laspeyres or similar formula.[9] Price relatives are ratios of current to previous period prices for specific products sold by specific establishments. The aggregation formula for an elementary price index typically includes weights for the price relatives that reflect shares of the total value of the transactions (and may also take sample selection probabilities into account). Similarly, weights that reflect shares of total expenditure for the products covered by each of the elementary indexes are used to aggregate the elementary indexes in order to arrive at higher-level and overall inflation measures like the "All Items CPI" or the "PPI for Final Demand."

The CPI is intended to measure the inflation experience of households, so the value share weights used for the CPI are based on household survey information. However, the product units included in the CPI basket are priced at selected retail outlets because it is operationally easier to collect prices from businesses.

The PPI primarily measures changes in prices received by domestic businesses in selling their products to other domestic or foreign businesses. Selected products are regularly priced at selected establishments of domestic producers. The PPI value-share weights are based on what domestic businesses report as their sales revenues by product.

The BLS produces the MPI as part of its International Price Program. The MPI is intended to be a measure of the inflation experience of domestic purchasers of imported products. Products are priced at selected U.S. importer establishments, and the value-share weights are based on U.S. survey and customs data for all imports.

We find it useful to differentiate what we call primary product and auxiliary product attributes. We define “primary product attributes” (or simply “primary attributes”) as characteristics of an item of the product when first sold by the original producer that continue to be characteristics of the product item regardless of where and how it may be resold on its way to the final purchaser. We define “product item attributes” as “auxiliary attributes” if an item acquires these attributes as a consequence of how it is cared for on its way to the merchant that makes the final sale or because of where or how it is sold. For example, being sold during a promotional sale is a potentially relevant auxiliary attribute of a product item in studies of price evolution and consumer behavior. As Hausman and Leibtag (2007, 2009) note, markets typically offer consumers product items that are sold by different merchants and have differing amenities, with those amenities being one sort of auxiliary product item attribute. For the issues we focus on in this chapter, it is useful to differentiate auxiliary product item attributes from primary product attributes that all items of a product have and that stay with those product items wherever and however they are sold.[10]

BASIC, HYBRID, AND CONVENTIONAL VERSIONS OF LASPEYRES, PAASCHE, AND FISHER PRICE INDEXES

We begin in this section with basic formulas for the Laspeyres, Paasche, and Fisher price indexes. These are the usual definitions given in economics and accounting textbooks and in the relevant scholarly literatures, although it is important to note that the U.S. CPI now relies on a weighted geometric mean formula to compute elementary indexes for physical commodities. We next take up the case of multiple transactions per product. The hybrid price indexes we develop for the multiple transactions case are what we recommend be used: that is, these are what we subsequently specify to be the target indexes.

We next show how our hybrid indexes that can accommodate the multiple transactions case can be rewritten to allow for grouping the transactions in each period. We then use the grouped-transaction representations of our hybrid price index formulas to relate what we label as conventional formulas (which embody a key feature of current statistical agency practice) to our target hybrid indexes. Once we can explicitly relate the conventional formulas to our target indexes, we show that formulas for various biases of the conventional indexes are easily derived.

Basic versus Hybrid Price Indexes

We denote by $n = 1, \ldots, N$ the products in the index basket for a price index. The time period is denoted by t. All the price indexes considered involve two time periods (e.g., two months for a monthly index), denoted as $t = 0$ and $t = 1$. Each of the J_n^t transactions for product n in period t ($j = 1, \ldots, J_n^t$) involves a seller k and a purchaser k'. Hence, for transaction j in time period t for product n, $q_{n,k,k'}^{t,j}$ is the quantity of the product bought by purchaser k' from seller k. This quantity is given in terms of the same units of measure used in reporting the price per unit of the product, and that price is denoted by $p_{n,k,k'}^{t,j}$.

In each segment of the chapter, we simplify the superscript and subscript notation by showing just the superscripts and subscripts needed there. Hence, in the rest of this section, just the superscript t and the subscript n are used. The total nominal revenue received or remittance paid for product n in period t ($t = 0,1$) is thus denoted here by R_n^t, and the total received or paid for all N products is

$$(2.1) \quad R^t = \sum_{n=1}^{N} R_n^t = \sum_{n=1}^{N} p_n^t q_n^t .$$

The basic Laspeyres price index (P_L) is given by[11]

$$(2.2) \quad P_L^{0,1} = \frac{\sum_{n=1}^{N} p_n^1 q_n^0}{\sum_{n=1}^{N} p_n^0 q_n^0} = \frac{\sum_{n=1}^{N} \left(\frac{p_n^1}{p_n^0} \right) p_n^0 q_n^0}{\sum_{n=1}^{N} p_n^0 q_n^0} = \sum_{n=1}^{N} s_n^0 \left(\frac{p_n^1}{p_n^0} \right);$$

the basic Paasche index (P_P) is given equivalently by

$$(2.3) \qquad P_P^{0,1} = \frac{\sum_{n=1}^{N} p_n^1 q_n^1}{\sum_{n=1}^{N} p_n^0 q_n^1} = \left[\sum_{n=1}^{N} S_n^1 \left(\frac{p_n^1}{p_n^0} \right)^{-1} \right]^{-1};$$

and the basic Fisher price index (P_F) is

$$(2.4) \qquad P_F^{0,1} = (P_L^{0,1} P_P^{0,1})^{1/2},$$

where S_n^t in Equations (2.2) and (2.3) denotes the value share of R^t for product n in period t given by

$$(2.5) \qquad S_n^t = \frac{p_n^t q_n^t}{\sum_{n=1}^{N} p_n^t q_n^t} = \frac{R_n^t}{R^t}.$$

From the final expression in Equation (2.2) and also in Equation (2.3), and from Equation (2.4), we see that the basic Laspeyres, Paasche, and Fisher price indexes are all summary metrics for price relatives for product n ($n = 1,\ldots,N$), where a price relative is given by

$$(2.6) \qquad p_n^1 / p_n^0.$$

A price index is always evaluated for a given pair of time periods (i.e., the given current and comparison periods) and a given market area. To evaluate a basic price index formula like the Laspeyres given by Equation (2.2), each specified product covered by the index can only have one price in each time period. Historically, competitive forces have been appealed to (i.e., the "law of one price") as a justification for this one-price-per-product approximation to reality for a given time period and market area. Yet many businesses no longer set their prices on a product-by-product basis (if, indeed, they ever did that). Rather, they use pricing strategies aimed at maximizing their overall rate of return on their product sales. Hence product items typically end up being offered for sale at differing prices within a given market area, sometimes even by a single supplier.[12] Kaplan and Menzio (2014) use a large data set of prices for retail store transactions and show that the coefficient of variation of the average UPC price is 19 percent. The rapid rise of online retail seems likely to give rise to even greater opportunities for complex pricing strategies (Tran 2014).

Allowing for Multiple Transactions per Product at Multiple Prices

Suppose that there are multiple transactions per product (i.e., multiple product items are sold) each period and product items can sell for different prices in these transactions. Suppose, too, that we have the price and quantity details for the item-level product transactions. For these data to be used for price index evaluation, either we need a way of choosing one representative price for each product (the conventional approach), or the raw transactions-level data *must* be represented using some sort of price and quantity summary statistics. We use the word "must" because, in general, even if the number of products is the same, the number of product items sold usually will not be the same from one time period to the next. If we have an acceptable way of choosing a single transaction each period for an index basket product item, then it is those transaction prices that can be compared using a price index. Or, alternatively, some summary metric must be used for the transactions data, and then the values of that summary metric can be compared using a price index. Generating price observations that can be used to form price relatives, and in this manner can be compared over time, is a necessary step in constructing price indexes using raw transactions data, including scanner data.

The existence of multiple prices for a product in a time period can cause two kinds of bias in a conventional price index. The "formula bias" problem arises if a single price is selected to represent the multiple prices that exist in a given time period, and if the formula for the elementary price index is an arithmetic average of price relatives calculated as the ratio of the selected price for Period 1 to the selected price for Period 0. When multiple prices are present in the population and a single price is selected to represent the population in the price index, the price that is used in the price index becomes a random variable. Assuming that the two random variables are not perfectly correlated, the expected value of a ratio of random variables is an increasing function of the variance of the denominator, so the greater the variance of the price observations, the greater the upward bias in the average of price relatives. In the CPI of the United States and many other countries, formula bias is avoided by using geometric means to form the elementary indexes. The geometric mean of a set of price relatives is the same as the ratio of geometric means of the prices, so a geometric mean elementary index is, in effect, a ratio of average prices. The variance of the denominator will be so small that formula bias is not a problem if many price observations are averaged and the index is calculated as a ratio of the average prices.

The second kind of bias that can occur if a single price is used to represent the multiple prices that are present in a time period is that the behavior of the selected price may be unrepresentative of what is going on with the distribution of prices that are available to buyers. It is this problem that the rest of this chapter will focus on. Nevertheless, it should be noted here that the unit-value approach that we will recommend for reasons of maintaining sample representativeness also has benefits for eliminating formula bias and improving the statistical properties of the index. (For additional background on formula bias, see McClelland and Reinsdorf [1999], Reinsdorf [1998], and Reinsdorf and Triplett [2009].)

We denote the yet-to-be-specified price and quantity summary statistics for each product n in each period t by $p_n^{t,S}$ and $q_n^{t,S}$. The nominal value of the jth transaction is $R_n^{t,j} = p_n^{t,j} q_n^{t,j}$. Thus the nominal value of all transactions for product n in period t is

$$(2.7) \qquad R_n^t = \sum_{j=1}^{J_n^t} R_n^{t,j} = \sum_{j=1}^{J_n^t} p_n^{t,j} q_n^{t,j} .$$

If any important auxiliary product unit attributes do not vary systematically across transactions, the following is a desirable condition for the price and quantity summary statistics to satisfy for each of the N products covered by the price index:

$$(2.8) \qquad \frac{R_n^1}{R_n^0} = \left(\frac{p_n^{1,S}}{p_n^{0,S}} \right) \left(\frac{q_n^{1,S}}{q_n^{0,S}} \right).$$

This condition says that the growth in the per-period value of all transactions for product n from Period 0 to 1 can be expressed as the product of a pure price-change ratio times a pure quantity-change ratio. We call this condition the *product-level product rule*.[13]

The product-level product rule will always hold if, for each period ($t = 0,1$), the product of the price and quantity summary statistics equals the nominal value figure:

$$(2.9) \quad R_n^t = p_n^{t,S} q_n^{t,S}.$$

Moreover, it is readily apparent that the condition in Equation (2.9) will always hold if the quantity and price summary statistics are defined for each period ($t = 0,1$) as

$$(2.10) \quad q_n^{t,S} = \sum_{j=1}^{J_n^t} q_n^{t,j} = q_n^t$$

and

$$(2.11) \quad p_n^{t,S} = R_n^t / q_n^t = \overline{p_n^{t,\bullet}},$$

where the dot ($\bullet$) replaces the index over which the summation is taken to compute the per-unit price average.[14] The price summary statistic given in Equation (2.11) is the period *t unit value* for product *n*. The quantity summary statistic given in Equation (2.10) is the total quantity transacted of product *n* in the given period *t*.

Substituting the period *t* unit value, $\overline{p_n^{t,\bullet}}$, for the price variable p_n^t in the basic specifications for the Laspeyres and Paasche indexes given in Equations (2.2) and (2.3), and redefining the quantity variable as the summation over all transactions in the given period, we obtain, respectively, the following expressions for what we call the *hybrid Laspeyres index* (the *HLaspeyres index* for short)[15]

$$(2.12) \quad P_{HL}^{0,1} = \frac{\sum_{n=1}^{N} \overline{p_n^{1,\bullet}} q_n^0}{\sum_{n=1}^{N} \overline{p_n^{0,\bullet}} \; q_n^0} = \frac{\sum_{n=1}^{N} \left(\frac{\overline{p_n^{1,\bullet}}}{\overline{p_n^{0,\bullet}}} \right) \overline{p_n^{0,\bullet}} q_n^0}{\sum_{n=1}^{N} \overline{p_n^{0,\bullet}} \; q_n^0} = \sum_{n=1}^{N} S_n^0 \left(\frac{\overline{p_n^{1,\bullet}}}{\overline{p_n^{0,\bullet}}} \right)$$

and for the *hybrid Paasche index* (the *HPaasche index*)

$$(2.13)\quad P_{HP}^{0,1} = \frac{\sum_{n=1}^{N} \overline{p_n^{1,\bullet}} q_n^1}{\sum_{n=1}^{N} \overline{p_n^{0,\bullet}} q_n^1} = \left[\sum_{n=1}^{N} S_n^1 \left(\frac{\overline{p_n^{1,\bullet}}}{\overline{p_n^{0,\bullet}}} \right)^{-1} \right]^{-1}.$$

Thus, the *hybrid Fisher index* (the *HFisher*) is given by

$$(2.14)\quad P_{HF}^{0,1} = (P_{AL}^{0,1} P_{AP}^{0,1})^{1/2}.$$

The value-share weights in Equations (2.12) and (2.13), S_n^0 and S_n^1, are given for all *n* by

$$(2.15)\quad S_n^t = R_n^t / R^t,$$

where R_n^t is now given by Equation (2.7) and where $R^t = \sum_{n=1}^{N} R_n^t$.

The HLaspeyres, HPaasche, and HFisher indexes use unit values for the first stage of aggregation, so these indexes can explicitly accommodate a product being transacted at multiple prices within a unit time period. They reduce to the basic formulas in situations in which there truly is just one price per period for each product. From Equations (2.12) to (2.14), we see too that the HLaspeyres, HPaasche, and HFisher indexes are summary metrics for relatives of average prices (i.e., what we will refer to as *unit-value price relatives*), defined as

$$(2.16)\quad (\overline{p_n^{1,\bullet}} / \overline{p_n^{0,\bullet}}).$$

These unit-value price relatives reduce to the usual price relatives given in Equation (2.6) when there is just one price per period for each product. Thus the HLaspeyres, HPaasche, and HFisher formulas are generalizations of the basic formulas.

Analysts who have estimated price indexes using raw scanner or other transactions-level data[16] from merchants or from financial markets are, in fact, already accustomed to evaluating price indexes based on unit-value price relatives,[17] but they have not always made this practice explicit by spelling out the data-processing specifics. By calling attention to how the formulas in Equations (2.12) through (2.16) depart from the corresponding basic formulas, and by providing terminology for these practices, we hope to facilitate efforts aimed at finding practical solutions to the problems statistical agencies face in dealing with the reality of multiple prices per index basket product per period.

An Important Historical Clarification

We chose to label as "hybrid" indexes the Laspeyres, Paasche, and Fisher formulas given in Equations (2.12) to (2.14) above. But, in fact, these are the "true" Laspeyres, Paasche, and Fisher indexes as introduced by the original authors. Only one of the multiple authors of this chapter (namely, Erwin Diewert) had the language skills needed to go back to the original German articles by Laspeyres (1871) and Paasche (1874). However, Walsh (1901, 1921) and Fisher (1922) wrote in English and are quite explicit that unit-value prices and total quantities transacted in a given time period and market place are the "right" *p*'s and *q*'s that should be used in a bilateral index-number formula at the first stage of aggregation over transactions that take place at different prices within the period.

Of course, when authors put their creations into the public domain, they cannot control how others alter what they originally proposed. It is clear that large numbers of authors have defined and used the indexes as in Equations (2.2) through (2.4) above, which correspond to what we have labeled as the "basic" indexes. And official statistics agencies have typically defined and used the indexes in the form we give subsequently (in Equations [2.31] through [2.33]), and which we refer to as the "conventional" indexes. It is in this context, and in the context of uses we make of the indexes subsequently in this chapter, that we refer to the formulas in Equations (2.12) through (2.14) as "hybrid" indexes.

Working with Grouped Transactions Data

Suppose we want to divide up the transactions for the N products covered by a price index according to one or more auxiliary attributes. For transaction j for product n in period t, the price and quantity are denoted here by $p_n^{t,j}$ and $q_n^{t,j}$. We can designate a total of C exhaustive and mutually exclusive groups for the transactions: $G1,\ldots,GC$. For each group of transactions, the total quantity and the average price (i.e., the group quantity and the group unit value) are given, respectively, by

$$(2.17)\quad q_n^{t,Gc} = \sum_{j\in Gc} q_n^{t,j} \quad\text{and}\quad p_n^{t,Gc} = \Big(\sum_{j\in Gc} p_n^{t,j} q_n^{t,j}\Big) / q_n^{t,Gc}.$$

Hence, for each product *n*, the overall quantity transacted in period *t* can be represented as

$$(2.18)\quad q_n^t = q_n^{t,G1} + \ldots + q_n^{t,GC} = \sum_{Gc=G1}^{GC} \left(\sum_{j\in Gc} q_n^{t,j} \right).$$

The overall unit price for product *n* in period *t* can now be given as

$$(2.19)\quad \overline{p_n^{t,\bullet}} = \Big(\sum_{Gc=G1}^{GC} \sum_{j\in GC} p_n^{t,j} q_n^{t,j}\Big) / q_n^t$$

$$= \Big(\sum_{Gc=G1}^{GC} p_n^{t,Gc} q_n^{t,Gc}\Big) / q_n^t$$

$$= \sum_{Gc=G1}^{GC} p_n^{t,Gc} s_n^{t,Gc},$$

where for group $Gc = Gc, \ldots, GC$, the following conditions hold for the quantity shares: $s_n^{t,Gc}$, for groups $Gc = 1, \ldots, GC$:

$$(2.20)\quad s_n^{t,Gc} = q_n^{t,Gc} / q_n^t \quad\text{and}\quad s_n^{t,G1} + \ldots + s_n^{t,GC} = 1.$$

Note that the quantity shares defined in Equation (2.20) can only be meaningfully computed when the product units being added are *homogeneous* with respect to their primary attributes. With this proviso, when the total quantity transacted in period *t* is computed as in Equation (2.18) and the period *t* unit value for each product *n* is computed as in Equation (2.19), then the HLaspeyres, HPaasche, and HFisher formulas given in Equations (2.12) through (2.14) can be evaluated. In other words, the only adjustment needed in this grouped-transactions case is to use Equations (2.18) and (2.19), rather than (2.10) and (2.11), to compute the quantity and price summary statistics.

A Formula for the Bias in Conventional Laspeyres, Paasche, and Fisher Indexes

As noted, with some exceptions, the conventional statistics agency practice is to collect just *one* price per index basket product at a selected establishment in a time period. Without loss of generality, we denote the one transaction used in the conventional index as Transaction 1 (i.e., as $j = 1$). The full set of transactions in a given period t for each product n can then be divided into two mutually exclusive and exhaustive groups, $G1$ and $G2$, with $G1$ containing the single transaction used in compiling a conventional price index and $G2$ containing the rest of the transactions, which are transactions ignored in the conventional way of compiling the index. Hence, for $G1$, the quantity and price summary statistics can be denoted, respectively, as

$$(2.21) \quad q_n^{t,G1} = q_n^{t,1} \text{ and } p_n^{t,G1} = p_n^{t,1},$$

and, from Equation (2.17), we see that for group $G2$ we have

$$(2.22) \quad q_n^{t,G2} = \sum\nolimits_{j=2}^{J_n^t} q_n^{t,j} = \sum_{j \in G2} q_n^{t,G2} \text{ and } p_n^{t,G2}$$
$$= (\sum\nolimits_{j=2}^{J_n^t} p_n^{t,j} q_n^{t,j}) / q_n^{t,G2} = (\sum_{j \in G2} p_n^{t,j} q_n^{t,j}) / q_n^{t,G2},$$

where $q_n^{t,G2}$ is the quantity total and $p_n^{t,G2}$ is the unit value for the $G2$ transactions.

The total quantity transacted for each product n in period t is the sum of the transaction quantities for the $G1$ and the $G2$ groups, so we have

$$(2.23) \quad q_n^t = \sum\nolimits_{j=1}^{J_n^t} q_n^{t,j} = \sum_{j \in G1} q_n^{t,j} + \sum_{j \in G2} q_n^{t,j} = q_n^{t,G1} + q_n^{t,G2}.$$

And, from the last expression in Equation (2.19), the overall unit price for product n in period t is

$$(2.24) \quad \overline{p_n^{t,\bullet}} = p_n^{t,G1} s_n^{t,G1} + p_n^{t,G2} s_n^{t,G2},$$

where now for the quantity share statistics we have

(2.25) $s_n^{t,G1} = q_n^{t,G1} / q_n^t$ and $s_n^{t,G2} = q_n^{t,G2} / q_n^t$ with $s_n^{t,G1} + s_n^{t,G2} = 1$.

For our price index bias analyses in the next section, it will prove useful to define a factor relating the average of the $G2$ transaction prices to the single $G1$ price. The *product-specific discount factor,* d_n^t, is defined so that 1 minus this discount factor is the factor of proportionality relating the average for the ignored $G2$ prices to the $G1$ price:

(2.26) $p_n^{t,G2} = (1 - d_n^t) p_n^{t,G1}$.

When the average price for the $G2$ transactions for product n in period t is less than the corresponding $G1$ price, then d_n^t will be strictly between 0 and 1. When the average for the $G2$ prices is greater than the $G1$ price, then d_n^t will be negative, making $(1 - d_n^t)$ greater than 1. The overall average price can now be represented as follows for product n in period t:

(2.27)

$$\begin{aligned}
\overline{p_n^{t,\bullet}} &= (p_n^{t,G1} s_n^{t,G1} + p_n^{t,G2} s_n^{t,G2}) && \text{using (2.24)} \\
&= p_n^{t,G1} s_n^{t,G1} + (1 - d_n^t) p_n^{t,G1} s_n^{t,G2} && \text{using (2.26)} \\
&= p_n^{t,G1} s_n^{t,G1} + p_n^{t,G1} s_n^{t,G2} - d_n^t p_n^{t,G1} s_n^{t,G2} && \\
&= p_n^{t,G1} (s_n^{t,G1} + s_n^{t,G2}) - d_n^t p_n^{t,G1} s_n^{t,G2} && \text{where } s_n^{t,G1} + s_n^{t,G2} = 1 \\
&= (1 - d_n^t s_n^{t,G2}) p_n^{t,G1} && \text{after factoring out } p_n^{t,G1}.
\end{aligned}$$

We see from the last line of Equation (2.27) that what we label as the *price quote representativeness term*, given by $(1 - d_n^t s_n^{t,G2})$, relates the unit value for *all* the period t transactions for product n to the one price quote used when following conventional index-making practice.

Now we define a product-specific *price index representativeness factor* $\gamma_n^{0,1}$ as the ratio of the price quote representativeness terms for Period 1 versus Period 0:

(2.28) $$\gamma_n^{0,1} = \frac{1 - d_n^1 s_n^{1,G2}}{1 - d_n^0 s_n^{0,G2}}.$$

This price index representativeness factor equals 1 when the representativeness term has the same value in both Period 0 and Period 1. As long as this factor is approximately equal to 1, then the overall average price for product *n* is related in the same manner in both Periods 0 and 1 to the one price quote conventionally utilized each period. In contrast, values of $\gamma_n^{0,1}$ that are appreciably different from 1 indicate that there is a difference between Periods 0 and 1 in how the overall average price relates to the price quote utilized. (Note that $\gamma_n^{0,1}$ exists and is positive if there are at least two transactions per period; $s_n^{t,G2}$ must be strictly less than 1 because *G*1 must contain a transaction for some positive quantity in both time periods, and d_n^t must be strictly less than 1 since the average *G*2 price is positive in either time period.)

The last expression for the HLaspeyres price index given in Equation (2.12) can now be restated to incorporate the relative price index representativeness factor $\gamma_n^{0,1}$:

(2.29)

$$P_{HL}^{0,1} = \sum_{n=1}^{N} S_n^0 \left(\frac{\overline{p_n^{1,\bullet}}}{\overline{p_n^{0,\bullet}}} \right) = \sum_{n=1}^{N} S_n^0 \left[\frac{(1 - d_n^1 s_n^{1,G2})\, p_n^{1,G1}}{(1 - d_n^0 s_n^{0,G2})\, p_n^{0,G1}} \right] \text{ using (2.27)}$$

$$= \sum_{n=1}^{N} S_n^0 \left[\frac{\left(\dfrac{1 - d_n^1 s_n^{1,G2}}{1 - d_n^0 s_n^{0,G2}} \right) p_n^{1,G1}}{p_n^{0,G1}} \right]$$

$$= \sum_{n=1}^{N} S_n^0 \left(\gamma_n^{0,1} \times \frac{p_n^{1,G1}}{p_n^{0,G1}} \right) \qquad \text{using (2.28).}$$

Similarly, the HPaasche price index given in Equation (2.13) can be restated as

$$(2.30)\quad P_{HP}^{0,1} = \left[\sum_{n=1}^{N} S_n^1 \left(\gamma_n^{0,1} \times \frac{p_n^{1,G1}}{p_n^{0,G1}} \right)^{-1} \right]^{-1}.$$

The HFisher counterpart of Equations (2.29) and (2.30) is still given by Equation (2.14), but with the HLaspeyres and HPaasche components now given by Equations (2.29) and (2.30).

We are now ready to define the price index formulas we will refer to as conventional.[18] To obtain the *conventional Laspeyres price index* ($P_{CL}^{0,1}$), we substitute the single price relative, given by ($p_n^{1,G1}/ p_n^{0,G1}$), for the price relative of the *average* prices, given by ($\overline{p_n^{1,\bullet}} / \overline{p_n^{0,\bullet}}$), in the first expression for $P_{HL}^{0,1}$ in Equation (2.29). This yields what we refer to as the conventional Laspeyres index, based on the conventional practice of only using one price observation per product in each time period:

$$(2.31)\quad P_{CL}^{0,1} = \sum_{n=1}^{N} S_n^0 \left(\frac{p_n^{1,G1}}{p_n^{0,G1}} \right).$$

Similarly, to obtain the *conventional Paasche price index* ($P_{CP}^{0,1}$), we substitute ($p_n^{1,G1}/ p_n^{0,G1}$) for ($\overline{p_n^{1,\bullet}} / \overline{p_n^{0,\bullet}}$) in the expression for $P_{HP}^{0,1}$ given in Equation (2.30). This substitution yields what we refer to as the conventional Paasche index, based also on the conventional practice of only using one price observation per product in each time period:

$$(2.32)\quad P_{CP}^{0,1} = \left[\sum_{n=1}^{N} S_n^1 \left(\frac{p_n^{1,G1}}{p_n^{0,G1}} \right)^{-1} \right]^{-1}.$$

The *conventional Fisher price index* ($P_{CF}^{0,1}$) is given by

$$(2.33)\quad P_{CF}^{0,1} = (P_{CL}^{0,1} P_{CP}^{0,1})^{1/2}.$$

In the index-number literature, the term “bias” refers to a systematic difference between the result that would be obtained for some index in use or considered for use versus a specified target index. To this point, we have only demonstrated the price index representativeness factor as an outcome of sampling error: basing an index on one product item will generally yield a different answer from using the entire population of product prices. In the next section, however, we present reasons why the price of the selected item could have a systematically different expectation from the population unit value. If we use P_{HL}, given in Equation (2.29) as the target index, then the bias of the conventional Laspeyres index given in Equation (2.31) is

$$(2.34)\quad B_{CL}^{0,1} = P_{CL} - P_{HL}$$
$$= \sum_{n=1}^{N} S_n^0 \left(\frac{p_n^{1,G1}}{p_n^{0,G1}} \right) - \sum_{n=1}^{N} S_n^0 \left[\gamma_n^{0,1} \frac{p_n^{1,G1}}{p_n^{0,G1}} \right]$$
$$= \sum_{n=1}^{N} (1-\gamma_n^{0,1}) S_n^0 \left(\frac{p_n^{1,G1}}{p_n^{0,G1}} \right)$$
$$= \sum_{n=1}^{N} \left(\frac{d_n^1 s_n^{1,G2} - d_n^0 s_n^{0,G2}}{1 - d_n^0 s_n^{0,G2}} \right) S_n^0 \left(\frac{p_n^{1,G1}}{p_n^{0,G1}} \right) \text{ using (2.28).}$$

Similarly, using Equations (2.30) and (2.32), the bias for the conventional Paasche index is

$$(2.35)\quad B_{CP}^{0,1} = P_{CP} - P_{HP}$$
$$= \sum_{n=1}^{N} \left[S_n^1 \left(\frac{p_n^{1,G1}}{p_n^{0,G1}} \right)^{-1} \right]^{-1} - \sum_{n=1}^{N} \left[S_n^1 \left(\gamma_n^{0,1} \frac{p_n^{1,G1}}{p_n^{0,G1}} \right)^{-1} \right]^{-1}.$$

It is cumbersome to develop a bias formula for the conventional Fisher index given in Equation (2.33). However, as Diewert and Nakamura (2010, appendix) explain, it is straightforward to develop formulas for the differences between the arithmetic averages of the Laspeyres and Paasche components for the conventional and for the target Laspeyres and Paasche components, respectively, of the conventional and the target Fisher indexes.[19] Thus, the bias of the conventional

Fisher index can be approximated by

$$(2.36)\quad B_{CF}^{0,1} = P_{CF}^{0,1} - P_{HF}^{0,1} \cong [(P_{CL}^{0,1} + P_{CP}^{0,1})/2] - [(P_{HL}^{0,1} + P_{HP}^{0,1})/2].$$

DIFFERENT SORTS OF PRICE INDEX SELECTION BIAS

In this section, we show how the expression in Equation (2.34) can be used to represent and provide a framework of analysis for price index bias stemming from various sorts of causes. We focus here on the Laspeyres bias formula because the BLS (and other statistical agencies) mostly use the Laspeyres index in their inflation measurement programs. However, comparable results for the Paasche and Fisher formulas can be derived starting instead from Equation (2.35) or (2.36).

Outlet Substitution Bias in the CPI

For the CPI, the BLS collects prices from selected retail outlets. In an effort to control for possible price-determining factors that can differ even for the same commercial product (i.e., to control for what we call auxiliary product item attributes), the BLS only forms price relatives for product items sold at the same retail outlet (see Greenlees and McClelland [2011]). Suppose, however, that households mostly care about what they must pay for products characterized by their primary attributes (including the brand and producer) and hence shift their expenditures among retail outlets in response to advertising about pricing policies and temporary promotional sales. The benefits of this sort of price-informed shopping in terms of the prices actually paid for the products used by any one consumer will be missed by a practice of only pairing prices for product items purchased at the same retail outlet in forming price relatives. If the ratio of the average price paid to the price used in the index is falling because opportunities for paying lower prices are increasingly being taken up by consumers using new forms of Internet- and cell phone–based advertising, then the conventional index will be upwardly biased.

The potential for outlet-specific evaluation to cause CPI price index bias was noted decades ago. In a 1962 report, Edward Denison raised the concern that, in his words, “revolutionary changes in establishment type that have taken place in retail trade” may have caused “a substantial upward bias” in the CPI (Denison 1962, p. 162).[20]

Marshall Reinsdorf empirically investigated Denison’s CPI bias hypothesis. The BLS produces average price (AP) series for selected food groups. These are unit-value series for certain food categories, though not for strictly homogenous products, as we advocate. Reinsdorf (1993) compared selected AP series for food and gasoline with the corresponding CPI component series. He discovered that from 1980 to 1990, the CPI and AP series for comparable products diverged by roughly 2 percentage points a year, with the CPI series rising *faster* than the AP series, as would be expected if the CPI systematically fails to capture the benefits to consumers of price-motivated retail outlet switching. These empirical results captured the attention of Erwin Diewert, inspiring him to derive a formula for what he called the outlet substitution bias problem (Diewert 1998).

Reinsdorf (1998) later found that formula bias in the CPI caused part of the divergences between CPIs and corresponding AP series, so the outlet substitution effects turned out to be less than what was reported in his 1993 paper. However, a still substantial bias of 0.25 percentage points per year was found for both food and gasoline. The combined efforts of Reinsdorf and Diewert then galvanized other economists and price statisticians to take the outlet substitution bias problem seriously.[21]

If a significant number of consumers regularly switch where they shop among multiple retail outlets depending on the product prices each is currently offering, then we would expect d_n^t, defined in Equation (2.26), to be strictly between 0 and 1 in value for both Periods 0 and 1. This alone, however, will not cause a bias problem. We see from Equation (2.34) that the key question is whether the term $d_n^t s_n^{t,G2}$ has been *changing* in value over time. If the value of this term happened to stabilize, there would then be no outlet substitution bias. We believe, however, that the $G2$ quantity share ($s_n^{t,G2}$) has been growing over time for two sorts of complementary reasons. The first is that there have been steady improvements in the access that consumers have to current information about retail prices at different outlets in consumers’ market areas, including now even “smart phone” geotargeted advertising. The second is that modern information technologies have made it cheaper and easier for retailers to implement strategically designed temporary promotional sales, which tend to generate high demand given the expanded abilities of advertisers to inform consumers of promotional sales. Hence, we expect the Laspeyres index bias given by Equation (2.34) to be positive.

CPI Promotional Sale Bias

Outlet substitution bias, discussed above, can result from a failure to capture a growing trend for consumers to take advantage of temporary sale and other price differences among retail outlets. However, even at the *same* retail outlet, units of a product are often sold at both regular and promotional sale prices within a month, which is the unit time period for the CPI. The frequency of temporary sales is believed to be increasing in the United States. The information available to consumers about sale pricing has been steadily expanding, too, presumably allowing consumers to take progressively greater advantage of temporary promotional sale prices.[22]

The BLS collects and uses for the CPI whatever prices are in effect at the time the price quotes are collected from each selected retail outlet, regardless of whether the prices are identified as "sale" or "regular" prices.[23] Temporary sales are believed to be in effect for any one product at any one outlet for less than half of the days or hours of business. Hence, the value of d_n^t is expected to be predominantly between 0 and 1. Nevertheless, because the capture of regular or sale prices is random, the value of d_n^t can be either positive or negative.

The volumes sold at promotional sale prices tend to be large and, as already stated, the frequency of temporary sales is believed to be rising, in the United States at least. As is evident from Equation (2.28), the sign of the change in the term $d_n^t s_n^{t,G2}$ determines the sign of the promotions bias.[24] Because the U.S. CPI includes sales prices in proportion to the percentage of time in which they are offered, increased frequency of sales could result in either a rise or a fall in this term. A fall would occur if the increased frequency of sale-price offerings increased the relative frequency of sale prices being selected for the CPI by more than it increased the relative frequency of sale prices being paid by consumers. On the other hand, if consumers' costs of acquiring information fell, the term would likely rise, implying a positive promotions bias.

Information costs have, indeed, fallen, so promotions bias is expected to be positive on average.[25]

Sourcing Substitution Biases in the PPI and MPI

Finding cheaper input sources and then making sourcing substitutions is a prevalent strategy for lowering business costs. Empirical evidence suggests that this sort of supplier switching behavior plays an economically important role in the survival and growth of new firms (e.g., Bergin, Feenstra, and Hanson 2009; Foster, Haltiwanger, and Syverson 2008).[26] If both the old and the new suppliers are domestic, it is the uses of the Producer Price Index (PPI) as a deflator for inputs that can be affected. If both the old and the new suppliers are foreign, it is the Import Price Index (MPI) that can be affected.

For both the PPI and MPI cases, we would expect the values of d_n^t in Equation (2.26) to be strictly between 0 and 1. Moreover, we would expect the $G2$ quantity share ($s_n^{t,G2}$) to have been growing over time because of expanding information availability about suppliers and their prices, enabling purchasers to take greater advantage of lower-priced offers. Hence, we would expect positive biases in the relevant price indexes from sourcing substitutions.[27]

We next provide a simple example illustrating the sourcing substitution bias problem for the MPI. We then go on to take up two other possible sorts of producer sourcing changes that may cause bias problems.

An Example of MPI Sourcing Substitution Bias Due to Import Sourcing Switches

Here we distinguish a supplier (k) from a buyer (k'). For our example, Businesses 1 and 2 are foreign suppliers (hence, $k = 1,2$), and Businesses 3 and 4 are domestic buyers (hence, $k' = 3,4$) for a single product. The quantities and prices are denoted by $q_{k,k'}^t$ and $p_{k,k'}^t$. With only one product, a Laspeyres (or Paasche or Fisher) price index reduces to a ratio of a single price or average price for the one product in each of the two time periods for the price index

The value flows summarized in Table 2.1 reflect the following specifics:

Table 2.1 Value Flows for the Four Businesses

Output flows		Input flows	
Business 1	Business 2	Business 3	Business 4
Period 0 value flows			
$p^0_{1,3}q^0_{1,3}$	$p^0_{2,4}q^0_{2,4}$	$-p^0_{1,3}q^0_{1,3}$	$-p^0_{2,4}q^0_{2,4}$
Period 1 value flows			
$p^1_{1,3}q^1_{1,3}$	$p^1_{2,3}q^1_{2,3}+p^1_{2,4}q^1_{2,4}$	$-p^1_{1,3}q^1_{1,3}-p^1_{2,3}q^1_{2,3}$	$-p^1_{2,4}q^1_{2,4}$

- Business 1 is a developed-country supplier to Business 3, with this supply arrangement having been in place already for more than two periods as of the start of Period 0 for this example.
- Business 2 is a cheaper, developing-country supplier that has a supply arrangement with Business 4 that was in place already for more than two periods as of the start of Period 0.
- Business 3 purchases from Business 1 in both Periods 0 and 1. In Period 1, Business 3 also enters into a new purchasing relationship with the low-cost supplier Business 2. Houseman et al. (2011) note the potential importance of the entry of lower-cost suppliers in the domestic economy (as well as competition from foreign producers, which is the case to which they devote more attention). What a new supplier charges has no effect on the "conventional" price index.
- Business 4 has had an ongoing purchasing relationship with Business 2 and continues to buy exclusively from Business 2 in Periods 0 and 1.
- The following inequalities hold:

$$p^0_{1,3} > p^0_{2,4} > 0,\ p^1_{1,3} > p^1_{2,4} > 0,\ p^1_{1,3} > p^1_{2,3} > 0.$$

The price indexes for domestic businesses 3 and 4 can be regarded as the MPI index series.

The conventional price index for Business 4, $P^{(4)}_{CL}$ is the same as our hybrid Laspeyres target price index for that business, $P^{(4)}_{HL}$, because

Business 4 uses just one supplier each period. That is, for this case, the conventional price index equals the target price index:

(2.37) $$P_{CL}^{(4)} = p_{2,4}^{1} / p_{2,4}^{0} = P_{HL}^{(4)}.$$

Thus there is no bias problem for $P_{CL}^{(4)}$.

In contrast, we can show that the conventional price index for Business 3 is biased, and we can show what the bias depends on. For Business 3, the conventional price index is

(2.38) $$P_{CL}^{(3)} = p_{1,3}^{1} / p_{1,3}^{0} = 1 + i,$$

where (1 + i) is the measured inflation rate using this conventional price index. This conventional price index takes no account of the fact that in Period 1, Business 3 not only bought from Business 1 but also used a new supplier, Business 2. In contrast, and under our assumption that Business 3 views the products from the two suppliers as equivalent, the specified target index for Business 3 uses the information for all the transactions in Period 1. This price information is summarized in Period 1 by the unit value

$\overline{p_{\bullet,3}^{1}}$; i.e., we have

(2.39) $$\overline{p_{\bullet,3}^{1}} = \frac{p_{1,3}^{1} q_{1,3}^{1} + p_{2,3}^{1} q_{2,3}^{1}}{q_{1,3}^{1} + q_{2,3}^{1}} = p_{1,3}^{1} s_{1,3}^{1} + p_{2,3}^{1} s_{2,3}^{1},$$

where

(2.40) $$s_{1,3}^{1} = \frac{q_{1,3}^{1}}{(q_{1,3}^{1} + q_{2,3}^{1})},\ s_{2,3}^{1} = \frac{q_{2,3}^{1}}{(q_{1,3}^{1} + q_{2,3}^{1})}, \text{ and } s_{1,3}^{1} + s_{2,3}^{1} = 1.$$

Hence, the target output price index for Business 3 is given by

(2.41) $$P_{HL}^{(3)} = u_{3}^{1} / p_{1,3}^{0} = (p_{1,3}^{1} / p_{1,3}^{0}) s_{1,3}^{1} + (p_{2,3}^{1} / p_{1,3}^{0}) s_{2,3}^{1}.$$

It is the price charged by the lower-priced supplier, Business 2, that is ignored by the conventional price index for Business 3. The price charged by Business 2 is what constitutes the $G2$ group price for this example, whereas $p^1_{1,3}$ is the $G1$ price. Using Equation (2.26), we have

$$(2.42)\quad p^1_{1,3} = (1 - d^1)\, p^1_{2,3}\,,$$

where $0 < d^1 < 1$. In Period 0, there is only the one supplier for Business 3. Hence, applying Equation (2.34) yields the following:[28]

$$\begin{aligned}(2.43)\quad B^{0,1}_{CL} &= P^{(3)}_{CL} - P^{(3)}_{HL} \\ &= d^1 s^1_{2,3}\left(\frac{p^1_{1,3}}{p^0_{1,3}}\right) \\ &= d^1 s^1_{2,3}(1+i) > 0 \qquad \text{using Equation (2.38).}\end{aligned}$$

The last two lines of Equation (2.43) are convenient alternative expressions for the sourcing substitution bias of $P^{(3)}_{CL}$.

We note that the last expression in Equation (2.43) is the same as Equation (2.12) in Diewert and Nakamura (2010).[29] This bias is seen to depend on

- the rate of price inflation as measured by the conventional index,
- the proportional cost advantage of any ignored supply source(s), and
- the quantity share for any ignored supply source(s).

If estimates can be made for the above factors, then a rough approximation to the bias given in Equation (2.43) can be made using this formula, which is a special case of our general bias formula found in Equation (2.34).

Domestic to Foreign Supplier Switches and a Proposed True Input Price Index (IPI)

We next consider the case of a business that switches from using a domestic supplier to a foreign one, thereby benefiting from an input cost decrease.[30] Neither the PPI nor the MPI can capture the cost savings from this sort of a sourcing substitution. The PPI's domain of definition does not include imports, and the MPI measures price changes beginning in the second month in which a newly selected imported product is observed. The resulting price index coverage gap is worrisome, since most of the increase in the relative importance of trade in the U.S. economy is accounted for by the expansion of imports of intermediate products.[31]

The pricing gap between the PPI and the MPI programs could be closed by creating a true Input Price Index (IPI) program that is defined to measure the inflation experience of producers in buying their inputs from all sources: foreign as well as domestic. In this case, the price evolutions measured should include those associated with shifts in purchase shares from more to less expensive domestic producers, and from more to less expensive foreign producers, as well as from domestic to cheaper foreign producers.

The BLS has put forward a plan for a true IPI (Alterman 2008, 2009; Chapter 10, this volume). With an IPI, a newly imported product that matches the primary attributes of a domestically supplied product could be brought into the IPI as a directly comparable substitute. Also, in principle, the purchaser of the inputs would be able to report the price per unit irrespective of the sources for inputs they treat as homogeneous in terms of what is done with the product purchases.

However, current BLS practice is not to average over prices for items of different products, even when they were explicitly designed to meet the same product specifications and differ only in terms of the producer of the product items. If this practice is retained for the IPI program too, then the new IPI could also be subject to sourcing substitution bias.[32] This potential IPI bias can be represented using Equation (2.34) in the same manner as for the PPI and MPI cases, except that purchases for domestic as well as imported inputs must now be covered. For the same sorts of reasons as discussed above for the PPI and MPI, we would expect this potential bias problem to be positive.[33]

Inflation Measurement Problems Due to the Initial Switch to Outsourcing

When a business switches from in-house production to procurement of an intermediate input, this is usually done in hopes of realizing cost savings. The fact that this sort of cost savings will not be picked up by the PPI or MPI programs is sometimes treated as an aspect of the new-goods price index bias problem, even if there is nothing new in terms of the input product in question. We note, however, that there will usually be no way for a business to make this sort of a change without alterations to the operating processes of the business. Perhaps, therefore, this sort of sourcing change should be viewed as a business technology change that should be counted as a contribution to productivity growth. Nevertheless, regardless of which of these perspectives is adopted, this sort of change is outside the scope of this chapter.

FIVE SORTS OF BARRIERS TO ADOPTION OF UNIT VALUES FOR OFFICIAL STATISTICS PURPOSES

The target indexes we recommend incorporate unit values. As we have noted, there are impediments to the adoption of indexes like this by statistics agencies in their official published series. Here we deal with what we see as the main impediments, grouped under five subheadings.

Impediment 1: Bad Reputation Due to Historical Misuse of Unit-Value Indexes

More than a half-century ago, the Price Statistics Review Committee chaired by George Stigler, also known as the Stigler Committee, considered the relative merits of unit value versus what is referred to as specification pricing. It recommended the latter. Under the heading of “Specification vs. Unit Pricing,” the Stigler Committee report states the following:

> In 1934, the Bureau of Labor Statistics adopted “specification” pricing, and since then has sought to price narrowly defined commodities and services to obtain price relatives for price indexes…. The Committee believes that in principle the specification method of pricing is the appropriate method for price indexes. The changing unit values of a *broad* class of goods (say shirts or automobiles) reflect both the changes in prices of comparable items and the shifting composition of lower and higher quality items. (Price Statistics Review Committee 1961, p. 32, italics added)

Note, however, that the Stigler Committee’s opposition to unit values did not arise in the context of price collection for carefully and very narrowly specified products, as we are recommending; rather, it arose in the context of prices collected for what nowadays would be viewed as very broadly specified products.

The Stigler Committee report recommended that the BLS move to probability sampling methods for narrowly specified products rather than using the customs administrative data, which were for unacceptably broad product groups. For example, with the BLS practices based on customs data, the price of new cars was based on the average of what were referred to as the "low-priced three" makes of automobile (Chevrolet, Ford, and Plymouth), with no adjustment for quality as the models evolved over time. The committee report particularly was concerned that "in the case of the Farm Indexes the classes over which unit values are computed are still often too wide" (p. 33). An accompanying study by Rees (1961) argued that the Farm Index measure of rugs, which did not specify the fiber content, failed to capture a substantial rise in the price of wool rugs as reflected in the BLS data (and in Sears and Ward catalogs) because it increasingly captured the pricing of wool-rayon blend rugs (pp. 150–153).[34] Similarly, the old U.S. Census Bureau unit-value indexes for imports and exports were based on customs administrative data for very broad product categories. As a result, the Census Bureau unit-value average prices were clearly subject to mix shifts.

As part of its response to the Stigler Report, in 1973 the BLS began producing rudimentary versions of an Import Price Index (MPI) and an Export Price Index (XPI) using price quotes and value-share weights produced by methods similar to those used for the PPI program. Full coverage of import and export goods categories was achieved by 1982 for the MPI and XPI (Silver 2010). Nevertheless, the Census Bureau unit-value indexes were not discontinued until July 1989. Alterman (1991) takes advantage of data from the overlap years to conduct a comparative empirical study of the Census Bureau unit-value indexes versus the MPI and XPI produced by the BLS. That study notes that if unit values are computed for what, in fact, are different products, then those price indexes will reflect not only the underlying price changes but also any changes in product mix as well. By way of example, he goes on to state that if there were a market shift, say, "from cheap economy cars to expensive luxury cars, the unit value of the commodity (autos) will increase, even if all prices for individual products remain constant." This clarifying remark makes it clear that Alterman, in his 1991 paper, is referring to the commodity categories the Census Bureau used in constructing its unit-value indexes rather than to precisely and very narrowly defined products. Alterman's remark was true for the customs data that the Census Bureau used in constructing its unit-value indexes but does not pertain to our proposals, as seen in the following quotation:

> In comparing price trends of imported products, the BLS series, surprisingly, registered a consistently higher rate of increase between 1985 and 1989. Between March 1985 and June 1989 the BLS index rose 20.8 percent, while the equivalent unit-value index increased just 13.7 percent. . . .With the exception of motor vehicles, the major import components—foods, feeds, and beverages, industrial supplies and materials, capital goods, and consumer goods—*all* show larger increases in the BLS series than in the unit-value series. *The most dramatic difference between the two series is found in the comparison for imported consumer goods. Between March 1985 and June 1989 the BLS series recorded a 30.7 percent increase, while the comparable unit-value series rose just 10.3 percent.* (Alterman 1991, p. 116, italics added)

In the above quotation, Alterman (1991) also reports an interesting anomaly along with his other findings. As Alterman explains, his discovery that the Census Bureau unit-value series shows *smaller* price increases for imports than the MPI contradicts a common presumption about the nature of unit-value indexes. This is the presumption that quality levels tend to rise over time, so that the failure to adjust for product mix changes within the product categories for which prices are being averaged will typically cause unit-value indexes based on broad product categories to overstate the true price increases.[35]

We, however, now suspect that what Alterman identified as an "anomalous" result is a manifestation of sourcing substitution bias in the MPI: a problem that would not have affected the Census Bureau unit-value series in the same way. In particular, the MPI produced by the BLS could not capture direct cost savings that buyers achieved by switching to lower-cost suppliers. In contrast, the old Census Bureau unit-value series probably did capture at least some of those price-motivated buying switches among products sharing the same, or almost the same, primary attributes.[36]

Impediment 2: Questions Regarding the Proper Treatment of Auxiliary Attributes

Producers of mass-marketed products try to ensure the homogeneity of items of what they label as being the same commercial product. Producers usually want it to be the case that items of what they label as "a product" can be advertised and sold interchangeably. For example, a 10.75-ounce can of Campbell's tomato soup, as this is defined by the company that owns the brand, is intended by Campbell's to be the same product no matter when, where, or how a can of the soup is purchased. Nevertheless, as has been noted, product items that all have the same primary attributes can acquire different auxiliary attributes such as having been sold at regular price or during a temporary promotional sale, or at a neighborhood convenience store versus a superstore.

We argue that in terms of the final uses made of products, it is usually just the primary attributes that matter. For example, when it comes to using cans of soup in a kitchen cupboard that may have been purchased from different outlets to take advantage of price promotions, typically no account is taken of the forgone effort or time of the family member who did the shopping. This is in line with current practices for compiling the gross domestic product (GDP). That aggregate is compiled for the United States by the Bureau of Economic Analysis (BEA) following the guidelines of the System of National Accounts (SNA). It is explicit in the SNA that no account is taken of unpaid time expenditures of household members, whether for picking up groceries at a superstore as opposed to a nearby convenience store, or for any other activity (United Nations Statistics Division 2014). Moreover, the nominal value of the consumption aggregate includes *all* sales of consumer products at the prices for which they were, in fact, purchased. One main purpose of the CPI program is to provide components to be used for constructing deflators for the consumption aggregate of the GDP.

We can, nevertheless, see reasons for wanting to hold a variety of auxiliary attributes constant in estimating the price relatives that are used in compiling a price index. After all, customers are willing to pay more per unit for the soup cans sold in a convenience store, and, in that sense, those cans of soup are definitely of "higher quality" than lower-priced units of the product sold at a discount superstore. An important secondary consideration from our perspective is that whatever product differentiation and index basket definitions are adopted for price-quote collection purposes, it is important that those same index basket product definitions are used as well in collecting the data for and in producing the product-specific value-share weights for the price index. The question of if and when auxiliary product unit attributes should be used in forming index basket product definitions is deep, and largely beyond the scope of this chapter.

Impediment 3: Producer Goods with Different UPCs but the Same Primary Attributes

The mechanics of price measurement for producer goods are greatly simplified when the products can be specified as individual product UPCs or predefined groups of these. It is the primary product characteristics that usually matter for how product units are utilized in a production process, and differences in primary attributes are always reflected in different UPCs.

Nevertheless, UPCs for product units sometimes differ even though the product units are, for all practical purposes, identical. For example, as previously noted, many large manufacturers issue precise specifications for needed intermediate products, and then purposely select multiple suppliers from among the businesses that bid on the supply contract opportunity. If intermediate product units are produced according to specifications that are identically the same but they nevertheless come from different producers, then the product units from each producer will have a different producer-specific UPC. For price index compilation purposes, we recommend that items of products that are believed to be the same and are utilized in the same manner by the final user should usually be treated as the same product for price index evaluation purposes even when their UPCs may differ. In addition, if a producer indicates that the product items from different suppliers are used or sold in the same way except for some allowance for a quality difference (e.g., through purchase order adjustments to allow for supplier-specific defect rates), then the producer could also be asked to report and evaluate the quality difference, and that information could be used in implementing quality adjustments so that the items from the different suppliers can all be treated as quality-adjusted items of the same index basket product.

However, defining meaningful classification systems of UPCs can be expected to be a laborious process.

Impediment 4: Consumer Products Sharing Primary Attributes but Not UPCs

Concerns have also been raised regarding the inflation measurement implications of a growing proliferation of retail products with different UPCs even when the producer is the same and the primary product-attribute differences are trivial. One reason for this proliferation may be that producers supplying retail products fear that their customers may switch to buying the products of competitors if they raise their prices. Hence, they instead may bring out new versions of a product that are minor variants: variants that are advertised as being improved and that are offered at increased prices that yield higher profit margins. The corresponding old versions can then continue to be sold too, only to be discontinued if and when a new version has become a sales success (see Nakamura and Steinsson [2008, 2012]).

Another reason for the introduction by a producer of a new product that intentionally has primary attributes that are highly similar to the attributes of an existing product may be a desire to take market share from competitors with successful products. In these cases, the producer wants the new product to differ enough from the old one marketed by the competitor to avoid successful trademark or patent infringement lawsuits but hopes that potential users will judge the new product to meet all the needs and uses of the old one they were purchasing. We view this as the spirit, for example, in which large grocery store chains often introduce their own "private label" variants of popular established brand-name products. Similarly, clothing makers often try to bring out styles like those of popular designers. And pharmaceutical companies often try to find ways of producing drugs as effective as the successful drugs produced by competitors. These products have different UPCs but are deliberately similar to existing products in terms of the primary attributes.

Conversely, but equivalently for measurement purposes, a producer may have the goal of maintaining a constant price by replacing a product with another that is less costly to produce.

Although statistical agencies like the BLS do not average over changing sets of multiple-price quotes for individual products, for price change to be measured correctly, unit values are sometimes defined in BLS price index programs to encompass multiple UPCs that represent the same index basket product. Adoption of our recommendations implies an extension of these practices. However, the task of determining when consumer products with different UPCs should be treated as the same index basket product for inflation measurement purposes may be harder than the corresponding problem discussed above for producer products. There are three reasons for this:

1) Consumers are far more numerous than producers, and they generally each buy much smaller amounts than producers purchasing intermediate products. Hence the product-use views and experiences of much larger user groups would need to be considered to follow an approach for consumers like what we suggest above for producers.
2) Producers inevitably keep and analyze data about the performance of units of an intermediate product that are obtained from different suppliers. Consumers, on the other hand, are not usually in a position to systematically note primary attribute quality differences for similar product items from different producers.
3) Producer products that are similar enough that it might make sense to consider them as being the same index basket product were often *requested* by the purchaser. Thus, the product item sameness is an openly declared objective to satisfy specifications issued by the purchaser. In contrast, sameness in the consumer case that results from an effort to expand or enter a market by competing with the product of a competitor is usually illegal if the duplication is exact. Hence, for consumer products, design work is needed to produce a similar product that is nonetheless sufficiently different so that allegations of patent or trademark infringement can be defended against. Foreign suppliers trying to gain market share from domestic producers of consumer products often invest heavily in that sort of product design work. A great deal of effort can go into legally producing a product that is almost identical to one that already is being sold by some other producer.

Even when a very similar new product is developed by a producer as an alternative for one of the producer's own established products—perhaps in the hopes of being able to use the new product as a means of making a de facto price adjustment—design work is usually required. This is so no matter how small the differences may seem. From some perspectives, product development should be treated as part of productivity growth rather than as a price change mechanism. Hence, maybe these products truly should be treated as new products rather than as quality-adjusted old products. Kaplan and Menzio (2014) offer data on the distribution of prices across similar products as well as within UPCs; their analysis sheds some light on the relative importance of alternative product specification methods. We do not attempt to provide answers here to these difficult questions.

Nevertheless, the issue must be faced of when and how to average prices over units of consumer products with very similar primary attributes, as is now sometimes done on the consumer side using hedonic and other quality-adjustment methods. This is so whether or not our recommendation to use unit-value price indexes is adopted. The BLS is already engaged on an ongoing basis in deciding when different commercial products are similar enough to be treated as the same index basket product, but those efforts, however important, are outside the scope of this chapter and are not covered here.

Impediment 5: A Need to Change Current Data Collection Arrangements

The most straightforward impediment to conquer might be the most serious. The information requirements for a unit-value price approach based on narrowly defined index basket products are much larger than for the approaches used for conventional price indexes. Nevertheless, private businesses have paved the way. Businesses formerly carried out their decision making and forecasting using sample and other sorts of incomplete information for their own transactions. In contrast, modern big businesses strive to operate with full, real-time transactional visibility.

Thus the nature of the needed changes at the BLS and other national statistics agencies can be seen from the way in which large private-sector businesses have remade their data systems over the recent decades and have then also remade their business processes to utilize their improved information capabilities. The needed hardware and software have been developed. Nevertheless, moving a national statistics agency into a position of roughly equivalent data storage and handling capabilities with what big companies now have will require budget allocations and investments in training and hiring people with the needed capabilities. Private-sector data system experts do not have official statistics expertise, and those already with the statistics agencies have had no opportunity to master data capture, warehousing, and utilization methods of the sort that have become common for big businesses, or the intricacies of the UPCs.[37]

It is instructive to briefly examine the steps that the private sector had to take to attain its modern data-handling capabilities. The 1961 Stigler Report was written before the business world had UPCs. Indeed, for most of the twentieth century, as stores got bigger and varieties multiplied, the only way for a grocer or other retailer to find out what was in stock was by physically counting all the cans, boxes, bags, and cartons. The achievement of widespread use of UPCs was the result of sustained business-world efforts of many sorts. A machine-readable product-code design had to be devised and agreed on. Equipment for cost-effectively reading the product codes and for storing and processing the product-code data had to be invented, produced, purchased, and put to use by businesses. A product-code numbering system had to be invented and widely accepted. And an organization had to be developed to oversee the assignment and use of product codes over time. Also, business processes had to be redesigned to make use of the product-code data.

More than a decade before the Stigler Report was written, Bernard Silver and Norman Joseph Woodland developed (and in 1952 were granted a patent for) a bar-code design consisting of concentric circles that could be scanned from any direction. However, without a cheap, fast, and convenient way to read and record bar-code data, their invention could not be put to use. The development of cheap lasers and integrated circuits in the 1960s made bar-code scanners and bar-code data handling potentially affordable for retailers. However, the original Silver-Woodland "bull's-eye" bar-code design performed poorly in an important field test. Also, there was the challenge still to be met of getting all needed participants to more forward together.

In the early 1970s, IBM researcher George J. Laurer devised a new bar-code design for which the field test results were acceptable. He then succeeded as well in getting the U.S. Supermarket Ad Hoc Committee interested in what was named the IBM Universal Product Code (UPC) system.[38] On April 3, 1973, the Ad Hoc Committee voted to accept the symbol proposed by IBM.

Standardization made it worth the expense for manufacturers to put bar codes on their packages and for printers to develop the needed new ink types, plates, and other necessities for reproducing the code with the accuracy required for the UPC scanners, and the Ad Hoc Committee succeeded in bringing the grocery industry and other needed participants together to implement UPC scanning at the point of sale (POS). This included agreement on a standardized system for assigning and retiring bar-code product numbers. To facilitate this, the nonprofit Uniform Code Council (UCC) was established. Businesses applied for registration with the UCC, which eventually changed its name to Global Standards One, or GS1.[39] Each business that was accepted as a registered member began paying an annual fee and was then issued a manufacturer identification number and given training on how to register its products and on how to assign and retire UPCs as needed.

Use of scanners grew slowly at first. In 1978, less than 1 percent of grocery stores nationwide had scanners. By mid-1981, the figure was 10 percent. Three years later it was 33 percent. And by 1999, it was already over 60 percent.[40]

GS1 today manages what is collectively referred to as the Global Trade Item Number (GTIN) System, which includes the UPCs (GS1.org 2014). The official GS1 member organization for the United States is now called GS1 US. The modern logistics, inventory management, pricing, advertising, and supply chain coordination operations of businesses of many sorts, especially including grocers and general merchandise retailers, would be inconceivable without the information derived from tracking items of product units identified by UPCs.

In 1999, the Supermarket Ad Hoc Committee commissioned PricewaterhouseCoopers to make a report examining the extent to which the aims of the original Ad Hoc Committee business plan had materialized (Jones, Garg, and Sheedy 1999). The resulting report finds that the direct savings from bar-code adoption (i.e., savings at the checkout counter) proved greater than originally projected. The report also finds, however, that it was the general merchandise companies, rather than the supermarkets, that managed to most fully realize the projected *indirect* savings from bar-code scanning, and it argues that the supermarkets have been losing market share to superstores because of this reality.

(The indirect savings envisioned by the original Ad Hoc Committee pertain to business functions such as inventory management.) We see Walmart as a notable example of this last point.

From 1973 on, as grocery and other retail chain stores grew, the chains almost all established semiautonomous regional data centers that collected and processed bar-code scanner data. The reason for the regional data centers that most chains created and many still have is that the volume of the bar-code data seemed too large for processing in a single data warehouse for even a midsized chain store. Nevertheless, in 1979 Walmart built an initial *company-wide* data warehouse (Metters and Walton 2007). Walmart was also the first large retailer to give its suppliers access to Walmart's point-of-sale and inventory data for the products of each of those suppliers, thereby helping the suppliers reduce costs due to under- or overproducing. Walmart recognized that by sharing this information with its supply-chain partners, the company and its suppliers could all gain from improved coordination.

To improve the reliability of access to its data warehouse, Walmart in 1987 also built the world's largest private-sector satellite communications system. Then, in 1991, the company reportedly spent $4 billion more to create its new Retail Link company-wide data warehouse. Nowadays, Walmart suppliers are able to monitor in almost real time how their products are selling on Walmart store shelves everywhere that Walmart carries their products. The POS data is credited with enabling Walmart suppliers to reduce their inventories, shorten their lead times, and increase their profitability. Also, with product items being electronically identified at the checkout counters and with financial as well as physical inventory records being updated on an ongoing, almost real-time basis, store managers in Walmart outlets everywhere as well as those in the company headquarters can plan better.

Investments that bring the data capabilities of official statistics agencies more into line with what big companies have could pay big dividends.[41] This and our other reform suggestions are presented in the final section. However, before proceeding to those suggestions, we briefly note how price indexes affect some other key economic performance metrics.

INFLATION MEASUREMENT EFFECTS ON OTHER ECONOMIC PERFORMANCE MEASURES

Price indexes are used to measure inflation for nations and to transform nominal into real values. Real values of national output are then used to measure economic growth, and for creating measures of productivity growth and growth in material well-being over time.

Previously we defined R^t in Equation (2.1) as the sum of *either* the nominal period t revenue for all products sold by some economic entity or the nominal period t remittance paid (i.e., the cost) for all products bought by a given economic entity. However, outputs need to be distinguished from inputs for productivity and economic well-being measurement purposes. Productivity is a measure of the efficiency of an economic entity in turning inputs into desired outputs (see, e.g., Diewert [2007] and Diewert and Nakamura [2007]), and economic well-being is usually gauged by restating in per-capita terms a measure of the total output for a nation (such as GDP).

For some given economic entity, here we redefine R^t, p_n^t, q_n^t, and the index limits N and J as pertaining just to *output* products (rather than including inputs too, as in our previous definitions). Thus the total nominal revenue in period t for a specified economic entity is now given by

$$(2.44) \quad R^t = \sum_{n=1}^{N} R_n^t = \sum_{n=1}^{N} \sum_{j=1}^{J_n^t} p_n^{t,j} q_n^{t,j} .$$

Here, we redefine $P^{0,1}$ as an index measure of *output* price change from $t = 0$ to $t = 1$.

The most commonly used productivity performance metric for nations is labor productivity growth. Suppose L^t is defined as a pure quantity measure of labor services input such as aggregate hours of work. Labor productivity growth from Period 0 to 1, denoted here by $LP^{0,1}$, can be measured as the ratio of real revenue growth to a growth ratio for aggregate hours of work:

$$(2.45) \quad LP^{0,1} = \frac{(R^1 / R^0) / P^{0,1}}{L^1 / L^0} .$$

The interpretation people want to make of labor productivity values is that values greater than 1 (less than 1) mean that real GDP has grown faster (slower) over time than the quantity of labor required to produce the real output.

We now consider how the price-index bias problems discussed in previous sections of this chapter could distort measures of real GDP growth. Nominal GDP for period t is defined as

$$\text{GDP} = C + I + G = (X - M), \tag{2.46}$$

where C denotes aggregate consumption, I is investment, G is government expenditure, X is exports, and M is imports. If inflation is overestimated (underestimated) for the C component of GDP, this will cause the growth of real GDP to be underestimated (overestimated), since C enters with a positive sign into GDP. If inflation is overestimated (underestimated) for the M component of GDP, this will cause the growth of real GDP to also be overestimated (underestimated), since M enters with a negative sign into GDP.

The outlet substitution bias problem explained in the subsection titled "Outlet Substitution Bias in the CPI" is believed to have contributed to the overestimation of inflation for C, and hence to the underestimation of real GDP growth. The MPI sourcing substitution problem explained in the subsection "Sourcing Substitution Biases in the PPI and MPI" is also believed to have contributed to an overestimation of inflation—for imports in this case—which would contribute to an overestimate, rather than an underestimate, for GDP growth because M enters the expression for GDP with a negative sign.[42]

The extent to which these bias effects on real GDP cancel each other out is an empirical question. Although for the United States the C component of nominal GDP is much larger than the M portion, there are fairly narrow limits on the proportion by which it makes sense for a retailer selling in any given market area to undercut the prices of competitors. This places bounds on the likely size of the CPI outlet substitution bias problem. In contrast, intermediate product-supply contracts can be very large, and suppliers sometimes have labor, raw-materials access, patent, government subsidy, or other cost advantages that make it possible for them to profitably sell their products, if they wish, at prices far below what competitors are charging. Hence, it is plausible that positive MPI bias problems have outweighed positive CPI bias problems, resulting in the systematic overestimation of real GDP growth. There is an urgent need for empirical research on this point.

Haskel et al. (2012) paint a vivid picture of real income declines for the large majority of Americans over the previous decade. They classify U.S. workers into five groups by their levels of education—five groups that *all* enjoyed substantial increases in average real income in the second half of the 1900s. However, since 2000, these same groups of workers have suffered real average-income declines. This is perplexing, Haskel et al. note, since the U.S. economy enjoyed superior measured labor-productivity growth.[43] They point out that the last 10 to 15 years have also brought dramatic changes in economic globalization, but that connections between globalization and the observed economic trends are unclear based on available research. Our own results, considered along with other findings cited in our chapter, raise the possibility in our minds that price-index bias problems that have been indirectly worsened by the growth of electronic information processing and communications and associated business process changes (changes that enabled globalization) may, in part at least, be responsible for the perplexing picture of how the U.S. economy has been doing, as reported by Haskel et al.

We conclude with suggested changes in official statistics price measurement that we feel could improve our ability to understand the evolving economy.

POSSIBLE PRICE MEASUREMENT PRACTICE REFORMS

We have shown that the bias formulas derived in this chapter can be used to represent the sourcing substitution bias problem in the Import Price Index (MPI) and the Producer Price Index (PPI), and the potential sourcing substitution bias problem in the proposed Input Price Index (IPI) (see Alterman 2008, 2009, and Chapter 10 of this volume), as well as the outlet substitution and promotions biases in the Consumer Price Index (CPI). Our recommendations in this final section are aimed at reducing the noted bias problems.

Our main recommendation is that when items of the same commercial product unit are sold at multiple prices even by the same merchants during a time period such as a month, then the conventional practice of using a *single* price observation per period for the product from each establishment where the product is priced during the time period (with this single price then being used to represent the price *distribution* at each establishment) should be replaced by the use of establishment-specific unit-value prices. Hence, we argue for greater adoption of unit-value-based price indexes to handle cases of multiple prices for the same product in the same period. This first recommendation implies a need for modifications of both data collection operations and compilation procedures. In the text, the need for these modifications is part of what we allude to as the fifth and most serious of the impediments to the adoption of unit-value-based price indexes. We propose a way here in which the BLS might proceed incrementally toward a capability for unit-value-based price-index compilation.

At present, the BLS price-quote-collection operation for each of the agency's main price index programs (e.g., the CPI, the PPI, and the International Price Program) starts with selecting establishments on a probabilistic basis from comprehensive lists of various sorts. Next comes the selection of products on a probabilistic basis at each selected establishment. Then, the BLS collects a *single* price quote in each pricing period (typically a month) for each selected product at each of the selected establishments.[44] The way products are selected for pricing at different establishments does not usually result in the same product being chosen for price collection at more than one establishment in a given geographic market area. Moreover, even when the BLS price collection approach does yield multiple price observations for the same product version, the BLS does not average over changing sets of the price observations.[45] In addition, for producer products, an effort is made to only make price comparisons over time for the same buyer-seller pairs. These are the main reasons why the BLS price-collection operations could not, at present, support a switch to compiling unit-value-based price indexes.

Yet most businesses in a developed country like the United States have their full transactions data for at least the current month readily available in electronic form. Hence, with equal ease, a business *could* give the BLS information on the quantity of the selected product that was bought or sold along with the price per unit that the BLS presently collects. Moreover, most modern businesses could provide their transaction value and quantity as well as price data for all transactions over some recent time period, such as a month, for a list of UPC-identified products. Feenstra and Shiells (1997) made a similar recommendation almost 20 years ago. The respondent burden would barely vary depending on the length of the product list. Hence, the same basic probabilistic selection approach for products at each selected establishment could be retained if desired, but the products selected at each establishment could be added to a common product list for all establishments, and then a month's worth of transactions data could be obtained from *all* selected establishments for *all* products on the common list.[46] The BLS would then have the option of producing various sorts of unit-value price indexes.

If averaging of prices for UPC-identified products is done over time, month by month, for each establishment, it should be possible to produce unit-value-based price indexes that are largely free of promotions bias problems. However, the outlet substitution bias would remain as long as there is no averaging over establishments. Alternatively, if unit values are produced by averaging of prices for UPC-identified products over the establishments in each designated market area, then it should be possible to produce unit-value-based price indexes that are largely free of outlet substitution as well as promotions bias problems.

Unfortunately, though, even averaging over establishments and time will not help with MPI and PPI sourcing substitution bias problems. The reason is that items of intermediate products that are the same from the perspective of how the purchasing firm plans to use the items are often bought from multiple suppliers, and product items from different producers have different UPCs even when all their attributes are identical. Thus the sourcing substitution bias problem would remain. Nor would this averaging of prices help with the product replacement bias phenomenon identified by Nakamura and Steinsson—another important case in which the UPCs differ for product items that have essentially the same attributes and that should perhaps be treated as the same index basket product.

At least for producer intermediate products, however, the user of the intermediate product units is in a position to specify the UPCs that are, from that user's perspective, for the same product. Hence, we recommend asking all producers from whom price quotes are collected whether they regard some of the UPC-identified products they purchase as identical, in that they use the product items interchangeably and in identically the same manner. Moreover, if a producer indicates that the product items from different suppliers are used or sold in the same way except for some allowance for a quality difference (e.g., purchase order adjustments to allow for supplier-specific defect rates), then the producer could also be asked to report and evaluate the quality difference, and that information could be used in implementing quality adjustments so that the product items from the different suppliers could be treated as items of the same constant-quality product.

As we have noted, there are also four other sorts of impediments to the adoption of unit-value-based price indexes by an official statistics agency like the BLS. One is an established and somewhat indiscriminate prejudice against unit values. We have argued that the reasons that led to this prejudice do not apply when the unit values are for UPC-identified or similarly very narrowly defined products, which is what we recommend.[47]

We differentiate what we call primary product and auxiliary product attributes. We define *primary product attributes* as characteristics that a product item has when first sold by the original producer and that normally continue to be characteristics of the product item regardless of where and how it may be resold. We define *auxiliary product item attributes* as attributes that a product item acquires as a consequence of where and how it is sold. A second impediment we then identify is that some of what a producer ships out as items of the same product can acquire additional auxiliary price-determining attributes, depending on where and how the product items are sold. We note that there are difficult conceptual and operational questions that arise regarding the treatment of auxiliary product attributes.

We can, as already acknowledged, see reasons for wanting to hold a variety of auxiliary attributes constant in estimating the price relatives that are used in compiling a price index. However, if an auxiliary attribute is used in product differentiation for price-quote collection purposes, then it is important for that same auxiliary-product attribute to be taken into account too in collecting the data for and in producing the product-specific value-share weights for a price index.

A third impediment is that there are unresolved issues regarding the price measurement appropriateness and the operational difficulty of recognizing the sameness of units of producer intermediate inputs from different suppliers that are viewed as identical (or almost so) by the businesses using these inputs. Related issues arise as well for consumer products, and we label those issues as the fourth impediment. So both Impediments 3 and 4 relate to situations where the UPC product definitions may be narrower than ideal for inflation measurement purposes. We view the task of determining when units of consumer products with different UPCs are, in fact, the same—or sufficiently similar that they should be treated as the same for inflation measurement purposes—as intrinsically harder than the corresponding problem discussed above for producer products.

Clearly, we do not provide full solutions to all the problems noted,[48] and some of our proposed solutions may prove to be suboptimal. We offer these suggestions in the spirit of a search for better ways, which we believe are possible now, given product code and other modern information-technology developments.

The incremental new transactions data collection approach outlined above would allow estimates to be made of the importance of the identified price-index bias problems, since this recommended approach nests the current BLS price-quote collection processes. The BLS could also draw on the growing experiences of other national statistics agencies that are now producing unit-value-based price indexes using electronic data from businesses (though, as we understand, without designating them as different from the conventional price indexes or explaining the relationship).[49]

We note too that the suggested incremental new data-collection approach would vastly enrich the BLS research databases, in addition to contributing to the price-index improvement agenda. Price indexes are ubiquitously used as measures of inflation and as deflators. In addition, however, the BLS research databases have been enabling a true empirical examination of the origins and transmissions of price signals in the U.S. economy.[50] If the BLS is given the resources needed to harness the power of the new information technologies, including making fuller use of the product codes now ubiquitously used by businesses, and if our recommendations (or appropriate modifications of these) are accepted, we believe the eventual result will be far superior price indexes.[51] We also believe this will result in great improvements in the accuracy of a host of other economic measures that embed price indexes as component parts, as well as an even greater flowering of insights into price signals, which are fundamental to the functioning of a free-market economy.

Notes

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1. Statistical agencies with practices more in line with our recommendation are noted in the seventh section, titled "Possible Price Measurement Practice Reforms." In addition to those agencies, many countries rely on monthly unit values for some of the prices used to compile their PPIs.
2. If that is how the proxy price is arrived at, an implicit assumption is being made that consumers are indifferent between the 10.75-ounce and the 15.2-ounce formats for the Campbell's tomato soup content. Other, more elaborate methods of quality adjustment might be utilized if that assumption were believed to be inappropriate.

3. Reinsdorf (1993) and Diewert (1995, 1998) defined and brought attention to this price-index bias problem. For related materials, see Greenlees and McClelland (2011), Moulton (1993, 1996a,b), Reinsdorf (1994a,b,c, 1998, 1999), and Reinsdorf and Moulton (1997), as well as Hausman (2003), Nakamura (1999), and White (2000).
4. Diewert and Nakamura (2010) define this bias problem and provide a measurement formula for it, having been inspired to work on this problem by the arguments and empirical evidence of Houseman (2007, 2009, 2011), Mandel (2007, 2009), and Mandel and Houseman (2011). See also Fukao and Arai (Chapter 7, this volume), Houseman et al. (2011), and Inklaar (2012).
5. Reinsdorf and Triplett (2009) review the context and content of the Stigler Committee's recommendations.
6. The person who purchases a can of soup may have preferences regarding shopping at a convenience store or a superstore for various sorts of products, but others who end up eating the soup at home will likely not care where a particular can of the soup happened to have been purchased and often will not even be aware of that detail.
7. See Nakamura and Steinsson (2008, 2012) for more on this sort of "price flexibility" and its significance for understanding and for the management of inflationary pressures in the macro economy.
8. Superlative indexes, defined by Diewert (1976, 1992), have many desirable properties when it comes to taking account of buyer substitution behavior, but they cannot properly account for the effects on the prices paid by buyers when that behavior changes because buyers progressively learn about cheaper sources of products rather than because of suppliers lowering their prices. See also Diewert (1987, 2013a,b); Diewert and Nakamura (1993, 2007); Nakamura (2013); and Reinsdorf, Diewert, and Ehemann (2002) regarding aspects of the Fisher index of relevance for the use of price indexes in the making of productivity indexes for nations.
9. The Laspeyres formula is defined below. It can be calculated in multiple stages of aggregation or in a single step. The Paasche index, also defined below, shares this convenient property.
10. Note that attributes of the product content will always be primary attributes of a product item.
11. See, for example, United Nations Economic Commission for Europe et al. (2009), Chapter 10, p. 147, expression 10.1. There, the quantity weights are for a base period other than the base period for the price observations because of the additional time often needed to obtain the data for estimating the index weights. We ignore this additional complication in this chapter.
12. There are many documented examples of narrowly defined products for both households and businesses being available from different producers for different prices. See, for example, Byrne, Kovak, and Michaels (2009); Foster, Haltiwanger, and Syverson (2008); and Klier and Rubenstein (2009).
13. While not defining the product-level product rule as we do here, von der Lippe and Diewert (2010) do make a similar sort of argument. They note that economic agents often purchase and sell the same commodity at different prices over a single

accounting period. They assert that a bilateral index-number formula requires that these multiple transactions in a single commodity be summarized in terms of a single price and quantity for the period. They explain, moreover, that if the quantity is taken to be the total number of units purchased or sold during the period and it is desired to have the product of the price summary statistic and the total quantity transacted be equal to the value of the transactions during the period, then the single price must be the average value. They note that this point was also made by Walsh (1901, p. 96; 1921, p. 88) and Davies (1924, 1932) and more recently by Diewert (1995). See Diewert (1987) and Diewert and Nakamura (2007) on the conventional product test.

14. Note that if there truly is just one price for each unit time period as each product n is defined, then each individual price observation equals $p_n^{t,\bullet}$ for the given n,t combination. Hence, the condition in Equation (2.11) will be satisfied when the conventional statistical agency practice of utilizing a single price observation for each product in each time period is followed.
15. The term “hybrid” was suggested to Marshall Reinsdorf by Harlan Lopez of the Central Bank of Nicaragua.
16. By “raw” we mean transactions data not already aggregated over time. Providers of what is labeled “transactions data” often, in fact, deliver data sets consisting of the total quantities transacted and the unit values for some unit time period such as a week. See, for instance, Nakamura, Nakamura, and Nakamura (2011) for a study done using transactions data of this sort.
17. See, for example, Ivancic, Diewert, and Fox (2011) and Nakamura, Nakamura, and Nakamura (2011).
18. In defining these formulas, we ignore the important aspect of conventional practice that is the focus of the Lowe index literature: namely, that the data used in estimating the value shares is collected separately from the price information used in index making, and is not usually even for the same time periods. See Balk (2008, Chapter 1) and Diewert (1993) for more on this issue.
19. For a formal proof of this result, see Diewert and Nakamura (2010, appendix), where this result was first presented.
20. For more on the practical aspects of these “revolutionary changes” that Denison (1962) noted and foresaw, see Brown (1997); Freeman et al. (2011); Hausman and Leibtag (2007, 2009); Jones, Garg, and Sheedy (1999); and Senker (1990).
21. Important papers on this topic include Greenlees and McClelland (2011), Hausman (2003), Hausman and Leibtag (2007, 2009), and Moulton (1993, 1996a,b). Also, White (2000) presents related evidence for Canada.
22. For more on the importance of temporary sales for explaining retail price dynamics, see Nakamura and Steinsson (2008, 2012), Pashigian (1988), and Pesendorfer (2002).
23. The same is true for Statistics Canada (1996, p. 5): “Since the Consumer Price Index is designed to measure price changes experienced by Canadian consumers, the prices used in the CPI are those that any consumer would have to pay on the day of the survey. This means that if an item is on sale, the sale price is collected.”

The BLS does, however, have other special procedures for handling sale prices of apparel at the end of the selling season.

24. The statistical agencies for some U.S. trading partners exclude temporary sale prices in compiling their Consumer Price Index (CPI). For example, price collectors are instructed by the Statistics Bureau of Japan not to collect sale prices. More specifically, price collectors are instructed that "the following prices are excluded: Extra-low prices due to the bargain sales, clearance sales, discount sales, etc., which are held for less than seven days" (Statistics Bureau of Japan 2012, p. 3, item 10). (See also Imai, Shimizu, and Watanabe [2012].) This methodology difference could definitely affect inter-nation comparisons of inflation, economic growth, and well-being, and the formula in Equation (2.34) can be useful for understanding these effects.
25. We thank Brent Moulton for comments that greatly improved this section of the chapter.
26. Supply chain models like what Oberfield (2013) specifies assume that much of what typically is measured as technical progress in fact reflects the cost savings from supplier switches.
27. Houseman et al. (2011) provide a variety of relevant empirical evidence for the MPI case.
28. Note that the terms in Equation (2.34) involving d_n^0 drop out of the final expression in this case, and also that here we have $S^0 = 1$ because, in period 0, there is only the one supplier for Business 3, charging a single price.
29. Equation (2) in Reinsdorf and Yuskavage (2014) modifies this formula to use a value share weight instead of a quantity share by multiplying by a factor that is between 1 and $1/d^1$. Also, Houseman et al. (2010, p. 70) derive a formula for calculating quantity shares from value shares and the discount d^1. A related formula for outlet substitution bias is found in Diewert (1998, p. 51).
30. Houseman et al. (2011) also provide relevant empirical evidence for the IPI bias case, including pointing out evidence in studies of others about the cost savings possible to a business from switching from domestic to foreign suppliers for intermediate products. They note as well that "the foreign price deflator for intermediate materials rose somewhat *faster* than the domestic deflator" (p. 122). This result is the opposite of what, as they explain, would be the expected result and could be explained by price-index bias problems of the sort we consider here and in the previous section. They empirically implement a bias correction to an input price index under a range of alternative possible assumptions.
31. See Eldridge and Harper (2010); Kurz and Lengermann (2008); and Yuskavage, Strassner, and Medeiros (2008).
32. This point was independently noted both by Diewert and Nakamura (2010) and by Reinsdorf and Yuskavage (2014).
33. An additional conceptual test is international aggregation, as in Maddison (2001). The sum of world GDP should be a consistent measure of world investment and consumption; this implies that exports and imports (with shipping costs) equate across nations in real terms. Eliminating sourcing biases moves us toward an ability to meet this test.

34. From 1948 to 1959, the relevant BLS price index services and Sears and Montgomery Ward prices grew by 50 percent, whereas the Farm Index series grew by less than 10 percent.
35. Alterman (1991) proposes and checks out other possible explanations as well for the results he observed, but he reports that those other hypotheses were rejected by the data.
36. Written comments by Pinelopi Koujianou Goldberg on Nakamura and Steinsson (2012), shared with us by those authors, led us to see this point, and made us aware that similar issues may affect a variety of other studies and views on changes over time in price flexibility and related issues for the U.S. economy and for international comparisons.
37. There is an even larger knowledge gap opening up between the business world and the official statistics agencies as the business world now begins to move from UPCs and bar code scanners to Electronic Product Code (EPC) and Radio Frequency Identification (RFID) usage. See Roberti (2005) for more on the nature of and reasons for this continuing evolution.
38. The Ad Hoc Committee consisted primarily of presidents, vice presidents, and CEOs who were selected from manufacturers, distributors, and retailers so as to ensure that the interests of all parts of the grocery supply chain were represented. In addition to being corporate executives, the individuals selected for the committee had significant knowledge, respect, and influence within the entire industry.
39. See http://www.upccode.net/upc-guide/uniform-code-council.html.
40. On how bar codes can be obtained in each nation, see http://www.gs1.org/barcodes/need_a_bar_code. For more on this history, see http://en.wikipedia.org/wiki/Universal_Product_Code and also Kennedy (2013).
41. Walmart's superior information systems have even enabled the company to respond better to emergencies such as hurricanes than government agencies, as was widely reported during Hurricane Katrina (see, e.g., Barbaro and Gillis 2005).
42. We focus on just the bias problems for the CPI and MPI here because those bias problems affect the computation of real GDP. In contrast, whereas bias problems for the PPI or the proposed IPI are relevant for estimation of real input values for intermediate products, these problems do not affect in any direct way the computation of official real GDP estimates, hence they do not directly affect the labor productivity growth estimates of official statistics agencies like the BLS. Houseman (2007, 2009, 2011) and Mandel (2007, 2009) have explored and helped raise interest in these issues. See also Fukao and Arai (Chapter 7, this volume); Howells et al. (2013); Inklaar (2012); and Strassner, Yuskavage, and Lee (2009).
43. Haskel et al. (2012) refer to BLS data series #PRS85006092 at http://www.bls.gov.
44. So if an establishment, in fact, charged or paid multiple per-unit prices for a chosen product in a given month, there would be no evidence of this in the BLS price-quote data.
45. As noted above, the geometric mean indexes used in the CPI amount to averaging prices, but the sample of prices that are averaged is held constant between the two time periods being compared. In contrast, unit-value indexes allow the composition of the averages to change.

46. It is important for this sampling to include Internet and multichannel retailers (Metters and Walton 2007).
47. Indeed, the UPC-identified products may be too narrowly defined in some cases, so sometimes it may be judged to be better for inflation measurement purposes to treat a stated group of UPCs as being all for the same product.
48. For example, we have not even made a start on considering the problems of producing unit values for products such as computers that are currently handled using hedonic methods (see, for example, Baldwin et al. [1996], Berndt and Rappaport [2001], Pakes [2003], and Pakes and Erickson [2011]), or pharmaceuticals and medical services (Berndt and Newhouse 2012).
49. The Australian Bureau of Statistics and the New Zealand Bureau of Statistics have reportedly been exploring ways of obtaining supermarket scanner data directly from the main supermarket chains in those nations and then of using weekly unit-value prices for grocery products that are computed by the statistical agencies directly from grocery-store scanner data. Also, as Guðmundsdóttir, Guðnason, and Jónsdóttir (2008) explain, Statistics Iceland collects electronic data from the information systems of firms. Besides prices and quantities, the data Statistics Iceland harvests show customer identifiers and business terms for each customer at the time of the trade. Statistics Iceland reports that electronic data collection has resulted in lower collection costs and lighter response burdens for the participating firms. Statistics Iceland also reports that when the agency switched to electronic data collection from firms, it was also able to adopt a superlative approach for price-index compilation. Feenstra et al. (2013) analyze several sources of mismeasurement in the U.S. terms of trade and find that one important source of bias comes from the fact that the import and export price indexes published by the BLS are Laspeyres indexes, rather than being based on a superlative formula.
50. The CPI Research Database is a confidential data set that contains all the product-level nonshelter price and characteristics data that were used to construct the CPI from 1988 to the present. The goods and services included in the CPI Research Database represent about 70 percent of consumer expenditures, the excluded categories being rent and owners' equivalent rent. Nakamura and Steinsson (2008, 2012) created analogous data sets from the production files underlying the PPI and also the MPI and XPI. Those data sets have become the new research databases for the PPI and International Price Program. These BLS research databases are enabling far-reaching and fundamental advances in economic understanding.
51. It is possible that more than financial resources will be required. Participation in all BLS price surveys is voluntary, unlike the situation in many nations, and some businesses may consider the provision of electronic price and quantity data to be more burdensome than the current BLS data collection procedures.

Appendix 2A

Putting the Picture Together with a Final Example

The BLS collects and uses prices for the CPI regardless of whether they are "regular" or "sale" prices. In contrast, as noted in the text, some U.S. trading partners, such as Japan and the EU countries, exclude sale prices in compiling their CPI programs. A numerical example may help clarify why this choice matters. Consider the hypothetical data in Table 2A.1.

Table 2A.1 Regular and Temporary Sale Transaction Data for a Product

	Price ($)	Quantity	Transaction value ($)
		Period (t = 0)	
Regular price transactions for product *n*	2.00	2,000	4,000
Temporary sale discount price transactions	1.00	3,000	3,000
Total		5,000	7,000
		Period (t = 1)	
Regular price transactions for product *n*	2.20	1,000	2,200
Temporary sale discount price transactions	1.15	4,000	4,600
Total		5,000	6,800

Case 1. Suppose that only the regular price quotes are used for compiling a price index. As for the estimates of the value weights, following conventional practice, suppose these come from a household survey that does not distinguish between regular and sale transactions and will reflect all transactions for a product. With the hypothetical data in rows 1 and 4 of Table 2A.1 for regular price transactions, the resulting Laspeyres, Paasche, and Fisher price indexes[1] all equal 1.1.

Case 2. Next, suppose that both the regular and sale prices are used, treating the items of product *n* sold at regular price as a different product from the items sold during temporary sale periods. If we do that,[2] we get $P_L^{0,1} = 1.121$, $P_P^{0,1} = 1.333$, and $P_F^{0,1} = (P_L^{0,1} P_P^{0,1})^{1/2} = 1.127$.[3] Note that only the quantities of the product sold at the regular price are used now as weights for the observed regular-price quotes, and only the quantities of the product sold at a temporary sale price are used as weights for those price quotes, which is what one might expect to be the procedural implication of treating the two groups of units of the product as *different* products.

Case 3. Finally, suppose we treat each unit of a product as being the same regardless of whether it is sold at regular price or at a discount during a temporary sale period. In this case, we first compute the average price for the product *n* in each period:

$$\overline{p_n^{0,\bullet}} = \frac{\$4{,}000 + \$3{,}000}{2{,}000 + 3{,}000} = 1.4 \text{ and}$$

$$\overline{p_n^{1,\bullet}} = \frac{\$2{,}200 + \$4{,}600}{1{,}000 + 4{,}000} = 1.36.$$

Using the average prices for the price variable and the total transaction volumes for the quantity variable in each price index,[4] now we get

$$P_L^{0,1} = P_P^{0,1} = P_F^{0,1} = 0.9714.$$

In Period 0 and also in Period 1, the quantity of 5,000 units of product *n* was transacted. These transactions had a nominal value of $4,000 in Period 0 and $6,800 in Period 1. If we deflate the Period 1 nominal value by 0.9714, we get a *real value* of $7,000, so we find no change in the “real value” from Period 0 to 1: a result that is in agreement with the data on the physical quantities transacted. This result only pertains to the last of the above approaches for calculating a price index; the others do not yield this outcome.

Appendix Notes

1. $P_L^{0,1} = \frac{\$2.20 \times (2{,}000 + 3{,}000 \text{ items})}{\$2.00 \times (2{,}000 + 3{,}000 \text{ items})} = 1.1$, $P_P^{0,1} = \frac{\$2.20 \times (1{,}000 + 4{,}000 \text{ items})}{\$2.00 \times (1{,}000 + 4{,}000 \text{ items})} = 1.1$,

   and $P_F^{0,1} = (P_L^{0,1} P_P^{0,1})^{1/2}$.

2. We note again that the U.S. CPI actually would employ a geometric mean, rather than Laspeyres, formula.

3. $P_L^{0,1} = \frac{(\$2.20 \times 2{,}000 \text{ items}) + (\$1.15 \times 3{,}000 \text{ items})}{(\$2.00 \times 2{,}000 \text{ items}) + (\$1.00 \times 3{,}000 \text{ items})} = 1.1$ and

   $$P_P^{0,1} = \frac{(\$2.20 \times 1{,}000 \text{ items}) + (\$1.15 \times 4{,}000 \text{ items})}{(\$2.00 \times 1{,}000 \text{ items}) + (\$1.00 \times 4{,}000 \text{ items})} = 1.3.$$

   $$P_L^{0,1} = \frac{\$1.36 \times (2{,}000 + 3{,}000 \text{ items})}{\$1.40 \times (2{,}000 + 3{,}000 \text{ items})} = 0.971 \text{ and}$$

   $$P_L^{0,1} = \frac{\$1.36 \times (1{,}000 + 4{,}000 \text{ items})}{\$1.40 \times (1{,}000 + 4{,}000 \text{ items})} = 0.971.$$

Appendix 2B

An Example Showing How Product Definitions Matter

The producer-side product substitution bias problems identified by Nakamura and Steinsson (2008, 2012) and the sourcing substitution bias problems identified by Diewert and Nakamura (2010) have in common the fact that the solutions to both necessarily involve some sort of averaging of per-unit prices for products with different UPCs. As already noted, these bias problems force a consideration of how products are defined.

UPCs have the desirable attributes of being documented and electronically recognizable. Also, business data systems are built to keep track of product purchases and sales using UPC information, making it easy for businesses to provide information to statistical agencies for products identified by UPCs.

Consider the case of an economy with just two commercially distinct output products, *A* and *B*. We will briefly examine the measurement consequences of treating the two products as distinct for both price and value-share data collection purposes versus grouping them together as a single product. We will assume we have full price and quantity data for all transactions for the two products in both periods $t = 0$ and $t = 1$, and that there truly is just one price per product in each time period.

In row 1 of Table 2B.1 we show the nominal output growth ratio. Below that on the left-hand side we show the Fisher price index, the real output growth ratio created by deflating the nominal revenue ratio by the Fisher price index (which equals the Fisher quantity index), and the Fisher labor productivity index. (The results if a Laspeyres price index is used instead can be seen by ignoring the second term in the left-hand column and not taking the indicated square root in both row 2 and row 3 and also in the numerator in row 4.)

The counterpart expressions that are obtained if we use the same full transactions data but treat products *A* and *B* as the same product for measurement purposes are shown on the right-hand side of the table. The nominal revenue ratio is shown in the middle of row 1 because it is unchanged by whether we treat products *A* and *B* as distinct or as the same product for measurement purposes.

The consequences of choices made about product definitions are clearest perhaps from the quantity growth ratios in row 3. When we distinguish the products, the quantity growth measure involves price-weighted aggregates, whereas when we treat the items of *A* and *B* as all being items of the same index basket product, then the numbers of items of each are simply added into the total for each period without the use of weights.

Table 2B.1 The Consequences of Treating Two Products as Distinct versus the Same Index Basket Product

Using a Fisher price index for deflation with A and B treated as distinct index basket products	Using a Fisher price index for deflation with A and B treated as the same index basket product
$\frac{R^1}{R^0} = \frac{p_A^1 q_A^1 + p_B^1 q_B^1}{p_A^0 q_A^0 + p_B^0 q_B^0}$	
$P_F^{0,1} = \left[\left(\frac{p_A^1 q_A^0 + p_B^1 q_B^0}{p_A^0 q_A^0 + p_B^0 q_B^0}\right)\left(\frac{p_A^1 q_A^1 + p_B^1 q_B^1}{p_A^0 q_A^1 + p_B^0 q_B^1}\right)\right]^{(1/2)}$	$P_F^{0,1} = \frac{(p_A^1 q_A^1 + p_B^1 q_B^1)/(q_A^1 + q_B^1)}{(p_A^0 q_A^0 + p_B^0 q_B^0)/(q_A^0 + q_B^0)} = \left(\frac{R^1}{R^0}\right)\left(\frac{q_A^0 + q_B^0}{q_A^1 + q_B^1}\right)$
$\left(\frac{R^1}{R^0}\right) / P_F^{0,1} = \left[\left(\frac{p_A^0 q_A^1 + p_B^0 q_B^1}{p_A^0 q_A^0 + p_B^0 q_B^0}\right)\left(\frac{p_A^1 q_A^1 + p_B^1 q_B^1}{p_A^1 q_A^0 + p_B^1 q_B^0}\right)\right]^{(1/2)}$	$\left(\frac{R^1}{R^0}\right) / P_F^{0,1} = \frac{q_A^1 + q_B^1}{q_A^0 + q_B^0}$
$LP_F^{0,1} = \frac{\left[\left(\frac{p_A^0 q_A^1 + p_B^0 q_B^1}{p_A^0 q_A^0 + p_B^0 q_B^0}\right)\left(\frac{p_A^0 q_A^1 + p_B^0 q_B^1}{p_A^0 q_A^0 + p_B^0 q_B^0}\right)\right]^{(1/2)}}{\left(L_A^1 + L_B^1\right)/\left(L_A^0 + L_B^0\right)}$	$LP_F^{0,1} = \frac{\left(\frac{q_A^1 + q_B^1}{q_A^0 + q_B^0}\right)}{\left(L_A^1 + L_B^1\right)/\left(L_A^0 + L_B^0\right)}$

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3
Assessing Price Indexes for Markets with Trading Frictions

A Quantitative Illustration

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In the last half-century, reductions in transportation and communication costs have dramatically reshaped the spatial organization of manufacturing production. It is becoming common, for instance, for an input to be manufactured abroad and then shipped back to the firm that designed it (Hummels, Ishii, and Yi 2001). The physical manufacturing of the good in this case is increasingly concentrated in developing economies such as China, which tend to offer lower prices than incumbent producers.

What is the source of these lower prices? They may represent real discounts on the same physical good. But there is also a possibility the price differentials are spurious. They may reflect, for instance, unobserved differences in the composition of goods. Furthermore, even if the inputs are physically identical, the quality of the production *service* may vary—as judged, for instance, by the timeliness of delivery and the reliability of the finished product. As Carlton (1983) stresses, the service quality factors into the true price of the good to the buyer (and into the real resource cost of the transaction).

The answer to our question is of considerable importance to price index measurement. If price differentials are mistakenly assumed to be spurious, price indexes will be constructed to ignore the true decline that occurs when lower-price suppliers enter an intermediate market.

However, it is equally perilous to neglect the scope for unobserved variation in product and service quality. The challenge to statistical agencies is that, in practice, it is very difficult to isolate real price dispersion given data limitations.

In reaction to this, the present paper attempts to provide some guidance for price measurement. We explore how well imperfect, but *feasible*, price indexes approximate the true price change in markets where quality variation and real dispersion commingle. A price index is feasible if it can be computed from data only on observable outcomes, such as market prices. We apply these feasible indexes to markets characterized by two key features. First, even if physical products are identical, there is scope for variation in service quality that would be unobservable to the analyst. Second, the same product and service can still be priced differently because of a certain trading friction that impedes arbitrage.

We carry out our experiment within a simple duopoly pricing model. The structure of the model is designed to mimic salient features of the market for semiconductor wafers, the subject of our empirical application below. The latter market is an excellent example of the contract manufacturing sector, in which domestic firms design products and offshore all fabrication activities. This sector is expanding at a remarkable rate in the United States (Bayard, Byrne, and Smith 2013).

In the model, two large suppliers—a leader (the founding firm in the market) and a follower (who enters the market last)—produce an input for overlapping generations of buyers. We assume that the physical (observable) dimensions of the input are the same across suppliers. This assumption is relatively safe in our context since, in our empirical application, we have exceptionally detailed data on physical attributes. However, the model allows for variation in the quality of the manufacturing service. We make this notion more precise below; the bottom line is that lower-quality service will raise the effective price of transacting with the *follower*. At the same time, we introduce a trading friction that takes the form of a setup cost that must be paid if a buyer switches suppliers during the life of its product. The setup cost applies regardless of the identity of the supplier to whom the buyer is switching. This friction implies that, when the follower enters the market, the leader's customers may pay its high price even if there is no difference in production service.

In the second section ("A Pricing Game with Costly Switching"), we first solve the model numerically to illustrate its key implications for price dispersion and price dynamics. The presence of the setup cost implies that, when the follower enters, the extent of price dispersion exceeds that which could be attributed to quality variation. However, as the leader's contracts with its original customers end, it will compete more aggressively for new generations of buyers. This causes price dispersion between firms to narrow. In fact, under certain circumstances, the effect of the setup cost on price dispersion will abate to the point that the price differential at the end of the product life will reflect *only* variation in service quality. This is a key distinguishing property of the model—constant differences in service quality alone do not induce this pattern in the *dynamics* of price dispersion.

Before we apply the model to price index measurement, we first look for evidence consistent with these predictions. To that end, the third section ("An Application to the Semiconductor Industry") presents results from Byrne, Kovak, and Michaels (2013) that are consistent with these dynamics. The authors have data on transaction-level prices of semiconductor wafers along with the key technological attributes of each wafer. They can therefore control for differences across suppliers in product composition. However, there may still be differences with respect to service quality. Indeed, it is often thought that the leader in this market, Taiwan, has software tools that enable it to provide higher-quality service, for which it presumably charges a higher price than its main competitor, China.[1] The theory in Section Two suggests a way of identifying quality-*adjusted* dispersion in this setting: Byrne, Kovak, and Michaels can test for whether the price difference between these suppliers narrows after China's entry into a particular wafer market.[2] They find that, on average, the price differential between Taiwan and China does close substantially over the life of a given semiconductor technology: It falls from 39 percent in the year of Chinese entry to 10 percent after five years. This narrowing is consistent with the presence of real dispersion, although the differential remaining even at the end of the product life is suggestive of quality dispersion.

In light of this evidence, Section Four ("Feasible Price Indexes") returns to the model and uses it to study the performance of different price indexes when the observed change in average market price reflects both real dispersion and variation in quality. This section first calculates a benchmark index that assumes the analyst has perfect information regarding quality and is able to directly adjust for the effective cost of transacting with the follower. It then compares the results of this benchmark with feasible price indexes that can be calculated even when the analyst has access only to data on market prices. We consider three examples.

The first feasible index is based on the idea that price dispersion across suppliers derives exclusively from quality variation. In this case, the index can be computed by analogy to a standard superlative index, which treats a supplier's service as a separate "good" and averages price changes across providers. The second feasible index takes the opposite view: All of the observed differential represents a real discount. Accordingly, one can simply average price levels across suppliers and compute the change in the average price across periods. Not surprisingly, this index yields the largest declines in the price level when the lower-priced supplier enters the market. The third index is our preferred index, since it tries to strike a compromise between these two. It relies on a simple implication of the theory, noted above: the effect of the setup cost on price dispersion abates over the course of the product life cycle, leaving a price differential that reflects only variation in service quality. As a result, we can use the *observed* price differentials late in the product life cycle to proxy for unobserved quality variation. This enables a simple correction to market price data while not foreclosing a role for real price dispersion.

Section Four confirms that our preferred index performs best. Yet, as we detail later, the correction here is still somewhat conservative in that it continues to slightly understate the extent of the true price decline that occurs when the follower enters the market. We then illustrate how to adjust our preferred index so that it delivers an *upper* bound on the extent of the price decline. The true price change can then be bracketed.

Section Five offers a conclusion.

A PRICING GAME WITH COSTLY SWITCHING

This section begins by describing an extension of the simple pricing game in Byrne, Kovak, and Michaels (2013). Our modeling is guided by a large literature that studies price setting in markets under costly switching.[3] The model here deviates slightly from this preceding literature, which typically restricted attention to the analytics of games with symmetric players. Reflecting our interest in the quantitative dynamics following the entry of a low-cost supplier, we analyze a calibrated game with asymmetric actors. The leader is the founding firm in the market and enjoys monopoly status for a time. The follower enters the market subsequently and has a lower unit cost of production but inferior production technology. Each firm competes to supply an input to overlapping generations of final-goods producers—the consumers, or buyers, in this market.

The Model

The basic environment

The model is perhaps the minimalist structure needed to consider some of the questions of interest. There are three periods, and there are two types of agents in the market—buyers and manufacturers of an intermediate good. A cohort of buyers enters in each of the three periods. The period-1 cohort is present in periods 1 and 2, the period-2 cohort is present in periods 2 and 3, and the period-3 cohort is present in period 3. Each cohort is of mass 1. Buyers have unit demand, and they purchase from one of the suppliers as long as the price is less than the reservation value, a constraint that we discuss in detail below.

Even though buyers purchase the same physical input from both suppliers, we assume there are details of the production process that have to be tailored to the buyer's order. To preview the example in Section Three, consider the market for semiconductor wafers, where buyers are designers of integrated circuits. Suppliers are firms that fabricate silicon wafers on which the design is implanted. Each buyer purchases a wafer with the same size and density of transistors, but there are details of the design—the precise manner in which transistors are arrayed on the wafer—that require some specialization of the production process. Formally, we follow in the spirit of Klemperer (1995) and assume that design complexity, y, is distributed uniformly from 0 (lowest quality) to 1 (highest quality). This heterogeneity across buyers would be unobservable to an econometrician who has data only on the physical wafer size and line width. In this sense, the model allows for price dispersion that reflects unobserved heterogeneity.

Turning to the manufacturers, Firm A is the leader and is present in the market from period 1 onward. Firm B is the follower; it joins the market in period 2. We assume Firm A is at the technology frontier. To again borrow an example from the semiconductor wafer market, it is thought that Taiwan's fabrication firms have intellectual property that enables them to more efficiently produce a highly complex design. This means that, although Firm B (China, in the case of the wafer market) can fabricate any chip, the consumer must pay a cost to monitor and consult with this supplier. We assume that buyers who purchase from Firm B pay a per-period monitoring cost, τy (with $\tau > 0$), that is increasing in design complexity. What helps Firm B to compete in the face of this disadvantage is that it enjoys a lower unit cost of production, which we denote by c^B. Specifically, we assume that both firms have constant unit costs, and that $c^A > c^B$.

When a buyer initiates production with a supplier, it must pay a startup cost, s. This cost has to be paid again if the buyer switches suppliers. Thus, if a buyer purchased from Firm A in period $t - 1$ but switches to Firm B in period t, it must pay s again (independent of its quality). Hence, this buyer would pay a price, p_t^A, to remain with Firm A in period t, and would pay $p_t^B + \tau y + s$ to switch to Firm B, where p_t^B is Firm B's posted price in period t, τy is the monitoring cost, and the startup cost s acts as a cost of switching.

There are very clear examples of switching costs in the wafer market. To illustrate, certain equipment has to be supplied by the customer and calibrated to the processes and technologies of each supplier. For instance, the customer supplies the mask, through which its design of transistors is projected onto a wafer. The mask must be specified to sync with the supplier's proprietary technologies, which are generally incompatible across manufacturers. This makes it difficult to re-source a product once wafer production begins. In the case of a mask, the price of a new one is high, at over $1 million. As a result, notes one industry association, "The time and cost associated with [switching] tend to lock customers into a particular [supplier]" (Gabriel Consulting Group 2006, p. 1).[4]

Last, following much of the literature on costly switching, the model prohibits price discrimination. This restriction is roughly consistent with wafer supplier contracts, which limit a supplier's freedom in charging appreciably different prices across its customers.[5] Thus, we assume the price p_t^A (p_t^B) applies to all Firm A (B) buyers in period t.

The terminal period problem

The problem is solved by backward induction. To analyze the period-3 problem, we first conjecture that there is a threshold y_2 so that Firm B attracts all period-2 entrants with designs y that satisfy $y \leq y_2$. In other words, we assume the least "advanced" producer attracts buyers with the least complex designs. This conjecture will be confirmed in equilibrium. In what follows, since y is uniformly distributed, we refer to the mass of buyers y_2 as Firm B's customer base at the start of period 3. The mass of higher-quality buyers $1 - y_2$ makes up Firm A's customer base.

There are three groups of buyers to whom Firm A may sell: members of its own customer base, members of Firm B's customer base, and buyers who enter in period 3 (period-3 entrants). The demand schedules for each of these cohorts are given below. Throughout, we let σ_t^{jj} represent the share of Firm j's customer base that it retains in period t, σ_t^{j0} the share of period-t entrants that it attracts, and σ_t^{ji} the share of Firm i's customer base acquired by Firm j. Hence, for Firm A, we have

$$(3.1) \quad \begin{aligned} \sigma_3^{AA}\left(p_3^A; p_3^B, y_2\right) &= \Pr[p_3^A \leq p_3^B + \tau y + s \mid y > y_2] \\ \sigma_3^{AB}\left(p_3^A; p_3^B, y_2\right) &= \Pr[p_3^A + s \leq p_3^B + \tau y \mid y \leq y_2] \\ \sigma_3^{A0}\left(p_3^A; p_3^B, y_2\right) &= \Pr[p_3^A \leq p_3^B + \tau y] \end{aligned}$$

where p_t^j denotes the price of Firm j in period t.

Each of the components of Equation (3.1) is straightforward. Firm A retains a member $y > y_2$ of its customer base if its price, p_3^A, is less than the quality-adjusted price of its rival, $p_3^B + \tau y$, plus the cost of switching production to a new supplier, s. It poaches a buyer $y \leq y_2$ in Firm B's customer base if its price, plus the cost of switching, is less than $p_3^B + \tau y$. Last, Firm A attracts a new (period-3) entrant if its price is less than the quality-adjusted price of Firm B. Observe that s does not appear in the entrant's decision, since it must pay the cost of setting up regardless of the supplier from which it sources.

Absent from Equation (3.1) is any mention of the buyer's (gross) payoff from the sale of its final good. This is because the gross payoff is independent of the identity of the supplier. Thus, conditional on participation in the market, the buyer's choice of supplier depends only on the relative (quality-adjusted) prices and setup costs. We only assume at this stage that the gross payoff exceeds the minimum cost to the final-goods maker. Later, we will specify the payoff and calibrate it so that the participation constraint does not in fact bind in periods 2 and 3.

Firm A's terminal-period problem may now be stated as follows. From Equation (3.1), we have that total sales by Firm A in period 3 are given by

(3.2)

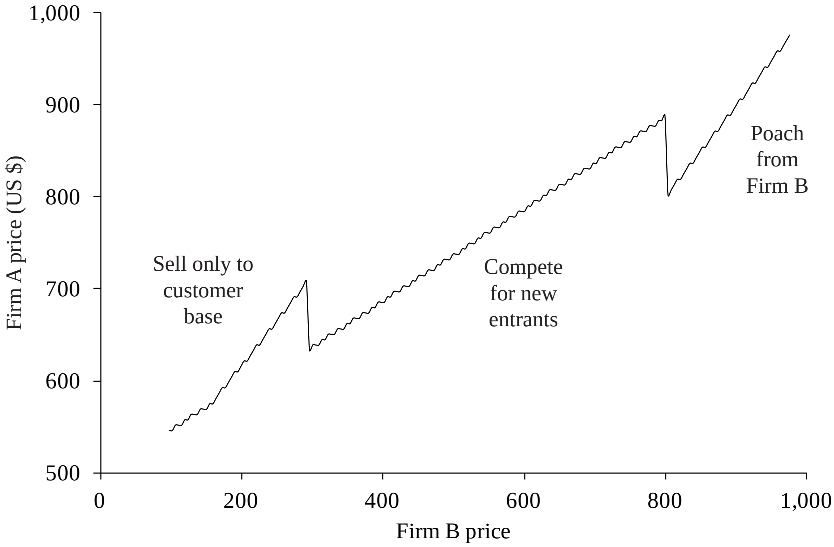
$$Y_3^A = \sigma_3^{AA}(p_3^A; p_3^B, y_2)(1 - y_2) + \sigma_3^{A0}(p_3^A; p_3^B, y_2) + \sigma_3^{AB}(p_3^A; p_3^B, y_2)y_2.$$

The leader then sets its price to maximize profits, $(p_3^A - c^A)Y_3^A$, which yields an optimal price of the form $p_3^A(p_3^B, y_2)$. Firm B faces the analogous problem, the solution of which is represented by $p_3^B(p_3^A, y_2)$. The intersection of the two best responses yields the terminal-period equilibrium, conditional on y_2. We denote the equilibrium prices by $P_3^A(y_2)$ and $P_3^B(y_2)$.

The (pure-strategy) pricing policy of a firm can typically be partitioned into three regions. Consider, for instance, the behavior of Firm A, whose optimal price is shown in Figure 3.1 as a function of Firm B's price. Over a range of low Firm B prices, Firm A will concede all new entrants to its rival. The reason for doing so is that it can earn greater profits by setting a higher price and selling exclusively to its partially "locked-in" buyers. As Firm B raises its price, it becomes profitable for Firm A to compete for new entrants. Thus, there is an intermediate range of Firm B prices over which Firm A both retains its own customer base and captures a share of new entrants. Lastly, still higher Firm B prices enable Firm A to poach from Firm B's customer base.

Interestingly, the pricing rule in Figure 3.1 is not necessarily continuous across these regions. As a result, one firm's best response can pass through the "gap" in the other's, yielding *no* equilibrium (in pure strategies).[6] The reason for these discontinuities can be traced to the fact that, given $s > 0$, no firm wishes to charge a price so as to acquire only

Figure 3.1 Firm A Best Response



NOTE: This shows Firm A's optimal price, given the Firm B price shown along the horizontal axis. The three regions of the graph are discussed in the main text.
SOURCE: Authors' calculations of simulation results from the model in Section Two.

a marginal share of new entrants. If Firm A does this, for instance, it renders the $y = 1$ entrant (the most complex design) indifferent between suppliers. But in that case, A's incumbents will be strictly inframarginal because they face $s > 0$. As a result, the firm can increase profit by discretely raising its price: It makes a higher profit from incumbents while sacrificing an infinitesimal share of new entrants. Accordingly, Firm A delays reducing its price to compete for incoming buyers. Then, when p^B is sufficiently high, Firm A can increase profits by reducing its price discontinuously and capturing a *discrete* share of new entrants, even while still charging a reasonably high price level to its incumbents.

Despite these discontinuities in the best responses, we identify a realistic calibration of the model under which there does in fact exist a Nash equilibrium in pure strategies, in which both suppliers sell to new entrants in each period (a "no-sale" equilibrium, to borrow from Farrell and Klemperer's [2007] language). We discuss this calibration in greater detail below.

The period-2 problem

We now turn to the period-2 problem. There are two types of buyers: new entrants and members of Firm A's customer base. We begin with the former. A period-2 entrant with design y will purchase from Firm A only if the presented discounted sum of period-2 and period-3 prices is less than what the entrant would face if it purchased from Firm B. This implies that the buyer at the threshold $y = y_2$ must be indifferent across suppliers. Accordingly, y_2 solves

$$(3.3)\quad p_2^A + \beta \min[P_3^A(y_2), P_3^B(y_2) + \tau y_2 + s]$$
$$= p_2^B + \tau y_2 + \beta \min[P_3^A(y_2) + s, P_3^B(y_2) + \tau y_2],$$

where $\beta < 1$ is the discount factor. Equation (3.3) implicitly defines the threshold, y_2, as a function of period-2 prices, $y_2(p_2^A, p_2^B)$. Thus, Firm A's demand schedule among period-2 entrants is $1 - y_2(p_2^A, p_2^B) \equiv \sigma_2^{A0}(p_2^A, p_2^B)$.[7]

In addition, Firm A begins the period with a customer base. Let y_1 denote the threshold level of quality so that all entrants in period 1 (the initial period of the market) with $y \geq y_1$ participate and so purchase for Firm A. Thus, Firm A's customer base is $1 - y_1$. These buyers remain in the market for period 2 and then exit. Hence, their problem is a static one: they remain with Firm A if $p_2^A \leq p_2^B + \tau y + s$. Since y is uniformly distributed (conditional on $y \geq y_1$), Firm A retains a measure of its old customers equal to

$$\sigma_2^{AA}(p_2^A, p_2^B;\ y_1) = \Pr[p_2^A \leq p_2^B + \tau y + s \mid y \geq y_1] = \frac{\tau - p_2^A + p_2^B + s}{(1 - y_1)\tau}.$$

Firm A now solves

$$\pi_2^A(p_2^B, y_1) = \max_{p_2^A}\Big\{\left(p_2^A - c^A\right)\cdot Y_2^A\left(p_2^A, p_2^B;\ y_1\right)$$
$$+ \beta\left(P_3^A\left(y_2\left(p_2^A, p_2^B\right)\right) - c^A\right)\cdot Y_3^A\left(y_2\left(p_2^A, p_2^B\right)\right)\Big\},$$

subject to period-2 sales

$$Y_2^A\left(p_2^A, p_2^B;\ y_1\right) = \sigma_2^{A0}\left(p_2^A, p_2^B\right) + \sigma_2^{AA}\left(p_2^A, p_2^B;\ y_1\right)(1 - y_1)$$

and period-3 sales $Y_3^A(y_2(p_2^A, p_2^B))$, given in Equation (3.2). Firm B solves the analogous problem. We denote the equilibrium prices in the period by $P_2^A(y_1)$ and $P_2^B(y_1)$.

The initial period problem

The period-1 problem is a monopoly problem, as Firm A is the only supplier. The period-1 cohort's problem is to source its input from Firm A or not participate in the market at all. To solve this cohort's problem, then, we must make more explicit the demand side of the market. Our goal here is modest: We wish to introduce a reduced-form demand schedule that enables us to pose a simple monopoly problem for Firm A in period 1 and is consistent with the full participation of all period-2 and period-3 entrants. To this end, we assume that the payoff, F, to the buyer from its (unit) sale of the final good has the form

$$F(y) = R + ry, \tag{3.4}$$

where $R,r > 0$. This assumes, reasonably in our view, that higher-quality final goods "fetch" a higher price, so the payoff is increasing in y.

Given Equation (3.4), the buyer's problem in period 1 can be made straightforward, if we make three assumptions. First, if the buyer chooses to leave the market altogether in period 2, *exit is costless*. This means that a *sufficient* condition for participation in period 1 is $F(y) > p_1^A$. To see this, note that a buyer who enters in period 1 and remains in the market through period 2 has a present discounted payoff from participation equal to

$$F(y) - p_1^A + \beta \max\{F(y) - p_2^A,\ F(y) - p_2^B - \tau y - s,\ 0\}.$$

Since exit is costless, the buyer will leave the market if the maximum payoff across the two suppliers is negative. Furthermore, it pays no cost to leave. In this case, could a lower-y buyer ever be better off if it waited and signed up with the lower-price supplier, Firm B, in period 2? If it did, its discounted payoff would be $\beta \max\{F(y) - p_2^B - \tau y - s,\ 0\}$. Notice the presence of s, since the setup cost has to be paid upon entry. Comparing the two payoffs, it is clear that, as long as $F(y) - p_1^A > 0$, the buyer is always better off participating in period 1 than waiting until period 2.

However, the latter is not, in general, a necessary condition. Even if $F(y) < p_1^A$, a buyer may stand to make a profit in period 2. Thus, it may still enter in period 1 if that is the only opportunity for it to enter. There are a number of ways to make $F(y) > p_1^A$ a necessary condition. We choose to do this by assuming that the firm has no access to external finance. This implies the firm cannot borrow to cover losses during period 1, which in turn implies a nonnegativity constraint on dividends: $F(y) - p_1^A > 0$. Thus, $F(y) > p_1^A$ is a necessary and sufficient condition for participation in period 1.

Last, what happens to a firm if it declines to participate on account of $F(y) < p_1^A$? We assume that ideas are *not* storable. This means that firms for which $F(y) < p_1^A$ do not retain the option to return to the market in period 2.[8] Therefore, we do not have to keep track of buyers that decline to enter in period 1.

These assumptions achieve a substantial simplification. In particular, if $F(y) > p_1^A$ is necessary and sufficient, then the choice of participation collapses to a static problem. From Equation (3.4), we see that the buyer, y, participates if $y \geq y\,(p_1^A) \equiv (p_1^A - R)/r$. It follows that the monopolist supplier faces a linear demand schedule $1 - y_1\,(p_1^A) = (R + r - p_1^A)/r$. The monopolist then selects its price p_1^A to maximize present discounted profits,

$$\max_{p_1^A}\left\{(p_1^A - c^A)\left(1 - y_1(p_1^A)\right) + \beta\pi_2^A\left(y_1(p_1^A)\right)\right\},$$

where $\pi_2^A\,(y_1)$ is the discounted present value of profits as of the start of period 2 conditional on the equilibrium plays in periods 2 and 3.

Quantitative Analysis

Calibration

We now illustrate the model's mechanics. To that end, we calibrate and solve it numerically. There are seven parameters $(\beta, c^A, c^B, s, \tau, R, r)$ that have to be chosen. Of these, only the discount factor β can be set without reference to a particular input market. We assume the period is one year and set $\beta = 0.95$, which implies an annual real interest rate slightly higher than 5 percent (Table 3.1). The remaining parameters will vary across markets. We calibrate the model to the offshore semiconductor wafer market.[9]

Table 3.1 Calibration

Parameter	Interpretation	Value	Target moment/reason
β	Discount factor	0.95	Real interest rate
c^A	Unit cost, Firm A	400	Long-run Taiwan price
c^B	Unit cost, Firm B	334	Long-run China price
τ	Monitoring cost	395	Long-run Taiwan mkt. share
s	Switching cost	197.5	Probability of switching
r	Buyer's payoff	432	Period-1 mkt. size
R	Buyer's payoff	688	Firm A profits

NOTE: This presents the calibration of the pricing game. The parameters are chosen so that the model induces the moments on the far right side of the table.

SOURCE: Authors' calculations of the values for the parameters used in the model simulation.

The costs of production and the quality premium, τ, are chosen to target the two suppliers' long-run price levels and the leader's (Firm A's) market share. To be more precise, we seek to have the model's terminal-period outcomes match observed outcomes "late" in a product's life cycle. As for how "late" ought to be measured, the model suggests that we would like to observe market outcomes after the initial cohort of Taiwan's customers conclude their production runs. The evidence available from supplier agreements indicates that customers arrange for at least three-year production runs, but with an option to renew.[10] To allow for some "slippage" around the three-year mark, we focus on market outcomes after the first five years of a product's life.

Next, we select s. We have no direct estimates of this, but the testimony of industry experts (see footnote 4) suggests that switches are very rare. We also observe that customers remain in very long-term arrangements with suppliers. Fabless firms' annual reports to shareholders, for instance, show that fabless firms maintain relationships with Taiwan's TSMC and China's SMIC for at least four to five years at a time. Therefore, we choose s to imply a "low" switch rate, which we take to be on the order of 10–15 percent of Firm A's period-2 customer base.

Last, we now calibrate Equation (3.4). For given R, the slope, r, in Equation (3.4) pins down the firm's incentive to target high-y buyers: if r is high, the supplier charges a high price to take advantage of these buyers' willingness to pay. But as a result, many low-y buyers elect not to participate. We therefore set r to target a size for the period-1 market relative to the size of the period-2 market. The idea here is that, in many markets, there is a ramp-up in terms of the volume of business after the introduction of a new product. Our data from the wafer market suggest that the size of the market at the time of product introduction is around one-half of its size in the mature phase of the product's life. Since there will be a measure 2 of period-2 buyers, we must then set r so that nearly a measure 1 of buyers elect to participate. This means that y_1 is not far from zero. Since there is a measure 2 of buyers in period 2, this corresponds to about one-half of the size of the market in the mature phase of the product life cycle.

As for R, this is chosen to ensure that all period-2 and period-3 entrants wish to participate. If R is sufficiently high, then Equation (3.4) indicates that even the lowest-quality buyer ($y = 0$) will make a purchase. In particular, one can easily show that, in order to guarantee full participation in periods 2 and 3, it is sufficient that $R > \hat{R} \equiv \max_{t=2,3} \{p_t^A, p_t^B\}$.[11] Of course, this provides only a lower bound; it does not point-identify R. To do the latter, we note that our model very likely understates the degree of competition in this market. Though Taiwan and China are the most significant producers, there are others. Therefore, we choose R in order to contain the rather outsized profits implied by the model. This means that R is set to roughly target $\hat{R}$.

Results: Price dispersion

We focus here on the model's predictions regarding the dynamics of price dispersion. We delay a discussion of aggregate price changes until later. Table 3.2 reports the results. There are two we wish to highlight.

First, the model implies that the degree of price dispersion declines over the product life cycle. The model implies a gap of roughly \$250 in the period in which the lagging supplier enters, and a gap of around \$150 in the next period. The source of these dynamics is very intuitive. In period 2, the leader charges a relatively high price to its customers, who are partially locked in because of the cost to switch. However, as the leader's original customers exit the market, it has a stronger incentive to compete aggressively for new entrants. The difference in prices between the leader and the follower therefore narrows. This result is a simple but important property of the model, and it is one that is absent if the only source of price dispersion is time-invariant unobserved het-

Table 3.2 Equilibrium Prices and Market Shares

Firm B period-2 price, p_2^B	456.37
Firm B period-3 price, p_3^B	686.80
Period-2 price differential, Δ_2	252.00
Period-3 price differential, Δ_3	150.38
Frictionless (s = 0) price differential	153.67
Measure of participants in period 1	0.99
Firm A period-2 market share	0.67
Firm A period-3 market share	0.55
Measure of switchers in period 2	0.13
Measure of switchers in period 3	0.00

NOTE: This presents the equilibrium of the pricing game discussed in the main text. The calibration underlying this solution is shown in Table 3.1.
SOURCE: Authors' calculations of simulation results from the model in Section Two.

erogeneity. Thus, it gives us a testable prediction to take to data, which we do in the next section.

We also note here that the magnitude of dispersion in period 2, and the extent of its decline in period 3, line up reasonably well with the estimates from the semiconductor wafer market discussed in Section 3. For this reason, we believe that our calibrated model, although quite simple, provides some insight into price determination in this market. As such, it should serve as a useful laboratory in which to study the properties of various price indexes, a topic to which we return in Section Four, "Feasible Price Indexes."

Second, the price differential not only narrows in period 3, but it very nearly approaches the differential in the *frictionless* model where $s = 0$. To see more clearly how this comes about, return to the period-3 problem for a moment. We impose the restriction that each supplier retains its customer base from the period-2 cohort, as occurs in equilibrium for our calibration (see the final row in Table 3.2). Under these conditions, a little bit of algebra reveals that the difference, $\Delta_3 \equiv p_3^A - p_3^B$, in period-3 prices is given by the expression

$$\Delta_3 = \Delta^* + (2(1 - y_2) - 1)\frac{\tau}{3}, \quad (3.5)$$

where Δ^* represents the difference between Firm A and B prices in the frictionless (s = 0) equilibrium.

We unpack Equation (3.5) in two steps. First, it is straightforward to show that Δ^* is the difference in market prices that makes the marginal buyer with design y^* indifferent across suppliers. This means that Δ^* compensates for the transaction cost, so that $\Delta^* = y^*\tau$. We therefore interpret Δ^* as the difference in market prices that could be accounted for by (unobserved) heterogeneity in quality. Second, the source of the wedge between Δ_3 and Δ^* is intuitive. To see this, note that the wedge vanishes if y_2=1/2. Each supplier in this case charges a higher price level than in the frictionless model, but the two suppliers' incentive to exploit their customer bases is the same. Hence, the price difference reflects entirely the difference in the quality of the production service. If $y_2 < 1/2$, in contrast, then Firm A's market share is relatively large. As a result, it charges a relatively high price to "milk" its customer base, and $\Delta_3 > \Delta^*$.

For our calibration, it is true that $y_2 \approx 1/2$, which implies $\Delta_3 \approx \Delta^*$. This suggests that one might use the *observed* difference in market prices late in the product cycle to proxy for the contribution of *unobserved* heterogeneity to the price differentials. In particular, one can subtract Δ_3 from price differentials earlier in the product life cycle, such as Δ_2, and thereby adjust prices all along the product life cycle for unobserved heterogeneity. This yields an estimate of the share of the period-2 differential that is due to frictional dispersion. More exactly, we have that

$$(3.6) \quad \frac{\Delta_2 - \Delta_3}{\Delta_2} \approx \frac{250 - 150}{250} = 40\% ,$$

which is the percentage of the observed differential that is "real."[12] As we discuss in greater detail below, this simple correction will significantly aid our measurement strategy in Section Four.

Before we turn to the model's implications for aggregate price changes, we digress slightly in the next section to consider some recent evidence for the model's key prediction regarding the dynamics of price dispersion.

AN APPLICATION TO THE SEMICONDUCTOR INDUSTRY

We believe that the model presented in the previous section captures features common to many intermediate input markets. Indeed, it is, in principle, relevant to any market with entry and clearly defined product turnover. But our empirical exploration of the model's implications is, of course, limited by available data. In a prior work (Byrne, Kovak, and Michaels 2013) we focused on the contract semiconductor manufacturing industry, for which we have detailed, transaction-level data. In the remainder of this section, we briefly review the structure of this market and the findings reported in Byrne, Kovak, and Michaels.

Semiconductor production involves a number of discrete steps.[13] A chip is first designed using computer-aided tools that convert the desired functionality into a network of transistors and interconnections. The chip is then fabricated by depositing and etching away conducting and insulating materials to create a three-dimensional pattern of transistors and connections on the surface of a silicon wafer. Each step in the process is repeated for each of many chips, called "die," resulting in a grid of identical, completed die on the surface of the wafer. The die are then tested, sliced up, and placed in protective packages with leads allowing the chips to be connected to circuit boards in a final product.

Byrne, Kovak, and Michaels (2013) focus on the second step in this production process—the fabrication of semiconductor chips based on a particular design. Semiconductor fabrication technology has evolved steadily over time and can be characterized by a few observable technological traits such as the size of the wafer and the size of the smallest feature that can be produced on the surface of the wafer, called the "line width." The number of physical layers needed to create the chips has also increased over time, reflecting increased design complexity and leading to increased fabrication cost. Semiconductor technology evolves discretely over time, with only a few specific wafer sizes and line widths present in the market at any moment in time, making it possible to control for technological differences across products very flexibly.

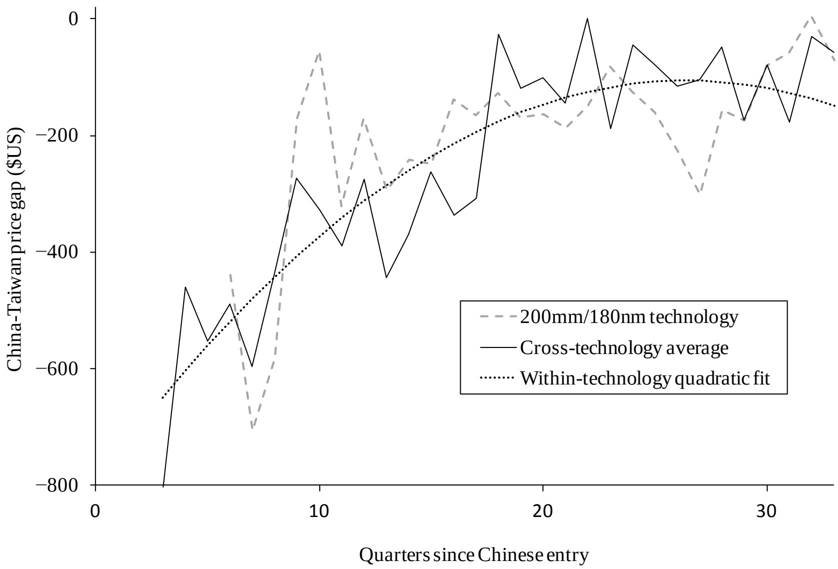
Byrne, Kovak, and Michaels' (2013) empirical results use data on arm's-length transactions between firms specializing in chip design and marketing, called "fabless firms" since they have no fabrication facilities, and firms called "foundries" that specialize in fabricating other firms' chips. Most fabless firms are located in the United States and Europe, and they correspond to the buyers in the model just described. The largest foundries are located in Taiwan and China, which together account for 74 percent of foundry output. Taiwanese foundries enter a product market, defined by a wafer-size and line-width combination, at least eight quarters ahead of Chinese foundries. The dominant Taiwanese foundry, Taiwan Semiconductor Manufacturing Company (TSMC), is the overall market leader—it is Firm A in the model. TSMC is widely considered as possessing the most advanced design integration tools and engineering support.

The data come from a proprietary database collected by the Global Semiconductor Alliance (GSA), a nonprofit industry organization. Byrne, Kovak, and Michaels' (2013) extract spans 2004–2010 and covers a representative sample of about 20 percent of the wafers produced by the worldwide foundry sector. The GSA data are unique in providing details on transaction prices, along with all technological characteristics of finished semiconductor wafers that are relevant for pricing, including wafer size, line width, and numbers of various types of layers. This detailed product-characteristic information makes it possible to compare average prices for physically identical inputs across suppliers located in different countries.

Formally, Byrne, Kovak, and Michaels (2013) implement such a comparison in a hedonic regression framework that relates wafer prices to observable technological characteristics, quarter indicators, and indicators for supplier's location.[14] The controls for product characteristics enable them to estimate the effect of location on price, holding fixed the composition of goods. The data reveal substantial price differences across suppliers. Comparing the two largest suppliers, a Chinese wafer sells at a 17 percent discount compared to an otherwise identical Taiwanese wafer.[15]

This average difference masks, however, interesting *dynamics* in price dispersion. Byrne, Kovak, and Michaels (2013) go on to estimate how the price differential evolves following Chinese entry. The key result is replicated in Figure 3.2 (which is Figure 4 in Byrne, Kovak, and Michaels). The dashed gray line plots raw quarterly price differences for the process technology with the largest sales during our time period, 200mm wafers with 180nm line width. Despite the noise in the series, it is clear that the average price differential closes considerably over the life of this technology. It falls from around $600 to around $150 more than five years after Chinese entry. This pattern applies to other technologies with smaller sales as well. The black solid line in the figure plots the difference in price averaged across all technologies in each

Figure 3.2 The Closing China-Taiwan Price Gap Following China's Entry



NOTE: This presents the difference between China's and Taiwan's price for certain categories of wafers. The 200mm/180nm is one of the most popular wafers in the sample. The cross-technology average measures the mean of the price differentials across wafers. The within-technology fit is derived from a regression model with wafer fixed effects and thus uses only within-technology variation in the price differential. See Byrne, Kovak, and Michaels (2013) for more.
SOURCE: Based on regression results in Byrne, Kovak, and Michaels (2013).

quarter following Chinese entry and exhibits quite consistent declines in the gap between Chinese and Taiwanese prices.[16] Last, whereas the solid line pools *across* technologies, the dotted line in the figure estimates the price differential based exclusively on the typical variation *within* the life of a technology. It reveals a very similar pattern.

As Byrne, Kovak, and Michaels (2013) stress, this dynamic pattern is unlikely to be driven by unobserved differences in products or services across Chinese and Taiwanese suppliers. The price differences start out large and then converge for each new process technology, so constant differences across suppliers or differences that evolve over calendar time for all technologies are unlikely to explain the observed pattern. In other words, steady improvements in the quality or reliability of China's production service may explain price differentials *across* technologies, but they are unlikely to account for the sharp, *within*-technology dynamics we observe. This also rules out explanations related to brand recognition, customer service, intellectual property-rights protection, tax policy, and other factors that might make Chinese producers more attractive over time.

Accordingly, Byrne, Kovak, and Michaels (2013) argue that the dynamics reflect the presence of real, frictional price dispersion. The pattern of narrowing differentials is clearly consistent with that predicted by the theory of switching costs sketched in Section Two, “A Pricing Game with Costly Switching.” This finding motivates our work in the next section, as we consider developing a price index that admits roles for both frictional dispersion and constant, unobserved heterogeneity.[17]

FEASIBLE PRICE INDEXES

Our goal is to measure the change in price of a production service in an environment in which the quality of service varies across suppliers. The *source* of the difference in service quality is not especially critical, though, for the purpose of this exercise. In our model, the quality of service varies inversely with the complexity of the design, y. But this is merely one way to operationalize the idea; heterogeneity across designs is *not*, per se, significant.

It is worth taking a moment at the outset to elaborate on this point. The following discussion should help reveal the generality of the problem confronting price index construction. In so doing, it also points the way toward developing the “ideal” price index in this setting, which will serve as the benchmark against which all feasible alternatives are judged.

A Benchmark

There is a way to reinterpret the model that is particularly helpful. Imagine that suppliers produce *and ship* the input to customers. Assume, moreover, that Firm B has an inferior transport technology. In this context, it is natural to reinterpret y as distance from Firm B. The cost, τy, is then read as a transport cost, so that a Firm B customer with unit demand who is y units away must purchase $1 + \tau y$ units because τy are "lost in transit." In this interpretation, it is the *customer* who implants its own design on the chip after receipt of the product.

This problem is formally identical to our own. But what design the retailer implants on the wafer *after* it is shipped by Firm B is clearly orthogonal to how we measure the price of the production (and transportation) service. In other words, in this (re)interpretation, the measurement of the input's price is unrelated to, and unaffected by, the presence of heterogeneous designs. All that matters, in terms of the real resource cost to customers, is the transaction cost, τy.

It follows that, in our preferred interpretation of the problem, design heterogeneity matters for price measurement only insofar as it implies a particular transaction cost. If we could just observe these costs (τy), we would fold them into a comprehensive, or quality-adjusted, measurement of the price paid by Firm B buyers, $\hat{p}^B \equiv p^B + \tau y$, for the production service. After adjusting for τy, this is the same service provided by Firm A. Hence, at that point, we simply aggregate across the p^A's and $\hat{p}^B$'s in a particular period and compare the result with the average price in the prior period. This is, in fact, how we will build our benchmark price index, to which we now turn.

Our benchmark index requires the most information on the part of the analyst. In particular, the analyst is assumed to observe the transaction cost, τy, paid by a Firm B customer with design y. Hence, the analyst measures prices, p^A and $\hat{p}^B$.

Since each price in the model (inclusive of τy) pertains to the same service, it is not hard to aggregate across observed prices. In any period t, there is a set I_t of buyers with measure μ_t. The period-t (with $t = 2$ or 3) price is then given simply by

$$\frac{1}{\mu_t}\int_{I_t} p_t(i)\mathrm{d}i \ ,$$

where $p_t(i)$ is the price paid by buyer $i \in I_t$ (and equal to either p_t^A or $\hat{p}_t^B$). This aggregates prices paid across the measure μ_t of buyers, weighting each equally, since all participants purchase one unit of the input.[18] This price is compared to the average price in the prior period to derive the price change.

To illustrate the calculations, consider the period-2 problem. It is helpful to first take the case where Firm A retains the full measure $1 - y_1$ of its period-1 customers but only sells to new entrants with $y \geq y_2$. It follows that a measure $2 - y_1 - y_2$ pays p_2^A for the input, whereas each new entrant $y \in [0, y_2]$ pays $p_2^B + \tau y$. Therefore, the average period-2 price, P_2^*, is

$$P_2^* \equiv \frac{1}{2 - y_1} \int_{[y_1,1]\cup[0,1]} p_2(i)\mathrm{d}i = \frac{2 - y_1 - y_2}{2 - y_1} p_2^A + \frac{1}{2 - y_1} \int_0^{y_2} [p_2^B + \tau y]\mathrm{d}y.$$

Since the only price in period 1 is p_1^A, the price index in period 2 would be P_2^* / p_1^A.

The problem is slightly more cumbersome if Firm B poaches in period 2, as occurs in the model. In this case, Firm B poaches from Firm A for all qualities less than a threshold, y_2^p, where the threshold satisfies $y_1 < y_2^p < y_2$. Therefore, Firm A supplies a measure $1 - y_2$ of entrants and $1 - y_2^p$ of incumbents. Firm B supplies, in turn, a measure of y_2 of entrants and $y_2^p - y_1$ of incumbents. Given this distribution of buyers across designs, the average price becomes

$$(3.7) \quad P_2^* \equiv \frac{2 - y_2 - y_2^p}{2 - y_1} p_2^A + \frac{1}{2 - y_1} \left\{ \int_0^{y_2} [p_2^B + \tau y]\mathrm{d}y + \int_{y_1}^{y_2^p} [p_2^B + \tau y]\mathrm{d}y \right\}.$$

In what follows, it will be instructive to integrate the terms enclosed in braces on the right half of Equation (3.7) and rewrite this as a weighted average of the suppliers' quality-adjusted prices,[19]

$$(3.8) \quad P_2^* \equiv \frac{2 - y_2 - y_2^p}{2 - y_1} p_2^A + \frac{y_2 + y_2^p - y_1}{2 - y_1} (p_2^B + \theta\tau),$$

where

$$(3.9) \quad \theta \equiv \frac{y_2}{y_2 + y_2^p - y_1} \cdot \frac{y_2}{2} + \frac{y_2^p - y_1}{y_2 + y_2^p - y_1} \cdot \frac{y_2^p - y_1}{2}$$

is the average design supplied by Firm B. Hence, the average price (Equation [3.8]) is a weighted average of the market prices plus a measure of the average transaction cost paid by Firm B buyers. Again, the price index is simply P_2^*/p_1^A.

Feasible Alternatives

In practice, the BLS does not observe the level of detail—namely, τ—needed to calculate the benchmark index. We now consider several indexes with less demanding data requirements. We refer to these as *feasible price indexes.*

Within index

The first of these is consistent with our understanding of BLS-IPP practice, which typically treats the identity of the seller as a price-forming characteristic (Nakamura and Steinsson 2012). In this case, there are, in effect, two types of goods: those sold by Firm A and those sold by Firm B. Under these circumstances, standard practice is to compute the price index by first calculating price changes within each supplier and then averaging these changes across suppliers. We refer to this as the *within* index. This contrasts with the benchmark index, which first averages prices across suppliers and then takes the difference.

Applied to the period-2 data, the within index is very simple. Since Firm B does not participate in period 1, the within index is computed just by taking the ratio of Firm A's market, p_2^A/p_1^A.

Average index

The second measure takes the opposite approach to the problem of unobserved quality. The strategy here is to take the average period-2 *posted market price* across suppliers for all qualities greater than y_1 and compare it to the period-1 price. We refer to this as the *average* index.[20]

This index is distinguished by the fact that it takes no account of the transaction costs—it makes no quality adjustment. Accordingly, the average index is calculated by simply excluding τy from the price paid by each of Firm B's customers in the benchmark index (Equation [3.7]). The average period-2 price is then

$$(3.10)\quad P_2^{\alpha} \equiv \frac{2 - y_2 - y_2^p}{2 - y_1} p_2^A + \frac{1}{2 - y_1}\left\{\int_0^{y_2} p_2^B \,\mathrm{d}y + \int_{y_1}^{y_2^p} p_2^B \,\mathrm{d}y\right\}$$

$$= \frac{2-y_2-y_2^p}{2-y_1} p_2^A + \frac{y_2+y_2^p-y_1}{2-y_1} p_2^B ,$$

and the index is calculated according to P_2^{α}/p_1^A. This approach is more concerned that the new supplier is likely to sell the same qualities at lower prices, which does in fact happen if $y_1 < y_2$. In these instances, quality-adjusted price declines faced by buyers are not recorded by the within index.

Diff-in-diff index

Last, we present an index that attempts to strike a compromise between the within and average indexes. The index confronts the challenge of unobserved heterogeneity but does not abandon the idea that there may be quality-adjusted price dispersion in equilibrium. At the same time, it does not place the same data requirements on the analysts as the benchmark index does.

The construction of what we will call the diff-in-diff index is guided by the model in Section Two ("A Pricing Game with Costly Switching"). One of the key points of the section was the idea that one can use the *observed* price differentials late in the product life cycle, Δ_3, to proxy for the contribution of *unobserved* heterogeneity, denoted by Δ^*. This implies that the quality-adjusted period-2 differential, Δ_2, can be estimated by netting off Δ_3, which is the most that could be attributed to quality. This boils down to doing quality adjustment by simply inflating Firm B's price by Δ_3. To see this, let $\check{p}_2^B$ denote our estimate of Firm B's period-2 price adjusted for service quality. We define $\check{p}_2^B$ according to the quality-adjusted period-2 differential, $p_2^A - \check{p}_2^B = p_2^A - p_2^B - (p_3^A - p_3^B)$. Canceling the p_2^A's, we have that $\check{p}_2^B = p_2^B + \Delta_3$.

This corrected price differential is the key input into the diff-in-diff index. The index itself is now easy to construct. We add Δ_3 to p_2^B in the average index (Equation [3.10]), use the proxy $\Delta_3 = \Delta^* = \tau y^*$, and integrate. (Recall that y^* is Firm B's market share in the frictionless equilibrium.) The result can then be written as

$$(3.11) \quad P_2^{\delta} \equiv \frac{2 - y_2 - y_2^p}{2 - y_1} p_2^A + \frac{y_2 + y_2^p - y_1}{2 - y_1} (p_2^B + y^* \tau).$$

Comparing Equation (3.11) to the benchmark (Equation [3.8]), we see our adjustment is exact only if $y^* = \theta$. In fact, a discrepancy between y^* and θ will likely arise. To see why, recall from Section Two that what drives a wedge between market prices in the frictionless equilibrium is the transaction cost faced by the *marginal* buyer (who is indifferent across the two suppliers). That is, the difference, Δ^*, in market prices is given by $y^*\tau$. However, a quality-adjusted price index like those in Equations (3.7) and (3.8) requires calculation of the *average* price inclusive of transaction costs among *all* Firm B buyers, as represented by θ. Since the transaction cost increases with y, the marginal cost exceeds the average. It is very likely, then, that $\theta < y^*$. In that case, P_2^δ would *over*estimate P_2^*.

The comparison between y^* and θ becomes clearer if we consider a special, but informative, case. Suppose that $y_1 = 0 = y_2^p$. This is an instructive case because, in our calibrated model, most buyers do in fact participate in period 1 (so that $y_1 \approx 0$), and switching is minimal in period 2. It follows that Equation (3.9) collapses to $\theta = y_2/2$, where y_2 is Firm B's share of period-2 entrants under $s > 0$. Hence, in this case, $\theta = y^*$ only if $y_2 = 2y^*$: Firm B claims *twice* as many period-2 entrants under $s > 0$ as it does in the frictionless equilibrium. The intuition behind this is that the average transaction cost, θ, approaches y^* only if Firm B supplies very complex designs when $s > 0$. This is unlikely, and our calibrated model doesn't bear this out. It follows that the quality adjustment is too large in Equation (3.11), so that $P_2^\delta > P_2^*$.

Reacting to this, we wish to make two observations. First, if we make no changes to Equation (3.11), it could still be used productively by agencies with the understanding that it provides an upper bound on the true quality-adjusted price. Second, we can complement this upper bound by considering a lower bound; a comparison of the two will help better identify the true change. To see this, suppose the switching cost did not distort the distribution of market shares, so that $y^* = y_2$. Accordingly, in the special case where $\theta = y_2/2$, one can align P_2^δ with P_2^* by just dividing $\Delta^* = y^*\tau$ in Equation (3.11) by 2. This yields an alternative to Equation (3.11),

$$\hat{P}_2^\delta \equiv \frac{2 - y_2 - y_2^p}{2 - y_1} p_2^A + \frac{y_2 + y_2^p - y_1}{2 - y_1}\left(p_2^B + \frac{y^*}{2}\tau\right).$$

In all likelihood, the switching cost *will* affect the distribution of market shares—in particular, the entering firm will compete relatively aggressively to attract customers, since the buyers will be subsequently locked in. This suggests that $y^* < y_2 = 2\theta$. As a result, $y^*/2 < \theta$, which means that $\hat{P}_2^{\delta} < P_2^*$: we obtain an estimate of P_2^* that is *down*wardly biased. Comparing $\hat{P}_2^{\delta}$ to the baseline diff-in-diff index (Equation [3.11]), one can better gauge the true price change. We implement this procedure below.

We complete this discussion by quickly mentioning how to apply these indexes to period 3. In correspondence with the calibrated model, we assume both firms retain all buyers in period 3. Hence, Firm A sells to a measure $1 - y_2 + 1 - y_3$, and Firm B sells to a measure $y_2 + y_3$. The calculations of each index then follow by analogy to their period-2 counterparts. For instance, the benchmark index is P_3^*/P_2^*, where P_3^* is given by

$$P_3^* \equiv \frac{2 - y_2 - y_3}{2} p_3^A + \frac{y_2 + y_3}{2} (p_3^B + \Theta\tau) \,,$$

and $\Theta \equiv \frac{y_2}{y_2 + y_3} \frac{y_2}{2} + \frac{y_3}{y_2 + y_3} \frac{y_3}{2}$

is the average design supplied by Firm B in period 3. Next, the within index is obtained by first computing the change in each supplier's *market* price and then aggregating these price changes across suppliers. We use Tornqvist weights in the latter step, which yields

$$\omega \frac{p_3^A}{p_2^A} + (1 - \omega) \frac{p_3^B}{p_2^B} \,,$$

where

$$\omega = \frac{1}{2} \left(\frac{2 - y_2 - y_3}{2} + \frac{2 - y_2^p - y_2}{2 - y_1} \right)$$

is the average Firm A market share across periods 2 and 3. Finally, using the appropriate period-3 market shares, the average and diff-in-diff indexes can be computed according to the expressions contained in Equation (3.10) and Equation (3.11).

Results

Table 3.3 uses our calibrated model to assess the accuracy of the feasible indexes. Each column corresponds to a period. Each row reports the gross price change implied by the index *relative* to the gross price

Table 3.3 Feasible Indexes Relative to Benchmark

	Period 2	Period 3
Within	1.082	1.047
Average	0.958	0.990
Diff-in-diff, baseline	1.032	1.001
Diff-in-diff, alternative	0.995	0.997

NOTE: This table uses the solution to the calibrated model to calculate the gross price changes implied by a variety of price indexes. The results are expressed here relative to the true gross price change. See main text for a discussion of the indexes and Table 3.1 for the calibration.

SOURCE: Authors' calculations of simulation results from the model in Section Two.

change implied by the benchmark. For instance, with respect to period 2, the row that reports the average index presents

$$\frac{P_2^{\alpha}/p_1^A}{P_2^{*}/p_1^A} .$$

Thus, if the estimate in the row is less than 1, the feasible index *under*-states the true change. Equivalently, the feasible index overstates the decline in the price level between periods 1 and 2.

The within and average indexes yield estimates in line with our expectations. As we showed in Section Two, roughly 40 percent of the period-2 price differential cannot be attributed to quality dispersion; Firm B does provide a real discount. As a result, the within index fails to capture the full extent of the decline in the average price level driven by the entry of Firm B. The table reveals that it overstates the price change (understates the price decline) by 8 percentage points. At the same time, as our discussion in Section Two noted, there is a quantitatively significant component of price dispersion owing to difference in service quality. The average index fails to account for this and so understates the true price change. Equivalently, it overstates the price decline—in this case by about 4 percentage points.

We now turn to the performance of the diff-in-diff index. The table reports results for both the baseline index derived from P_2^{δ} and the alternative based on $\hat{P}_2^{\delta}$. As we anticipated, the baseline index (Equation [3.11]) outperforms the within index, since it treats a portion of Firm B's price as a real, quality-adjusted discount relative to Firm A's price. Accordingly, it better captures the decline in the average price level when Firm B enters. Yet it still understates the extent of the price decline by 3 percentage points. Interestingly, the alternative index, based on $\hat{P}_2^{\delta}$, performs noticeably better. As we noted earlier, it should be the case that $\hat{P}_2^{\delta} > P_2^*$, but this discrepancy depends on the distance between y_2 and $y*$. This distance turns out to be rather limited in this calibration, but we stress that it is hard to judge the robustness of this result.

As for period 3, the diff-in-diff indexes perform very well. Mechanically, the reason is that P_2^{δ} and P_3^{δ} both overstate the corresponding true prices. These errors appear to cancel each other out, so the gross change, $P_3^{\delta}/P_2^{\delta}$, turns out to very nearly equal P_3^*/P_2^*. The same idea applies to the average index. However, with respect to the within index, errors do not cancel each other out so fortuitously; this continues to overstate the true price. Again, it is difficult to know if these results hint at a more general lesson. We hope continued work in this area will help elucidate this.

CONCLUSION

This paper has studied the problem of price index construction for intermediate inputs when observed price differentials are combinations of unobserved heterogeneity and real, or frictional, price dispersion. In particular, it assesses several price indexes that can be *feasibly* constructed. Our results provide some guidance for how to adjust price indexes when a new low-price supplier, such as China, joins a market. In our application to the semiconductor market, we find that if frictional dispersion is ignored, the price index overstates the true price decline due to entry by five to eight percentage points. Ignoring unobserved heterogeneity, in contrast, means that lower-quality service by the entrant is not accounted for, and thus the price decline is overstated. We then try to provide a pathway between these extrema. Our diff-in-diff index exploits a simple insight: the cost of switching to a new supplier in this market sustains frictional dispersion during the early life of a product, but this influence abates as the market matures and the market leader's original customers exit. Thus, late in the product life cycle, the price difference largely reflects time-invariant quality differences. Accordingly, one can use these observed late-in-life price differences to correct for unobserved heterogeneity and thereby isolate the extent of real price dispersion. For this reason, our diff-in-diff index performs quite well as an approximation to the true price change.

Our assessment, of course, is confined to a particular market in the semiconductor sector. Yet we believe our approach provides a fruitful way forward in this literature. That approach, in sum, consists of a few components: gather detailed data for a particular industry; develop a quantitative model of industry dynamics that can be fitted to these data; and assess alternative, feasible price indexes within the context of the parameterized model. If applied to several industries, we believe this approach has the promise of revealing more general lessons for price index measurement.

Notes

1. By “Taiwan,” we mean Taiwan Semiconductor Manufacturing Corporation, or TSMC, the largest wafer fabrication firm in Asia. Most of its properties are in Taiwan, though it has one plant in Shanghai. However, the vast majority of production in China is due to Semiconductor Manufacturing International Corporation, or SMIC. When we refer to “China,” then, we mean SMIC.
2. China typically enters two years after Taiwan initiates production.
3. See Farrell and Klemperer (2007) and Klemperer (1995) for surveys.
4. This quote is from a report describing the Common Platform technology alliance. This is an industry group consisting of a few large chip manufacturers—IBM, Chartered Semiconductor Manufacturing, and Samsung. The group advocates for a “common platform” that would standardize aspects of semiconductor production technology. However, this alliance has not yet had a material impact on standardizing mask sets (McGregor 2007).
5. We have obtained a handful of these contracts. A representative agreement in terms of how price discrimination is handled is one between Altera Corp. and TSMC. It states that “TSMC shall calculate an average price for such Process in use at all of TSMC’s . . . plants,” and if the buyer’s price “deviates, up or down, by more than three percent (3%) from the [average price],” the buyer’s price will be adjusted in the direction of the average price. Note that this agreement does not commit TSMC to a particular price path over time. The contract merely restricts price discrimination in a given period, consistent with the model’s assumptions. This agreement is found at http://corporate.findlaw.com/contracts/operations/purchase-agreement-taiwan-semiconductor-manufacturing-co-ltd.html (accessed April 22, 2014).
6. See Nishimura and Friedman (1981) for an analysis of this class of games. They provide sufficient conditions to ensure a pure-strategy equilibrium, but these conditions can only be confirmed ex post. This is, in effect, what we aim to do.

7. It is not immediate that there is a unique solution for y_2, but we have always located one in practice. The intuition for this is as follows. The discounted sum of Firm B prices is relatively low when y_2 is low (i.e., when Firm B's customer base is small, it sets lower prices in period 3 to attract new entrants). But the discounted sum of Firm B prices is also increasing at a relatively fast rate as y_2 rises. This reflects the quality premium, as captured by τy_2. Together, these features imply a single crossing, with the right side of Equation (3.3) cutting the left side from below.
8. Interestingly, another way to make $F(y) > p_1^A$ a necessary condition is to drop the nonnegativity constraint and to assume that ideas are instead *perfectly storable*. This would imply that a firm would never produce in period 1 if its instantaneous profits were negative; it would just store the idea and join the market in period 2. Note that, since production runs for two periods, these late entrants would presumably live through period 3. This points to the downside of this approach: delayed entry reverberates through the model's periods 2 *and* 3 and creates a more complicated dynamic problem. Moreover, the payoff from this added complication is rather small. As we discuss, the model will be calibrated in such a way that the measure of firms that delay entry is very small, so its quantitative implications cannot be too great. For this reason, we choose the simpler approach in the main text.
9. The subsequent two paragraphs are taken from Byrne, Kovak, and Michaels (2013) (see Appendix 6D).
10. For example, a contract between Quicklogic and TSMC states, "The term of this Agreement shall . . . continue for a period of three (3) years, renewable annually as a rolling three (3) year Agreement."
11. Since the lowest-quality buyer in Firm A's cohort has payoff $R + ry_t$ in period $t = \{2,3\}$, it follows that Firm A buyers will in fact participate if R exceeds $\max_t\{p_t^A\}$. Furthermore, if $r > \tau$ (as it does, in our calibration), then the highest-quality customer of Firm B will participate if R is greater than $\max_t\{p_t^B\}$.
12. We also stress that, although $y_2 \approx 1/2$ in our model, the approach suggested by Equation (3.4) can be applied robustly to real-world data even if there are certain deviations from this. For instance, if y_2 is smaller than ½, then Δ_3 *over*estimates its frictionless counterpart. As a result, if we used Δ_3 as a proxy for the contribution of unobserved heterogeneity to the price differential, we would obtain a *lower* bound on the degree of pure (frictional) price dispersion. This property can be desirable in certain circumstances. For instance, though we assume the suppliers provide the same physical input here, data limitations may make it impossible for a statistical agency to do any direct hedonic-style quality adjustments for product composition. In that case, it may want to err on the side of unobserved heterogeneity.
13. Turley (2003) provides an accessible overview of semiconductor technology, manufacturing, and business.
14. The GSA data do not provide firm identifiers, only the country in which the supplier is located.
15. See Table 3 in Byrne, Kovak, and Michaels (2013) for the full list of regression coefficients from the hedonic model.

16. To be more precise, Byrne, Kovak, and Michaels (2013) regress the price differential on, among other controls, a quadratic time trend and product fixed effects; the latter control for changes in the composition of technologies. The dotted line, referred to in Figure 3.2 as the "within-technology fit," is the estimated time trend.
17. Byrne, Kovak, and Michaels make the correction embodied in Equation (3.6) to the raw wafer price differentials in order to isolate the component that is due to real dispersion. In their application, they interpret "late in the product life cycle" to be roughly five years after Chinese entry, based on the length of typical semiconductor fabrication contracts (see the subsection titled "Quantitative Analysis," beginning on p. 100). Then, drawing from Figure 3.2, the authors interpret $\Delta_3 = \Delta^* \approx \$150$. Netting this off of the observed period-2 differential, Δ_2, yields the quality-adjusted component. For instance, the average differential 10 quarters after Chinese entry is about \$375, so the authors estimate that 60 percent $\left(\frac{375-150}{375}\right)$ reflects real price dispersion. Hence, the wafer data indicate more frictional dispersion than implied by the model.
18. Simple averaging across buyers is appropriate within our theoretical model because the production service, modulo τy, is in fact identical. The BLS does not follow this approach when aggregating across outlets' prices at the most detailed level (the item-area stratum) of the CPI. This is because BLS staff worry that different outlets' items are not in fact the same. See Hausman and Leibtag (2009) for more on this practice. See Shapiro and Wilcox (1996) for a general discussion of aggregation within the CPI.
19. The weights are formed from the quantity of units sold by each supplier. Throughout, we do assume that the statistical agency has access to price *and* revenue data from the supplier, so that quantities may be inferred. The BLS International Price Program does request data on the dollar value of trade for each good when a firm is initiated into the survey.
20. The average index does embody a slight recognition of quality differences, in that it excludes never-before-priced designs in period 2. In this sense, the index acknowledges that some period-2 goods are "too different" from the basket of goods in period 1 to be included in the index. We take this approach to try to capture the fact that the statistical agency does observe repeated sales of the same product, even if it does not observe quality precisely. Still, this inclusion only of designs $y > y_1$, as opposed to all designs, makes little quantitative difference to our results, since y_1 is so close to zero.

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4
Specific Trade Costs, Quality, and Import Prices

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Recently, quality differences among internationally traded goods have received significant attention. Differing import quality across markets, characterized by lower-income countries producing lower-quality products, is a robust empirical finding.[1] Johnson (2011) shows that quality differences account for most firm heterogeneity in trade. Baldwin and Harrigan (2011) argue that, in order to match the data, trade models must account for such differences. However, international price indices frequently cannot make quality adjustments. Correctly accounting for quality differences is important to the measurement of real trade, since mismeasurement of trade filters into other indicators such as real GDP and productivity. (See Feenstra et al. [2013], Houseman [2007], and Houseman et al. [2011].)

While quality measurement is an issue for all price indices, it is a particular challenge for international prices. There has been a significant increase in the number of goods that are traded. A large number of goods that are traded are only traded intermittently. The "new goods problem"—determining the quality of new goods relative to previously traded ones—is a frequent issue in international prices. A lack of quantifiable characteristics or agency resources often prevents explicit adjustments for quality, such as hedonics.

Statistical agencies have developed techniques to deal with environments with shifting sets of goods. A common way of accounting for the quality of newly measured goods is matched modeling. If an explicit adjustment for quality cannot be done, a good may be matched to a similar good. The price difference is attributed to quality differences.

To avoid having frequent replacement of goods in the sample, sampling techniques intentionally focus on consistently traded goods. Price changes of consistently traded goods within a category stand in for price changes of all goods in that category.

I examine these techniques in light of recent advances in trade theory. I use a version of the model in Baldwin and Harrigan (2011) to show theoretically that both methods are vulnerable to mismeasurement for goods with quality differences that pay specific (per-unit) trade costs. I then analyze the quantitative impact of these forces using U.S. import data.

I show theoretically that matched modeling will tend to overstate quality differences between goods. Specific trade costs weaken the link between price and quality. Prices are set as markup over production and trade costs. Lower-quality goods cost less to produce, and all goods pay the same specific cost regardless of quality. Therefore, a bigger share of a low-quality good's price is due to trade costs. The price difference between goods will be smaller than their quality differences. Using matched modeling will tend to overstate real imports of new goods. Since matched modeling overstates the quality of new goods, it underestimates the (quality-adjusted) price.

Dropping intermittently traded goods will tend to underestimate price changes. Specific trade costs systematically make goods that enter and exit different from continuing goods. Lower-quality goods are the least profitable, so they are the most sensitive to cost changes. Relatively small cost changes can make a previously profitable market unprofitable, and vice versa. Low-quality goods are more likely to be traded intermittently, and the prices of these intermittently traded low-quality goods are likewise more sensitive to cost shocks.

I show that the quantitative impact of this mismeasurement can be significant: in some cases, applying matched modeling leads to significant overstatement of the quality of new goods. For leather footwear, a major import category, matched modeling understates the quality gap between the highest- and lowest-quality goods by over 30 percent. However, the average impact has fallen over the period of 1974–2004, since transportation costs, which tend to be specific, have fallen.

The impact of dropping intermittently traded goods from the sample has likely increased. The size of the effect is proportional to the price gap between continuing and newly traded goods, a gap that has widened. By 2004, the model predicts that newly traded goods' prices were twice as sensitive to cost shocks as previously traded ones.

This chapter is part of a literature that examines mismeasurement of international prices. Feenstra and Romalis (2012) also examine international prices with specific trade costs. However, their focus is on macro-level data, while I analyze the micro-level data and the techniques used by statistical agencies. A number of papers have examined difficulties in matched modeling. Reinsdorf and Yuskavage (2011) examine country substitution bias, which arises when imports are sourced from new countries with different price levels. Gagnon, Mandel, and Vigfusson (2012) and Nakamura and Steinsson (2012) look at whether the tendency to introduce price changes at product introduction biases import price indices. This chapter is complementary to those papers, as it looks at a different mechanism. Berman, Martin, and Mayer (2012) examine whether entry and exit in response to exchange rates dampen the pass-through of exchange rate fluctuations. The mechanism is similar, though they do not examine its impact on statistical agency methods.

A theoretical literature examines how to accommodate new goods in international price measurement. Feenstra (1994) derives a method of calculating the ideal price index with new goods. This chapter focuses on statistical agency practice and does not deal with welfare.

MODEL

The model is adapted from that found in Bridgman (2013). This model is based on the Quality Heterogeneous Firm Trade (QHFT) model developed by Baldwin and Harrigan (2011) and is similar to that of Gervais (2008).

Households

There are J number of countries. The preferences of the representative household in each country is given by the following equation:

$$(4.1)\quad U=\left(\sum_{i\in\Omega_j}\left(c_j\left(i\right)q\left(i\right)\right)^{1-\frac{1}{\sigma}}\right)^{\frac{1}{1-\frac{1}{\sigma}}},$$

where $c_j(i)$ is units consumed of variety i in country j, and Ω_j is the set of available varieties. The preference parameters $q(i)$ are the quality of the variety and $\sigma > 1$. The household is endowed with L units of labor.

Production

Consumption goods are produced using labor. The wage in country j is w_j. There is a constant set of firms, each endowed with a technology to produce a variety. Output of a variety is

$$y(i) = \frac{L(i)}{a(i)} \ .$$

Higher-cost firms produce higher-quality goods. A firm with unit cost a produces a good of quality q according to the following equation:

$$q(i) = a(i)^{1+\theta} \ , \tag{4.2}$$

where $\theta > 0$. The assumption that $\theta > 0$ implies that the consumer's valuation of quality increases faster than marginal cost, so profit increases in marginal cost. Baldwin and Harrigan (2011) argue that the data support this assumption. Following Eaton, Kortum, and Sotelo (2012), profits are spent outside the economy.

Trade

There are three costs to export a variety. There is a market-entry fixed cost of $F_{od}^{f}(i)$ units of labor to export variety i from origin country o to destination country d. There is a specific (per-unit) cost with unit labor requirement $F_{od}^{s}(i)$. Finally, there is an ad valorem charge $\tau_{od}(i)$. Given a mill price $p_{od}(i)$, consumers pay delivered price

$$p_d(i) = p_{od}(i)\left(1 + \tau_{od}(i)\right) + w_o F_{od}^{s}(i).$$

Solution

This section characterizes the solution but does not fully solve it. A full solution to the model would require specifying a distribution of unit costs. Since the results do not require a distribution, I do not fully close the model.

Each representative household chooses $c_j(i)$ for $i \in \Omega_j$ to maximize Equation (4.1) subject to

$$\sum_{i \in \Omega_j} p_j(i) c_j(i) \leq L w_j \, .$$

For varieties that are available in a market, expenditure in destination country d is given by

$$p_d(i) c_d(i) = \left[\frac{q(i)}{p_d(i)} \right]^{\sigma-1} B_d \, , \tag{4.3}$$

where $B_d = \dfrac{w_d L_d}{P_d^{1-\sigma}}$ and

$$P_d = \left[\sum_i \left(\frac{p_d(i)}{q(i)} \right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \tag{4.4}$$

is the quality-adjusted price index of destination country d. The demand function in terms of the mill price $p_{od}(i)$ in origin country o for a good exported to destination country d is

$$c_d\left(p_{od}(i)\right) = \left[q(i)\right]^{\sigma-1} \left[p_{od}(i)\left(1+\tau_{od}(i)\right) + w_o F_{od}^s(i) \right]^{-\sigma} B_d \, .$$

Firms are monopolistic competitors that set prices to maximize profits. They can set different prices for each market. As a simplifying assumption, the firm takes the price index P as given.[2] The optimal mill price $p_{od}(i)$ is the solution to

$$\max_{p_{od}(i)} p_{od}(i) c_d\left(p_{od}(i)\right) - w_o a(i) c_d\left(p_{od}(i)\right) - F_{od}^f(i) w_o \, . \tag{4.5}$$

The mill price solution is

$$p_{od}(i) = \frac{w_o}{\sigma - 1} \left[a(i)\sigma + \frac{F_{od}^s(i)}{1+\tau_{od}(i)} \right] ,$$

which generates the delivered price

$$p_d(i) = \frac{w_o \sigma}{\sigma - 1} \left[a(i)\left(1+\tau_{od}(i)\right) + F_{od}^s(i) \right] \, .$$

The firm will only export if profits are nonnegative. The goods that are available are determined by whether it is profitable to sell to the market. A variety i will be exported from origin country o to destination country d if

$$(4.6)\qquad \left(\frac{a(i)^{1+\theta}}{a(i)+F_{od}^{s}(i)}\right)^{\sigma-1}\left(\frac{\sigma-1}{w_o}\right)^{\sigma-1}\frac{B_d}{\left(1+\tau_{od}(i)\right)\sigma^{\sigma}}\geq F_{od}^{f}(i)\,w_o\ .$$

SAMPLING

In this chapter, I attempt to match the model to how international prices are actually collected. Statistical agencies cannot collect price data for all goods that are traded. They must use a sample to stand in for nonsampled goods. In this section, I describe the sampling process the Bureau of Labor Statistics (BLS) uses for its International Price Program (IPP).[3] The BLS's sampling process is the most germane, since the empirical work examines U.S. trade. The sampling techniques and constraints faced are similar at other statistical agencies, so much of the description applies to other countries.

Selecting Quotes

Based on trade data, the BLS sets a sample to determine the number of price quotes needed for each item. The BLS then selects a set of companies to ask for quotes and determines which quotes to ask of each company. A field economist then approaches the company to determine the particular products that will be priced.

The BLS sets a number of goals for its price program and faces a number of constraints when setting its sample. Therefore, the sampling is not a pure proportional probability sample, but a compromise that attempts to achieve its goals within the constraints.

The sample is designed to get prices covering total trade as well as a number of subaggregate price indices. Therefore, it will oversample some products to maintain sufficient coverage of those subindices.

The survey is voluntary and requires the ongoing cooperation of importers or exporters. Resource constraints restrict the number of new prices that can be gathered and how often the sample is reset. It is more difficult to obtain prices from intermittently traded products, since items that trade too infrequently do not yield usable price changes, so field economists focus on items that are regularly traded. Firms that are involved in trade intermittently tend to cooperate with data collection less frequently; therefore, the survey design intentionally downweights such products and companies.

Not all intermittent trade is due to the effects identified in this chapter. For import prices, the BLS does not have jurisdiction to ask overseas exporters for price data. A foreign company's goods may be imported consistently, just not by the same importer. Since the BLS can only track the importer's side of the relationship, the goods from that foreign company will be intermittently traded in the sample. Some goods, like machinery installed in a new factory, are only demanded irregularly.

Quote Replacement

Quotes will drop out and need to be replaced periodically. There is both planned and forced substitution.

Planned substitution is replacement built into the sampling design. The sample is reset periodically to reflect changes in the set of products that are traded. Old items are cycled out and replaced by items in the new sample. Forced substitution is due to a product being discontinued or a firm ceasing business. In such cases, the field economist will attempt to get a replacement quote from the trading firm if possible.

Nakamura and Steinsson (2012) report that about half of the quotes that drop out do so because of forced substitution and that a quarter drop out because of planned substitution. The remaining quarter are cases where the firm ceases to provide quotes and gives no reason for stopping. Depending on factors such as how much longer the item was to be included in the sample, the item may either be replaced by a new quote from a different firm or discontinued.

If there is a forced substitution and the new item is substantially different, the reporter is asked for the value of change so it can be subtracted from the new item's price, a process called "linking." Gagnon, Mandel, and Vigfusson (2012) and Nakamura and Steinsson (2012) argue that this method is used relatively infrequently. If a new item is added (as in a planned substitution), there is no item with which to link.

When the import prices are put together by the BEA to deflate trade, quality adjustments are made to a few items, largely durable goods, where established hedonic methods are available (BEA 2011).

Nakamura and Steinsson (2012) argue that since explicit quality adjustment is done infrequently, import/export prices are approximately matched-model indices. That is, level differences between items within an index are attributed to quality differences and omitted. Of course, the data collection does not explicitly use matched modeling. However, quotes are often added to a cell without quality adjustment, and level differences between items do not get included. From the standpoint of the theory, this method is equivalent to matched modeling.

RESULTS

This section examines the theoretical difficulties in adjusting for quality. Specifically, I examine matched modeling and the problems posed by sampling intermittently traded goods less frequently. I show that specific trade costs interfere with the assumptions that support the use of these methods.

In the subsections that follow, I will focus on how statistical agencies measure international price change. The BLS uses a Laspeyres index for its import price indices (BLS 1997). The expression for the index measuring a price change from period 0 to period *t* is

$$P_t = \sum_i \frac{\omega_0(i)}{\sum_i \omega_0(i)} \frac{p_{od,t}(i)}{p_{od,0}(i)}, \quad (4.7)$$

where $\omega_0(i) = p_{od,0}(i) c_{d,0}(i)$.

This measure is distinct from the theoretical price index that measures the welfare effects of price change. The BLS (1997) states explicitly that the purpose of the international price indices is not to measure welfare.

To isolate the differential impact of costs on price across goods of different qualities, I assume throughout this section that trade costs are the same for all varieties.

Matched Modeling

Matched modeling works off the assumption that if two similar goods are available in the market at different prices, the price gap reflects differences in quality. We can recover the quality gap between an existing and a new good by examining the price gap. In this section, I show that specific costs weaken the link between price and quality.

Without specific costs ($F^s = 0$), prices closely reflect quality. The relationship between unit cost $a(i)$ and quality $q(i)$ can be written as

$$a(i) = q(i)^{\frac{1}{1+\theta}}.$$

The relative price of two goods i and i' that only differ in quality is

$$\text{(4.8)} \qquad \frac{p_{od}(i)}{p_{od}(i')} = \frac{\dfrac{q(i)^{\frac{1}{1+\theta}}\sigma w_o}{\sigma - 1}}{\dfrac{q(i')^{\frac{1}{1+\theta}}\sigma w_o}{\sigma - 1}} = \left[\frac{q(i)}{q(i')}\right]^{\frac{1}{1+\theta}}.$$

In this case, matched modeling works well. As long as wages paid by the producers of the two products are the same, the price difference reflects only quality differences. If a comparison good from a producer with similar input costs can be found (for example, from the same country), matched modeling is a practical method for dealing with the new-goods problem.[4]

This clear relationship between price and quality breaks down with specific costs. The relative price is now

$$\text{(4.9)} \qquad \frac{p_{od}(i)}{p_{od}(i')} = \frac{q(i)^{\frac{1}{1+\theta}}\sigma + \dfrac{F_{od}^s}{1+\tau_{od}}}{q(i')^{\frac{1}{1+\theta}}\sigma + \dfrac{F_{od}^s}{1+\tau_{od}}}.$$

As the specific cost term increases, prices are determined more by trade costs than by quality. Breaking the relationship between price and quality makes matched modeling more difficult. In matched modeling, the price gap between an old and a new good is attributed to quality. As Proposition 1 shows, this method underestimates the quality gap.

Proposition 1: Suppose $a_L < a_H$. Then $\frac{p_o(L)}{p_o(H)} > \frac{qL}{qH}$.

Proof: From the solution to the model, $\frac{p_o(L)}{p_o(H)} > \frac{qL}{qH}$ if

$$\frac{\frac{w_o}{\sigma - 1}\left[a(L)\sigma + \frac{F_{od}^s}{1+\tau_{od}}\right]}{\frac{w_o}{\sigma - 1}\left[a(H)\sigma + \frac{F_{od}^s}{1+\tau_{od}}\right]} > \left[\frac{a(L)}{a(H)}\right]^{1+\theta} . \tag{4.10}$$

This condition holds if

$$a(H)\sigma\left[\left(\frac{a(H)}{a(L)}\right)^{\theta} - 1\right] + \frac{F_{od}^s}{1+\tau_{od}}\left[\left(\frac{a(H)}{a(L)}\right)^{\theta} - 1\right] > 0 \cdot$$

This condition is always true, since $\frac{a(H)}{a(L)} > 1$ and $\theta > 0$ by assumption.

The specific cost F_{od}^s has more influence on the price of low-quality goods. Therefore, the price difference will be smaller than quality differences. New goods are of lower quality than prices indicate. This force will tend to overstate the real value of new goods imports.

Sampling

As long as the nonsampled prices move in the same way as the sampled goods, this method gives accurate price measures. However, specific trade costs can introduce differences. Newly and intermittently traded goods are likely to have systematically lower quality than continuing goods. These lower-quality goods react to trade cost changes differently, so deflating these goods by prices of high-quality goods can lead to mismeasurement.

Quality of new goods

Newly traded goods tend to be of lower quality than continuing goods. Since lower-quality goods are the least profitable, they are the most sensitive to cost changes. High-quality-goods exporters will serve even high-trade-cost markets, since they have high margins. Low-margin exporters of low-quality goods are much closer to the zero-profit cutoff. Relatively small cost increases can make a market unprofitable, so these exporters are the most likely to exit.

In the paragraphs that follow, I will vary a cost and hold all other quantities constant. That is, if an exercise changes a specific trade cost so that

$$F^{s}_{od,t+1} \neq F^{s}_{od,t},$$

all other trade costs and wages are held constant:

$$F^{f}_{od,\, t+1} = F^{f}_{od,t},\ \tau_{od,t+1} = \tau_{od,t}, \text{ and } w_{o,t+1} = w_{o,t}.$$

I define cutoff quality $\overline{q}_{od}$ as the quality level that sets Equation (4.6) at equality; however, changes in trade costs or input prices will change this cutoff. Lemma 1 shows that falling wages and trade costs (holding the other quantities constant) will lead to entry of low-quality goods.

Lemma 1: Holding all other quantities constant, if any of the following four conditions hold:

1) $F^{s}_{od,t+1} < F^{s}_{od,t}$,

2) $F^{f}_{od,t+1} < F^{f}_{od,t}$,

3) $\tau_{od,t+1} < \tau_{od,t}$, or

4) $w_{o,t+1} < w_{o,t}$,

then $\overline{q}_{od,t+1} < \overline{q}_{od,t}$.

Proof: For proofs of the first three conditions, see Lemmas 2, 3, and 4 in Bridgman (2013). For the proof of the final condition, rearranging the cutoff condition (Equation [4.6]) gives us

$$(4.11)\quad \left(\frac{a(i)^{1+\theta}(\sigma-1)}{a(i)+F_{od}^{s}(i)}\right)^{\sigma-1}\frac{B_d}{\left(1+\tau_{od}(i)\right)\sigma^{\sigma}} \geq F_{od}^{f}(i)\,w_o^{\sigma}\ .$$

If $w_{o,t+1} < w_{o,t}$, the right-hand side of the condition falls. This decline is equivalent to the fixed cost $F_{od,t}^{f}$ falling. Following the proof of Lemma 3 in Bridgman (2013), this implies that $\overline{q}_{od,t+1} < \overline{q}_{od,t}$.

Quality and price changes

The fact that new and intermittently traded goods are of lower quality would not be a problem for sampling if the price changes of low- and high-quality goods were the same. However, low-quality goods react more to cost changes than do high-quality goods. Since more of the price of low-quality goods reflects trade costs, these goods are more sensitive to changes in these costs. The prices of low-quality goods fall (rise) more when specific trade costs fall (rise) than do the prices of higher-quality goods. I show this formally in Proposition 2.

Proposition 2: If $a(H) > a(L)$ and either

1) $F_{od,t+1}^{s} \neq F_{od,t}^{s}$ or

2) $\tau_{od,t+1} \neq \tau_{od,t}$,

then $$\left|\frac{p_{t+1}(L)-p_t(L)}{p_t(L)}\right| > \left|\frac{p_{t+1}(H)-p_t(H)}{p_t(H)}\right|.$$

Proof: Define $\Delta p(i)$ by $p_{t+1}(i) = p_t(i) + \Delta p(i)$. For the condition

$$\left|\frac{p_{t+1}(L)-p_t(L)}{p_t(L)}\right| > \left|\frac{p_{t+1}(H)-p_t(H)}{p_t(H)}\right|$$ to hold, we have

$$\left|\frac{\Delta p(L)}{p_t(L)}\right| > \left|\frac{\Delta p(H)}{p_t(H)}\right|.$$

If either trade cost $\left(F^s_{od,t} \text{ or } \tau_{od,t}\right)$ changes, $\Delta p(L) = \Delta p(H)$. Formally, if

$F^s_{od,t+1} \neq F^s_{od,t}$, then

$\Delta p(L) = \Delta p(H) = \dfrac{F^s_{od,t+1} - F^s_{od,t}}{1+\tau}$, and if $\tau_{od,t+1} \neq \tau_{od,t}$, then

$\Delta p(L) = \Delta p(H) = \dfrac{F^s_{od}}{1+\tau_{od,t+1}} - \dfrac{F^s_{od}}{1+\tau_{od,t}}$. The condition holds if

$\dfrac{1}{p_t(L)} > \dfrac{1}{p_t(H)}$. Since $a(H) > a(L)$, $p(H) > p(L)$ and the

condition holds.

Since they show more price volatility, dropping low-quality goods will tend to underestimate price changes. To see this more concretely, consider the case where both a high- and a low-quality good—$c(H)$ and $c(L)$, respectively—are traded in a category, but only the high-quality good is included in the sample. Suppose the specific cost falls $\left(F^s_t < F^s_{t-1}\right)$. The measured price change for the category is

$P^M_t = \dfrac{\left[\omega_t(H) + \omega_t(L)\right]}{\sum_i \omega_t(i)} \dfrac{p_t(H)}{p_{t-1}(H)}$. The price change should be

$$P_t = \frac{\omega_t(H)}{\sum_i \omega_t(i)} \frac{p_t(H)}{p_{t-1}(H)} + \frac{\omega_t(L)}{\sum_i \omega_t(i)} \frac{p_t(L)}{p_{t-1}(L)}.$$

By Proposition 2, $\dfrac{p_{t+1}(L)}{p_t(L)} > \dfrac{p_{t+1}(H)}{p_t(H)}$. That implies that

$$\frac{\omega_t(H)}{\sum_i \omega_t(i)} \frac{p_t(H)}{p_{t-1}(H)} + \frac{\omega_t(L)}{\sum_i \omega_t(i)} \frac{p_t(H)}{p_{t-1}(H)} > \frac{\omega_t(H)}{\sum_i \omega_t(i)} \frac{p_t(H)}{p_{t-1}(H)} + \frac{\omega_t(L)}{\sum_i \omega_t(i)} \frac{p_t(L)}{p_{t-1}(L)} \quad (4.12)$$

Therefore, $P^M_t > P_t$, so the measured price change underestimates the price fall.

EMPIRICAL EVIDENCE

The previous section showed theoretically that specific trade costs can lead to mismeasurement. In this section, I examine how important this mismeasurement is empirically.

This section only performs an initial assessment of the empirical scope of the theoretical mechanisms. It does not "fix" the import price index. While I find that these mechanisms appear to have a quantitative impact in some cases, doing a full adjustment of the data will require additional work.

Data

The basic data I use in the data analysis are U.S. goods import data from the Census Bureau, as collected by Hummels (2007). These data give trade value on a customs value (FOB, or free on board), tariffs, freight charges, and weight of shipments from 1974 to 2004. A "good" is defined as an SITC Revision 2 item-and-country-of-origin pairing.

There are a couple of caveats to using these data. First, they are *not* the data that are used by the BLS to calculate import price indices. The price concept I use is unit value (value per weight) rather than price per product.[5] A product is much more aggregated compared to the prices used by statistical agencies, so it will likely underestimate the real impact of specific costs. Furthermore, the analysis does not cover all trade. Weight data only cover shipments brought in by water or air. Therefore, the portion of trade with Mexico and Canada shipped by rail or truck is excluded. Additionally, not all goods report a weight.

Despite the limitations of the data, they do have advantages that lead me to use them. Most importantly, they are publicly available, unlike the microdata. Quality variation across exporters and locations is a robust finding. (For example, see Bastos and Silva [2010]; Choi, Hummels, and Xiang [2009]; and Hummels and Klenow [2005].) Therefore, country-level variation generates sufficient quality differences to get a first-pass impact of quality difference on price measurement.

In the subsection that follows, I assume that tariffs are all ad valorem charges and that freight rates are all specific costs. That is, $\tau_{od}(i)$ is the tariff rate and $w_o F^s_{od}(i)$ is freight charge per kilogram. Price $p_{od}(i)$ is unit value. Hummels and Skiba (2004), among many others, find that freight rates are charged on a specific basis. Tariffs in the post–World War II era are typically charged on an ad valorem basis.

Matched Modeling

As documented in Proposition 1, specific trade costs change the relationship between quality and price compared to the case without such costs. To get an empirical measure of this impact, I compare the model's estimates of the cost parameter $a(i)$ with and without specific costs. Since we know that specific costs are present, I will assume that the specific trade-cost model is the "true" model. I will use the ratio of the "true" $a(i)$ and the estimate without these costs, as is usually assumed, as my indicator of quality mismeasurement.

The mill price is given by $p_{od}(i) = \frac{w_o}{\sigma - 1}\left[a(i)\sigma + \frac{F_{od}^s(i)}{1+\tau_{od}(i)}\right].$

We can rewrite this equation as follows:

$$(4.13) \quad a(i)w_o = \frac{1}{\sigma}\left[p_{od}(i)(\sigma-1) - \frac{w_o F_{od}^s(i)}{1+\tau_{od}(i)}\right].$$

Neglecting the impact of specific costs (setting $F^s = 0$) will give an estimate of $\hat{a}(i)$:

$$(4.14) \quad \hat{a}(i)w \qquad \frac{p_{od}(i)(\qquad)}{\qquad}.$$

Taking the ratio gives us a measure of the overstatement of quality differences from assuming only ad valorem costs:[6]

$$(4.15) \quad \frac{a(i)}{\hat{a}(i)} = 1 - \frac{w_o F_{od}^s(i)}{p_{od}(i)(1+\tau_{od}(i))(\sigma-1)}.$$

Specific trade costs are more likely to be an issue when one or more of the following characteristics are present:

1) High specific-cost goods (high F^s)
2) Low-quality goods (low $a(i)$)
3) Inelastically demanded goods (low σ)

Microanalysis

I begin the empirical analysis by examining one good, leather footwear, in detail. I selected this good for a number of reasons. It is one of the 10 largest import categories in the period examined. A wide variety of countries export this good to the United States, with the potential for significant quality differences. In addition, there are few observable attributes that can be used for hedonic quality adjustment. Therefore, there may be room for alternative methods such as the one proposed in this chapter.

I need a value of σ to estimate the mismeasurement. I use a value of 2.02, taken from Broda and Weinstein (2006).[7] Table 4.1 reports the estimated $a(i)$ ratio for Switzerland and Sri Lanka at the beginning and end of the sample period. I use these two countries since they represent the high and low ends of unit value, with Swiss exporters charging more than five times the price of their Sri Lankan counterparts in 1974. This spread reflects the fact that the richer countries tend to export higher-quality goods (Fajgelbaum, Grossman, and Helpman 2011).

In 1974, the impact of specific costs on mismeasurement is much stronger for Sri Lanka than it is for Switzerland. Price overstates quality by nearly 40 percent for Sri Lanka, whereas it overstates quality by only 4 percent for Switzerland. FOB prices are selected as a markup over production cost, which is correlated with quality, and over specific cost, which is not. For Switzerland, trade costs are low relative to price. Therefore, most of the price reflects production cost, which reflects quality. Specific costs relative to unit value are much higher for Sri Lanka, so more of the charged price is a markup over trade costs. In 2004, Sri Lanka's mismeasurement falls significantly. Specific costs

Table 4.1 Leather Footwear *a*(*i*) Ratios

	Switzerland 1974	Sri Lanka 1974	Switzerland 2004	Sri Lanka 2004
P_O	15.41	2.97	30.97	13.01
$F^S w_O$	0.70	0.93	1.49	0.80
τ	0.08	0.13	0.08	0.11
$\frac{\hat{a}(i)}{a(i)}$	1.04	1.37	1.05	1.06

SOURCE: Author's calculations, using data from Hummels (2007).

relative to unit value are much lower. Switzerland and Sri Lanka are much more similar in cost structure, so prices are more reflective of quality.

If each good was mismeasured by the same amount, there would be no impact on matched modeling. As shown above, specific costs affect low-quality goods more, so we would not expect the impact to be the same. To measure the impact on measurement, we need to compare goods across producers. An issue with the trade data is that the producers are different countries, so input costs are unlikely to be the same. The price levels of wealthier countries tend to be higher, as a result of the "Penn effect." (See Marquez, Thomas, and Land [2012] for a recent empirical confirmation of this effect.) Certainly, wages in Switzerland and Sri Lanka are different.

We can use the model to eliminate the wages from our estimates. If good k is produced by countries i and j, the price ratio without specific costs is

$\frac{p_i(k)}{p_j(k)} = \frac{w_i \hat{a}_i(k)}{w_j \hat{a}_j(k)}$. The equivalent ratio with the true $a(i)$ ratio is

$$(4.16) \qquad \frac{w_i a_i(k)}{w_j a_j(k)} = \frac{w_i \hat{a}_i(k)}{w_j \hat{a}_j(k)} \times \frac{a_i(k)}{\hat{a}_i(k)} \times \frac{\hat{a}_j(k)}{a_j(k)} .$$

The degree to which matched modeling underestimates quality gaps is

$$(4.17) \qquad \frac{w_i a_i(k)}{w_j a_j(k)} \times \frac{w_j \hat{a}_j(k)}{w_i \hat{a}_i(k)} = \frac{a_i(k)}{\hat{a}_i(k)} \times \frac{\hat{a}_j(k)}{a_j(k)} .$$

In 1974, the unadjusted price ratio overstates the quality difference by 32 percent. The unadjusted price ratio

$\frac{w_i \hat{a}_i(k)}{w_j \hat{a}_j(k)}$ is 5.19, while the adjusted ratio $\left(\frac{w_i a_i(k)}{w_j a_j(k)}\right)$ is 6.83.

In 2004, the overstatement falls to 1 percent. Since Swiss and Sri Lankan costs are more similar, so is the degree of mismeasurement. Therefore, the data better reflect the assumptions of matched modeling.

Overstating the quality of new goods will overstate imports. The effect is strongest for low-quality goods. Therefore, this effect will tend to overstate the U.S. trade deficit. American producers tend to produce higher-quality goods, since the United States is a high-income country. U.S. imports have begun to shift to lower-income countries, for whom the effect is stronger. Therefore, imports are more likely to be overstated than exports.

The size of the mismeasurement is sensitive to the elasticity used. For example, the $a(i)$ ratio for Sri Lanka in 1974 drops from 1.37 to 1.10 if σ is increased from 2.02 to 4.00. On the other hand, the ratio jumps up to 2.24 if σ falls to 1.50. The elasticity governs the degree to which price is marked up over cost. For low values of σ (inelastic goods), there are high markups that magnify the impact of specific costs.

Aggregate analysis

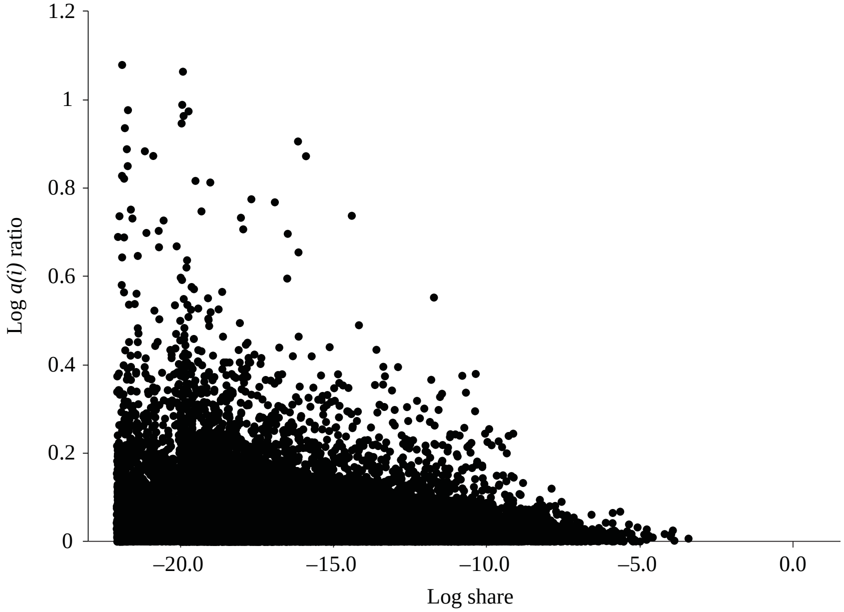
I now turn to the aggregate effect on quality measurement. I use $\sigma = 4$ for all goods. This is the value Simonovska and Waugh (2011) settle on as a consensus value using U.S. data; the value is within the usual range used in the literature. This will tend to underestimate the impact, since more differentiated goods tend to have a lower value of σ.

The impact of specific costs is heterogeneous. The range is large, from a ratio of 1 (no distortion) to 3 (200 percent overstatement). The average $\frac{\hat{a}(i)}{a(i)}$ ratio over the sample is 1.039, with a standard deviation of 0.067. The goods with the largest ratios are those shipped by air. The mismeasurement is larger for goods with high specific-trade costs. Since air charges are much larger than charges for goods shipped by water, goods shipped mostly or exclusively by air are more subject to this distortion.

So far, I have treated each good equally. To get a sense of the overall impact, Figure 4.1 plots the $a(i)$ ratio against its share in total imports within the sample for 2004.[8] The most distorted goods tend to be a smaller share of imports. However, there are a number of goods that are relatively important that show significant distortion.

As a measure of the aggregate impact, I calculate a trade-weighted ratio of all goods:

Figure 4.1 Estimated Mismeasurement vs. Log Share of Total Imports for 2004 (σ = 4.00)



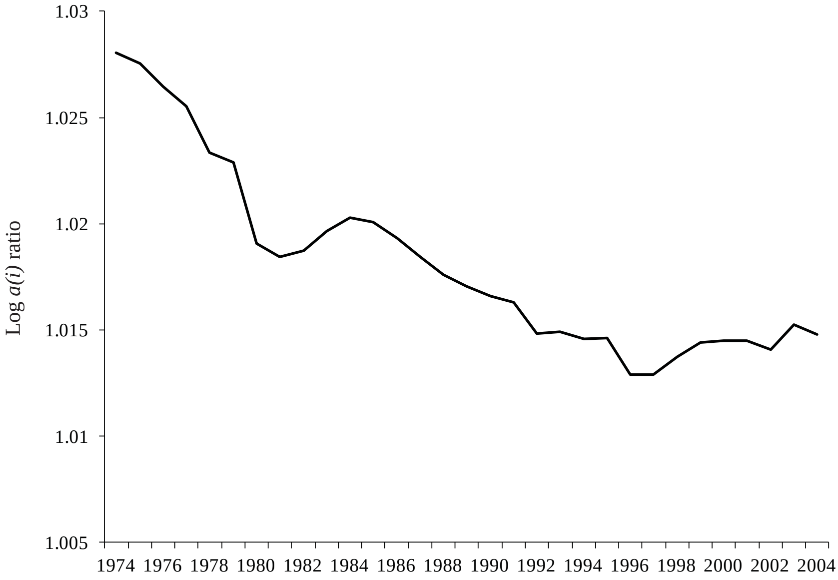
SOURCE: Author's calculations, using data from Hummels (2007).

$$(4.18)\quad \sum_i s_i \frac{w_i \hat{a}(i)}{w_i a(i)},$$

where $s_i = \dfrac{p_o(i)c(i)}{\sum_i p_o(i)c(i)}$.

Figure 4.2 shows the weighted ratio, which declines from 1.029 to 1.015. This decline follows the fall in freight rates documented in Hummels (2007). Of course, what matters for matched modeling is the relative mismeasurement within a category. As shown above with Sri Lankan shoes, the decline in specific costs will reduce the scope of this source of mismeasurement. Since the typical good's price reflects its quality more over time, the typical relative mismeasurement will likely decline as well.

Figure 4.2 U.S. Trade–Weighted Estimated Mismeasurement (σ = 4.00)



SOURCE: Author's calculations, using data from Hummels (2007).

The matched modeling issue may be important for at least some goods. There is reason to believe that this calculation underestimates the degree of mismeasurement. The data may understate actual specific costs. They do not include any other specific costs that accrue because of internal transportation and wholesale and retail trade. Rousslang and To (1993) find that internal trade barriers are significant. Internal transportation costs are 37 percent of international rates. If any of these costs are specific, these estimates will be too low. Using Norwegian data, Irarrazabal, Moxnes, and Opromolla (2011) estimate that the median specific trade cost is 34 percent of a good's value.

Using the same σ for all goods understates the impact on some differentiated goods whose demands are less elastic than $\sigma = 4$. If we set σ at 2, the magnitude of the average mismeasurement increases to 9.9 percent in 1974 and 5.4 percent in 2004.

Even if the impact for the average good is small, there are some goods for which it is likely to matter. Lower-income countries, which tend to produce lower-quality goods, have become more important in U.S. imports. The shift to air transportation, which has much higher freight rates, has increased the specific cost for some goods.

Sampling

The sampling method is less likely to collect quotes for intermittently traded goods, whereas the model predicts that new and intermittently traded goods are of lower quality than continuing goods. I begin the analysis by examining whether these goods are of lower quality in the data. Though quality cannot be observed directly, there is evidence that such goods are of lower quality than continuing goods.

Goods that were not traded in the previous year have lower unit values. This set of goods includes both completely new goods and intermittently traded goods that are imported again. Bridgman (2013) shows that newly traded goods enter at a lower unit value, while trade costs are similar across the two sets of goods.

Beginning with Besedes and Prusa (2006a,b), a growing literature has examined the duration of trading relationships. (See Besedes and Prusa [2010] for a survey.) This literature finds that most trade relationships are very short, with the median product being traded for only a year. Lower exporter income, as measured by GDP per capita, is associated with shorter trading relationships. As discussed above, lower-income countries tend to export lower-quality goods.

There is direct evidence that entering and exiting items are of lower quality than continuing goods. Mandel (2010) finds that U.S. goods that cease to be exported are of lower quality. In a later work, Mandel (2013) finds that Chinese exporters to the United States entered at low quality.

Impact of sampling

These data do not allow us to assess the quantitative impact of sampling, since we cannot identify which goods are excluded from the sample. However, we can do a back-of-the-envelope calculation to get a sense of quantitative impact. I examine the impact of trade cost changes for low- and high-quality goods. Specifically, I compare what the theory predicts the new prices would be if F^s changed to $F^{s,'}$. To parameterize the exercise, I use new and old goods in 2004 as reported in Bridgman (2013). I identify old and new goods as high- and low-quality goods, respectively. Their prices are $p_o(H)$ and $p_o(L)$. (H and L stand for high and low.)

Equation (4.19) gives us $a(i)w_o$. Using the price equation, we can calculate $p_o'(i)$ for $i \in \{H, L\}$, the predicted price when F^s changes to $F^{s,'}$ and all other quantities are held constant.

If trade costs F^s and τ are the same for high- and low-quality goods, which is the case for new and old goods in 2004, the relative growth rate of prices is

$$(4.19) \quad \left(\frac{p_o'(H)}{p_o(H)} - 1\right) / \left(\frac{p_o'(L)}{p_o(L)} - 1\right) = \frac{p_o(L)}{p_o(H)} .$$

In 2004, we have $\frac{p_o(L)}{p_o(H)} = \frac{0.59}{1.20} = 0.49$.

Therefore, high-quality goods are half as responsive to a change in specific trade costs.

While this example is quite stylized, it indicates that there can be significant differences in price responsiveness among goods of different quality. Using only high-quality goods will tend to underestimate price changes.

There are forces mitigating this effect. Most trade value results from trade relationships that are long lasting. If a trade relationship survives the first few years, the chances that it will end fall significantly (Besedes and Prusa 2010).

Trade relationships in differentiated goods tend to be longer. Besedes and Prusa (2006b) compare trade duration for goods in organized markets with differentiated goods using the classification reported in Rauch (1999). Trade relationships for commodities traded in organized markets tend to be shorter, since such markets lower the cost of switching. These are the goods for which the measurement issues resulting from quality differences are less important.

The impact on aggregate trade measurement is probably small. Most trade value is not impacted by this effect. However, it may have an impact on subindices. The price gap between new and old goods has been increasing, suggesting that the scope for mismeasurement is increasing.

This increasing scope of mismeasurement could have an impact on some of the other uses of trade prices, aside from deflating trade. For instance, it may have a role in explaining the low responsiveness of trade prices to exchange rates. Nakamura and Steinsson (2012) note that trade quotes change very little over time. The items that tend to be included in the price sample are those that are the least affected by cost shocks.

CONCLUSION

This chapter shows theoretically that two frequently used techniques in international price measurement, matched modeling and dropping intermittently traded goods from the sample, will mismeasure prices when there are quality-differentiated goods and specific trade costs. Specific costs weaken the link between a good's quality and its price. This effect causes matched modeling to overstate the quality of low-quality goods. Intermittently traded goods are typically low-quality goods, those whose prices are the most sensitive to shocks. Removing them from the sample will understate price movements. These effects may lead us to overstate the amount of trade from new, low-income exporters, since they tend to produce lower-quality goods. Determining the extent of this overstatement will require additional work using more granular data. However, initial data work indicates that these effects may be quantitatively important for some types of goods.

Notes

I thank Jeffrey Blaha, John Greenlees, Larry Lang, and Dave Mead for comments. The views expressed in this chapter are solely those of the author and not necessarily those of the U.S. Bureau of Economic Analysis or the U.S. Department of Commerce.

1. For example, see Hallak (2006); Hallak and Schott (2011); Henn, Papageorgiou, and Spatafora (2013); Hummels and Skiba (2004); Irarrazabal, Moxnes, and Opromolla (2011); Manova and Zhang (2012); Martin (2012); and Spearot (2011).
2. This assumption provides closed-form solutions for prices. As shown in Bridgman (2013), the impact of this assumption is small as long as there are a large number of varieties sold.

3. I thank the BLS's Jeffery Blaha, Larry Lang, and Dave Mead for extensive assistance in explaining the sampling process.
4. There are other issues with match modeling. If there are menu costs, firms may use the introduction of new models as an opportunity to change prices (Nakamura and Steinsson 2012). That concern does not arise in this model, since prices are fully flexible and there are no strategic or informational reasons for not adjusting prices. Therefore, that literature is complementary to this paper.
5. Amiti and Davis (2009) use unit values and argue that they are a reasonable proxy for broad price movements.
6. Quality is actually a function of this cost $q(i) = a(i)^{1+\theta}$. By only examining the ratio of the $a(i)$, we do not have to assign a value for θ. This ratio shows the impact of specific trade costs on quality measurement, but we would need a value of θ to assess the impact on welfare measurement.
7. This value is the 1974–1988 value for SITC Revision 2 Code 85102, taken from the working-paper version (Broda and Weinstein 2004). The published version reports elasticities for the more aggregated three-digit SITC level, while the working paper reports at the five-digit level.
8. I log both variables to make the figure easier to see. I use 2004, the final year of the sample, since it has the most observations.

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Part 2

Evidence of Biases to Statistics and Measuring Industry Competitiveness

5
Measuring Manufacturing

How the Computer and Semiconductor Industries Affect the Numbers and Perceptions

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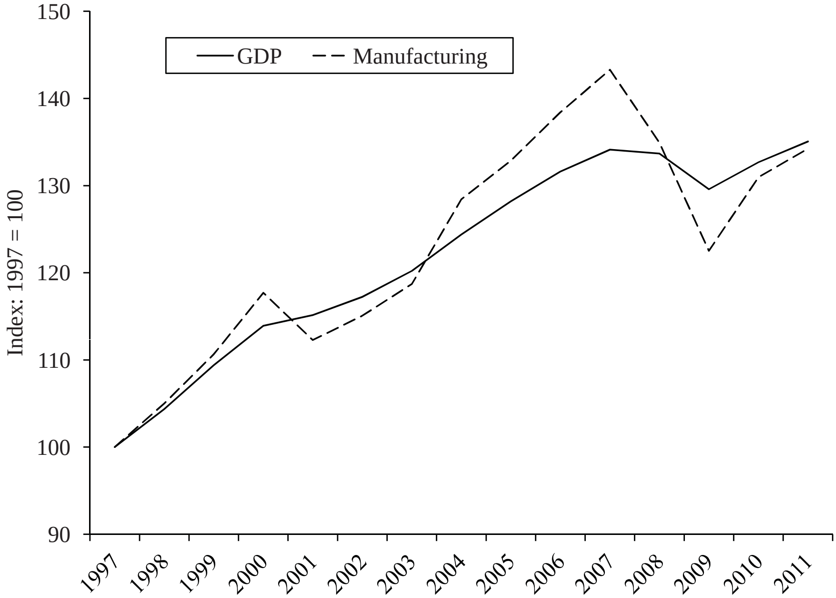
Since 2000, the U.S. manufacturing sector has lost more than five million jobs, or over 30 percent of its employment base. Large-scale employment losses in manufacturing are not confined to a few Rust Belt states. Manufacturing employment over the period has fallen in all but one state (Alaska), and the drop has exceeded 20 percent in 40 states. In response to these employment losses, as well as to a large trade deficit in manufactured goods and concerns that U.S. manufacturing is losing its international competitiveness, President Obama created a cabinet-level Office of Manufacturing Policy, and Congress has considered a number of measures to help U.S. manufacturers.[1]

The development of special policies to promote U.S. manufacturing has many detractors, however. At the heart of the debate is a basic disagreement over the state of U.S. manufacturing. Those who oppose government intervention typically argue that there is little need, pointing to robust output growth in the sector. Over the past decade the average annual growth of real value-added in manufacturing has outpaced that in the aggregate economy, except during recessions, and in quantity terms, the output of U.S. manufacturers relative to the rest of the economy has remained steady (Figure 5.1).[2] These statistics, by themselves, provide compelling evidence that manufacturing remains highly competitive. Citing such figures, Robert Lawrence and Lawrence Edwards

Figure 5.1 Growth in Real GDP for the Aggregate Economy and for Manufacturing, 1997–2011



SOURCE: Bureau of Economic Analysis (BEA).

recently asserted, "The concerns about U.S. manufacturing are not about output or growth but relate to employment" (Lawrence and Edwards 2013). High growth in real value-added coupled with large employment losses implies high labor productivity growth: many influential researchers and analysts promote the narrative that employment losses in manufacturing, as in agriculture, are largely a consequence of automation, not import competition.[3] As U.S. Chamber of Commerce Executive Vice President and Chief Operating Officer David Chavern put it, "Where did those [manufacturing] jobs go? Mostly to a country called 'productivity'" (Chavern 2013).

Statistics, and their interpretation, play a crucial role in shaping our understanding of the economy and informing policy. Yet, the debate over the state of U.S. manufacturing, with its dueling narratives, bolstered by apparently contradictory sets of statistics, illustrates how the rapid pace of globalization and technological change greatly complicates the collection and interpretation of economic data. Building on Houseman et al. (2011), we raise concerns about the widely cited output growth statistics in Figure 5.1, which have served as a basic indicator of the health of American manufacturing. That article focuses on biases to manufacturing statistics resulting from the rapid shift toward imported intermediates from low-wage countries and estimates that real GDP growth in manufacturing was overstated by up to 20 percent between 1997 and 2007. In this chapter, we argue that, even in the absence of such biases, the manufacturing output statistics in Figure 5.1 are misleading and commonly misinterpreted.

First, it is generally unknown that the robust growth in real GDP in the manufacturing sector is largely driven by one industry: computers and electronic products. For most of manufacturing, real output growth has been relatively weak or negative.[4] When the computer and electronic products industry is excluded, real GDP growth in manufacturing falls by two-thirds between 1997 and 2007, the decade leading up to the Great Recession. In 2011, without computer-related industries, real GDP in the manufacturing sector was actually lower than in 2000. The computer and electronic products industry similarly drives real manufacturing output growth in most U.S. states. Real manufacturing GDP growth between 1997 and 2007 falls by more than half in a majority of states and by at least 25 percent in all but 10 states.

Furthermore, the extraordinary growth in real value-added in manufacturing and the accompanying productivity growth in the computer and electronic products industry results largely from two sets of products, computers and semiconductors, that, when adjusted for quality improvements, have prices that are falling rapidly. These quality improvements, in turn, largely reflect better design and increases in the density of electronic circuitry. While changes in manufacturing processes are necessary to produce these improved designs, the production processes in computers and semiconductors have been automated for many decades. Thus, the high growth in real value-added and productivity in the computer and semiconductor product segments, and by extension the manufacturing sector, reflects, to a large degree, product improvements from research and development rather than automation of the production process. Unlike productivity resulting from automation, which involves the substitution of capital for labor, productivity arising from improvements to product design and already-automated production processes does not, in and of itself, cause job losses.

Ironically, the extraordinary growth in real value-added and productivity in the computer and semiconductor industries does not signal the competitiveness of the United States as a manufacturing location for these products. Drawing on new market research data, we provide evidence of the shift in the location of computer and semiconductor manufacturing to Asia. Few personal computers and servers are assembled in the United States today, and, consequently, the United States runs a large trade deficit for these products. The United States retains a significant presence in semiconductor wafer fabrication, but over the past decade manufacturing capacity has expanded much more rapidly in Asia, and, as a result, U.S. market share has declined rapidly. Although many of the computers and semiconductors produced overseas are still designed in the United States, the shift in the location of production has a direct bearing on the number and types of U.S. jobs.

The effect that computer-related industries have on measured growth in manufacturing real GDP has important implications not only for the interpretation of published statistics but also for research based on them. We illustrate with an empirical analysis of the relationship between employment and real output growth using state manufacturing data. The computer and electronic products industry is an outlier in manufacturing, characterized both by extraordinary real value-added growth and by above-average employment declines. An increase in a state's manufacturing output resulting from higher demand for its products should lead to an increase in employment, but we find no such employment effect in instrumental variables regression analyses. Although a naïve interpretation of this finding would suggest that policies to promote U.S. manufacturing will fail to generate jobs, the finding makes no sense, and such an interpretation would be incorrect. When the computer and electronics product industry is dropped from the manufacturing measures, the expected relationship between output and employment holds: higher demand generates roughly equal percentage increases in real manufacturing shipments and employment.

Misleading statistics have helped shape an important policy discussion concerning U.S. manufacturing. To address the problem, statistical agencies first and foremost should take steps to assure that the outsized effect that computer-related industries have on manufacturing-sector statistics is transparent to data users. This could easily be accomplished by publishing real output and productivity statistics for the manufacturing sector less computer-related industries.

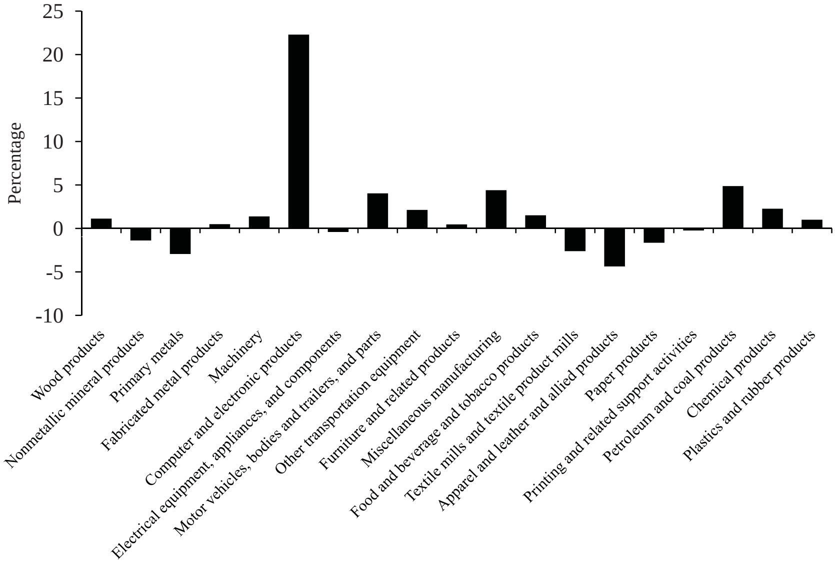
In the remainder of the paper, we do three things. First, we detail the influence that computer and electronic products manufacturing has on real manufacturing GDP growth nationally and in states. We also estimate the bias to real GDP growth in state manufacturing sectors from offshoring in the appendix to this chapter. Second, we examine the global competitiveness of the U.S. computer and semiconductor industry segments and the sources and interpretation of the rapid real value-added and productivity growth in them. And third, we illustrate the distorting effect computer-related industries may have on research findings through an empirical examination of the relationship between output and employment growth using state manufacturing data. We conclude with recommendations for statistical agencies.

THE EFFECT OF THE COMPUTER AND ELECTRONIC PRODUCTS INDUSTRY ON REAL GDP GROWTH IN MANUFACTURING

Manufacturing output statistics mask divergent trends within the sector. Figure 5.2 displays annual average growth rates for each three-digit NAICS manufacturing industry. Real value-added in the computer and electronic products industry, which includes computers, semiconductors, telecommunications equipment, and other electronic products manufacturing, grew at a staggering rate of 22 percent per year from 1997 to 2007.[5] In contrast, real value-added in petroleum and coal products manufacturing, the second-fastest growing industry, expanded less than 5 percent per year. Real value-added declined in seven industries over the decade. As shown formally below, without the computer and electronic products industry, which accounted for just 10 to 13 percent of value-added throughout the decade, manufacturing output growth in the United States was relatively weak.

The rapid growth of real value-added in the computer and electronic products industry, NAICS 334, can be attributed to two subindustries: computer manufacturing, NAICS 334111, and semiconductor

Figure 5.2 Real Value-Added Average Annual Growth Rate, 1997–2007



SOURCE: Authors' tabulations using BEA industry accounts data.

and related device manufacturing, NAICS 334413.[6] The extraordinary real GDP growth in these subindustries, in turn, is a result of the adjustment of price indexes used to deflate computers and semiconductors for improvements in quality. From 1997 to 2011, for example, the BLS producer price indexes have fallen at a compound annual rate of 52 percent for microprocessors, 36 percent for portable computers, and 28 percent for desktop personal computers and workstations.

Contribution of the Computer and Electronic Products Industry to Aggregate Manufacturing Growth

Growth rates for industry subsets may be approximated from published data using a Törnqvist formula. Specifically, the growth rate of real value-added for a subset of industries, expressed as a logarithmic change, is approximately equal to the weighted average of the growth rates of the component industries:

$$(5.1) \quad \ln(Q_t / Q_{t-1}) \approx \sum_i w_{i,t} \ln(q_{i,t} / q_{i,t-1}) ,$$

where $q_{i,t}$ is the published real dollar value-added or (equivalently) quantity index for industry i in year t and w_{it} is the average of industry i's share of nominal manufacturing value-added in adjacent time periods $(t, t-1)$;[7]

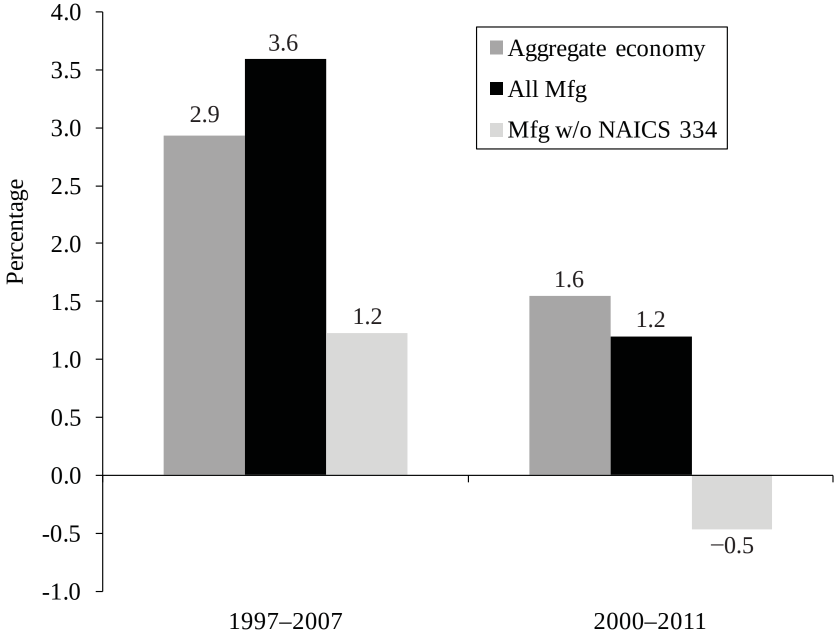
$$\sum_i w_{i,t} = 1.$$

Figure 5.3 shows average annual growth in real GDP for U.S. manufacturing as published and for manufacturing excluding the computer and electronic products industry (NAICS 334) along with aggregate real GDP growth rates from 1997 to 2007 and from 2000 to 2010.[8] Although the computer and electronic products industry only accounted for between 10 and 13 percent of value-added in the U.S. manufacturing sector throughout the period, it has an outsized effect on manufacturing statistics. Without NAICS 334, U.S. manufacturing's real GDP growth was only 1.2 percent per year from 1997 to 2007, a third of the published aggregate manufacturing growth rate, and was much weaker than overall growth in the economy. The manufacturing sector is disproportionately affected by recessions, and so when computed over a more recent period, real GDP growth was somewhat lower in manufacturing than in the aggregate economy. From 2000 (a business cycle peak) to 2011, real GDP grew at an annual rate of 1.3 percent in manufacturing compared to 1.7 percent for the economy overall. Without the computer and electronic products industry, however, real value-added in manufacturing was about 5 percent lower in 2011 than in 2000. The computer and electronic products industry has a similarly large impact on manufacturing productivity statistics. For example, manufacturing's multifactor productivity growth rates between 1997 and 2007 fall by almost half when NAICS 334 is excluded (Houseman et al. 2011).

Contribution of the Computer and Electronic Products Industry to State-Level Manufacturing Growth

The nationwide pattern of strong manufacturing output growth in combination with a large employment decline is also apparent in most states. In the decade leading up to the Great Recession, real manufactur-

Figure 5.3 Average Annual Growth Rate in Real GDP for the Aggregate Economy and for Manufacturing with and without Computer and Electronic Products Manufacturing

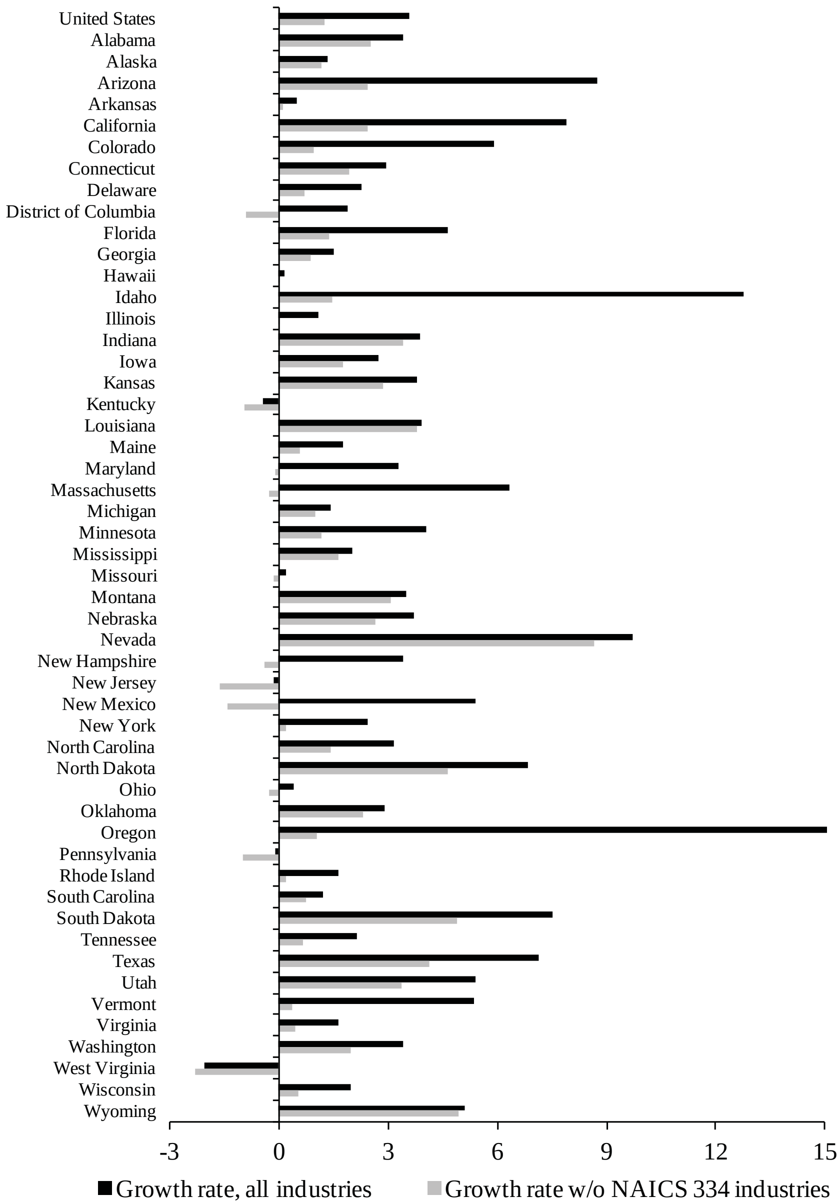


SOURCE: Authors' calculations using BEA industry accounts data.

ing value-added declined in only four states (Pennsylvania, New Jersey, Kentucky, and West Virginia), while the growth rate of real manufacturing value-added exceeded 20 percent in 33 states and real value-added more than doubled in seven (Oregon, Idaho, Nevada, Arizona, California, South Dakota, and Texas). In spite of strong manufacturing output growth, the large majority of states experienced significant employment declines in the sector. Manufacturing employment declined by more than 10 percent in 37 states and the District of Columbia and expanded in just four states over the decade.

Paralleling our analysis of national manufacturing data, we examine the extent to which state-level manufacturing's real GDP growth is attributable to the computer and electronic products manufacturing industry (NAICS 334). Figure 5.4 displays state-level average annual

Figure 5.4 Manufacturing Real Value-Added Growth Rates, 1997–2007 (% annual growth)



SOURCE: Authors' calculations using BEA data.

growth rates of real GDP for all manufacturing and for manufacturing excluding NAICS 334 from 1997 to 2007. The influence of this industry on the manufacturing sector's real value-added growth naturally is greatest in states with relatively high or significantly growing concentrations of computer and electronic products manufacturing.[9] For example, when NAICS 334 is omitted, manufacturing's average annual real GDP growth rate between 1997 and 2007 falls from 8.7 percent to 2.4 percent in Arizona, from 7.9 percent to 2.5 percent in California, from 5.9 percent to 1.0 percent in Colorado, from 12.8 percent to 1.5 percent in Idaho, from 6.3 percent to −0.3 percent in Massachusetts, from 5.4 percent to −1.4 percent in New Mexico, and from 15.1 percent to 1.1 percent in Oregon.

The influence on manufacturing output growth rates is substantial, however, even in states in which computer and electronic products manufacturing has a modest presence. That growth rate falls by more than half in 28 states and the District of Columbia when NAICS 334 is excluded and by at least 25 percent in all but 10 states. And without NAICS 334, real GDP for the rest of manufacturing experienced an absolute decline in 10 states and the District of Columbia in the decade before the Great Recession.

A state's manufacturing output growth often is used to assess the sector's overall health and competitiveness vis-à-vis manufacturing in other states. Although computer and electronic products manufacturing is an important component of manufacturing in some states, we argue below that the extraordinary growth in real value-added and productivity in this industry segment largely reflects product innovations resulting from research and development (R&D), and such innovations may not have occurred in the state, potentially giving a distorted picture of the relative competitiveness of states' manufacturing sectors.

Table 5.1 shows, for selected states, rankings according to manufacturing's real value-added growth from 1997 to 2007, as published, and new rankings based on real value-added growth rates of manufacturing excluding NAICS 334. For 22 states and the District of Columbia, rankings change by at least 10 when growth rates exclude NAICS 334; rankings for five states fell by more than 20. As expected, states with large or growing shares of computer and electronic products manufacturing tend to have the highest manufacturing GDP growth rates and experience the largest decline in ranking when the growth is calculated

Table 5.1 Rankings by Growth Rate in Manufacturing Real Value-Added and Real Value-Added Excluding NAICS 334, 1997–2007, Selected States

	Rank, all mfg.	Rank, mfg. less NAICS 334	Change in rank
New Mexico	11	49	−38
Massachusetts	9	43	−34
Oregon	1	25	−24
New Hampshire	22	45	−23
Vermont	13	35	−22
Idaho	2	20	−18
Colorado	10	27	−17
Maryland	25	41	−16
District of Columbia	35	46	−11
Arizona	4	14	−10
Connecticut	27	17	10
Georgia	39	28	11
Indiana	18	7	11
Iowa	29	18	11
Louisiana	17	6	11
Alabama	24	12	12
Montana	21	9	12
Wyoming	14	2	12
Oklahoma	28	15	13
South Carolina	42	29	13
Michigan	40	26	14
Mississippi	33	19	14
Alaska	41	23	18

SOURCE: Authors' calculations using BEA regional data.

without NAICS 334. Still, the changes are dramatic. Most notable are the drops in the rankings for New Mexico (from 11 to 49) and Massachusetts (from 9 to 43). Oregon, the state with the highest manufacturing GDP growth rate over the period in official statistics, falls to 25 in the new rankings. Correspondingly, 12 states with a relatively small presence of computer manufacturing experience significant improvements under the new ranking. In sum, states with apparently rapidly expanding manufacturing sectors are for the most part simply states with sizable computer and semiconductor industries.

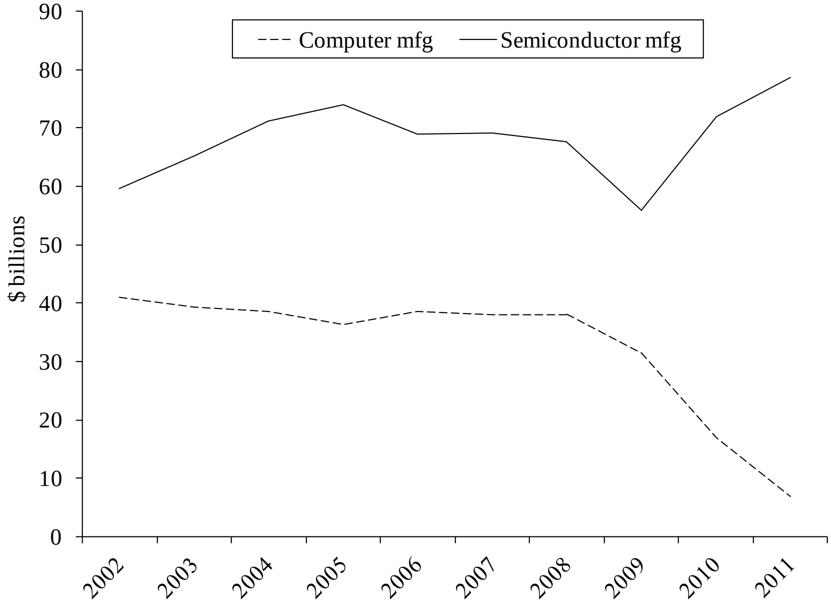
INTERPRETING THE EXTRAORDINARY REAL OUTPUT AND PRODUCTIVITY GROWTH IN THE COMPUTER AND SEMICONDUCTOR INDUSTRIES

So far, we have argued that U.S. manufacturing-sector statistics are often misinterpreted because it is not understood that computer and related industries largely drive the apparent robust growth in real manufacturing GDP and have a large effect on the manufacturing productivity measures. One might suppose, at least for this industry segment, that the strong real output growth indicates the competitiveness of the United States as a location of production and that the sharp drop in employment is a consequence of productivity growth. Both, however, would be a misinterpretation of the numbers.

The Competitiveness of the United States as a Location for Production of Computers and Semiconductors

As noted, the influence of computer and electronic products manufacturing (NAICS 334) on aggregate manufacturing's real GDP growth largely derives from electronic computer manufacturing (NAICS 334111), whose key product segments are personal computers and servers, and from the semiconductor industry (NAICS 334413), which in the United States largely comprises the production of integrated circuits. To put their influence into perspective, we plot data on the (nominal) value of shipments published by the Census Bureau in these two subindustries for the 2002–2011 period in Figure 5.5.[10] Semiconductor shipments were relatively flat until the 2008 recession, declined during the recession, and have expanded significantly since 2009.[11] In contrast, the value of shipments in electronic computer manufacturing was relatively flat until the recession in 2008 and has declined precipitously since. Although these two subindustries accounted for most of the growth in manufacturing real GDP over the period, because of rapidly declining

Figure 5.5 Computer (NAICS 334111) and Semiconductor (NAICS 334413) Shipments, 2002–2011 ($ billions)



SOURCE: U.S. Census Bureau, Annual Survey of Manufactures.

price deflators their share of the manufacturing sector's output did not increase; together, they accounted for only 2 to 3 percent of all manufacturing shipments throughout the period. Real output and productivity statistics are commonly used as indicators of the competitiveness of U.S. industries, but the extraordinary growth of these measures for the computer and semiconductor industries may be a poor indicator of the overall competitiveness of the United States as a location for manufacturing these products.

How competitive is the United States in computer and semiconductor manufacturing? To address this question, we present market research data and analysis on trends in the global location of production of personal computers, computer servers, and semiconductors. We supplement these data with import and export data in these product groups from the UN Comtrade database.

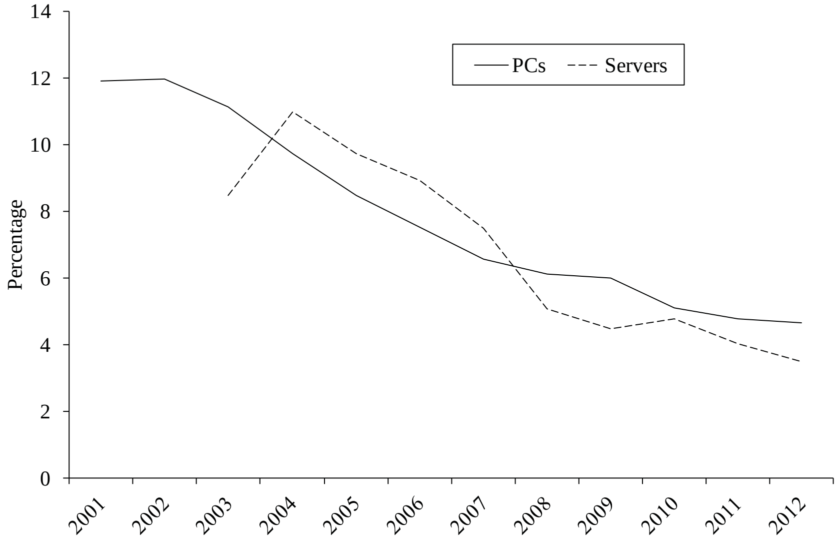
Personal computers and servers

Personal computers (termed "single-user computers" in U.S. statistics) include desktop and portable computer devices, while servers (termed "multiuser computers") provide shared data services. Figure 5.6 displays estimates by the market research firm International Data Corporation (IDC) of the share (in units) of worldwide production of personal computers (PCs) and servers assembled in the United States since the early 2000s. In both product segments, the share assembled in the United States is small and has fallen dramatically over the last decade. In 2001, an estimated 12 percent of personal computers were manufactured in the United States; by 2012 that share had fallen by more than half, to about 5 percent. U.S. assembly is most common with desktop computers; portable computers are almost exclusively manufactured in Asia. The shift in demand away from desktops in favor of portable computers partly explains the decline in U.S. market share. As with PCs, a growing share of servers are manufactured in Asia and Mexico and a declining share in the United States. Large Internet content providers (e.g., Google), retailers (e.g., Amazon), and social media companies (e.g., Facebook) did some assembly in the United States for their own server farms in the early 2000s—explaining the increase in U.S. market share around 2003 in Figure 5.6—but have since discontinued that practice, according to the IDC.

What PC product segments are still assembled in the United States? According to IDC analysts, U.S. assembly is primarily done for government- and education-sector orders that require domestic content. In addition, for PCs, last-minute customized configuration is sometimes carried out domestically for desktop PC units, though several such plants have recently closed (Ladendorf 2012). PC configuration generally entails inserting specific processors, memory, and hard disk drives into mostly built-up machines to meet the requirements of specific orders. Because the manufacturing process requirements are minimal, PC configuration facilities are sometimes referred to as "screwdriver plants" in the industry.

The shift of PC production away from the United States is reflected in trade statistics. The nominal value of U.S. PC exports rose only 3.6 percent on an average annual basis from 2002 to 2012 (from \$1.8 to \$2.6 billion), while world exports rose 18.4 percent annually (from

Figure 5.6 U.S. Share of Personal Computers and Computer Servers Production (in units)



SOURCE: International Data Corporation (IDC).

$28.3 to $153.1 billion), causing the U.S. share of world PC exports to fall from 6.5 percent in 2002 to 1.7 percent in 2012. Most of this growth in world exports has come from China. China's exports rose 42 percent on an average annual basis from 2002 to 2012 (from $3.5 to $117.4 billion), and its share of world exports soared from 12.4 to 76.6 percent. During the same period, PC imports to the United States rose at an average annual rate of 14.7 percent, and as a result, by 2012 the United States ran a trade deficit of $38.3 billion in PCs.

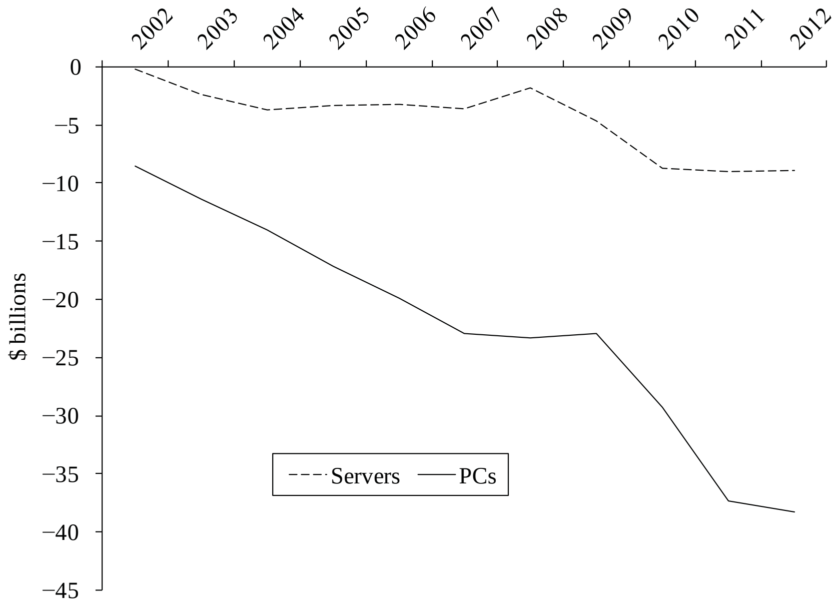
The center of PC production clearly has shifted to China, where PCs (increasingly in notebook format, since that format is cost-effective to ship by air) are assembled in huge numbers, largely by Taiwan-headquartered contract manufacturers such as Quanta and Foxconn for major global brands such as Lenovo, Hewlett-Packard, and Apple. Although U.S.-based PC companies remain important as brand leaders and orchestrators of the global PC value chain, little production occurs within the borders of the United States.[12]

World trade in computer servers displays a similar pattern. In 2005, China surpassed the United States as the world's largest exporter of computer servers. The nominal value of U.S. server exports rose only 4.4 percent on an average annual basis from 2002 to 2012 (from $2.8 to $4.2 billion), while world exports have risen 5.8 percent annually (from $18.3 to $32.1 billion). During the same period, China's exports rose 25 percent per year (from $1.1 to $10.2 billion), and the number-two server exporter, Mexico, increased exports at a rate of 12.4 percent per year (from $1.3 to $4.3 billion). At the same time, huge server farms were being erected in the United States to support the expansion of the Internet, driving import growth at an annual average rate of 16.3 percent per year, from $2.9 billion in 2002 to $13.1 billion in 2012. By 2012, server imports to the United States accounted for 34.9 percent of the world total, far higher than server imports to Japan, the second largest importer, which accounted for only 7.8 percent of total world imports. These figures reflect the continued dominance of the United States as a hub of the global Internet, with imports to the United States rising much faster than worldwide imports (16.3 percent per year for the United States compared to 5.8 percent worldwide). As with PCs, the shift of server manufacturing to outside the United States does not mean that American-branded server companies are losing global market share, only that the United States is losing ground as a location for server manufacturing. As a result, the U.S. trade balance has declined dramatically in the past 10 years in both PCs and servers (see Figure 5.7).

Semiconductors

To gauge the relative position of the United States as a location for semiconductor manufacturing, we acquired annual data on all major semiconductor fabrication plants (called "fabs") worldwide from the market research firm IHS Global Inc. for the period 2000 to 2013. Semiconductor fabs fall into two general categories: 1) integrated device manufacturing (IDM) plants (e.g., Intel and Samsung), which mainly produce semiconductors that are designed and sold by the fab's owner, and 2) "foundries," which produce semiconductors designed by others on a contract basis (the largest are Taiwan Semiconductor Manufacturing Company and United Manufacturing Corporation, both based in Taiwan). Foundries are analogous to the PC contract manufacturers (e.g., Foxconn) mentioned earlier.

Figure 5.7 U.S. Trade Deficit in PCs and Servers, 2002–2012

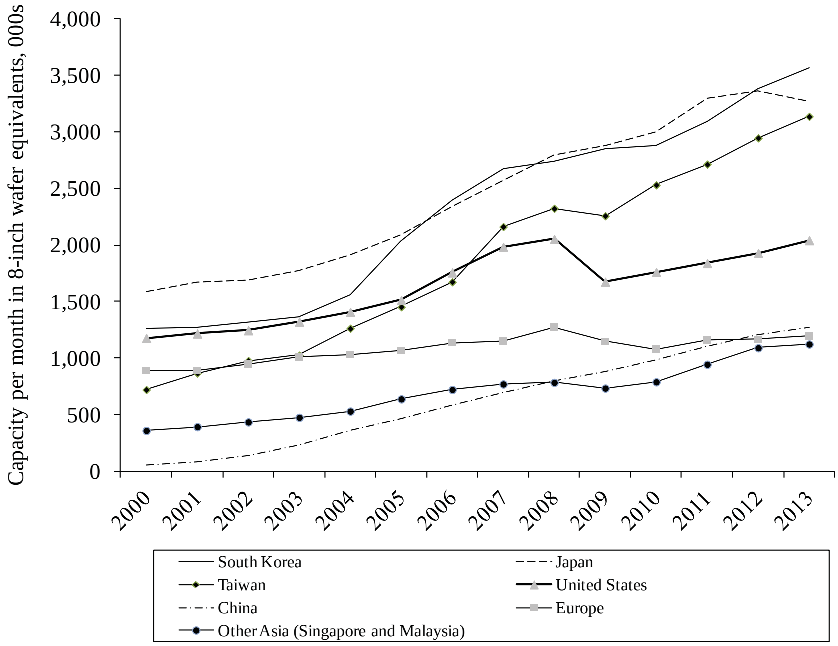


SOURCE: UN Comtrade data.

For IDMs, the data include, among other things, information on plant capacity (normalized to eight-inch wafer size), product type (logic, memory, analog, microcontroller, and discrete), plant location, and the average cost of producing wafers (also normalized to eight-inch equivalence) by product type and level of technology. For foundries, which almost exclusively produce logic chips (programmable, often application-specific [ASIC] microprocessors), the data include the same information, except product type.

Figure 5.8 shows the growth of total semiconductor production capacity by country or region between 2000 and 2013. Strikingly, total capacity has grown at a considerably slower pace in the United States and Europe than in key semiconductor-producing countries in East Asia. Specifically, the compound annual growth rate of total capacity was 4.2 percent in the United States and 2.3 percent in Europe, compared to 8.0 percent in South Korea, 8.7 percent in Singapore and Malaysia, 11.3

Figure 5.8 World Semiconductor Wafer Production Capacity by Country or Region, 2000–2013



percent in Taiwan, and 23.8 percent in China. (Table 5.2 translates Figure 5.8 into numerical values and gives the rankings of the countries.) While China's growth is measured from a low base, its global share of semiconductor capacity nonetheless grew by 7 percentage points, from less than 1 percent in 2000 to 8 percent in 2013. At the same time, the U.S. share of global semiconductor capacity shrank from 19 percent to 13 percent, and Europe's share fell from 14 percent to 7 percent. Most strikingly, Taiwan's share of world semiconductor fabrication capacity increased from 12 percent to 20 percent over the same period, driven mainly by the popularity of the fabless/foundry model, as we will discuss below.

The trends displayed in Figure 5.8 may be misleading because capacity is aggregated across all types of semiconductors, combining products with quite different design parameters, prices, and manufacturing requirements. As Table 5.3 shows, the most expensive and design-intensive semiconductors are digitally programmable devices

Table 5.2 World Semiconductor Wafer Production Capacity by Country or Region, 2000 and 2013

2000			2013			Annual growth for latter country (%)
Country ranking		Wafer units	Country ranking		Wafer units	
1	Japan	1,590,549	1	South Korea	3,570,447	8.0
2	South Korea	1,262,014	2	Japan	3,265,501	5.5
3	United States	1,178,370	3	Taiwan	3,136,841	11.3
4	Europe	889,309	4	United States	2,042,534	4.2
5	Taiwan	722,255	5	China	1,274,393	23.8
6	Other Asia	360,645	6	Europe	1,194,959	2.3
7	China	57,687	7	Other Asia	1,124,601	8.7

NOTE: Units normalized to eight-inch wafer equivalents.
SOURCE: IHS Global Inc.

Table 5.3 Semiconductor Manufacturing Requirements, Design Requirements, and Typical Selling Prices, by Product Type

Product type	Manufacturing requirements	Design requirements	Typical selling prices	Typical use
Logic	High	High	High	Digital processing (programmable devices, such as CPUs and ASICs)
Memory	Very high	Low	Medium to low	Information storage and retrieval
Analog	Low	High	Medium	Analog signal processing (e.g., radio and other "real world" signals)
Microcontrollers	Low	Medium to low	Low	Single-function systems (nonprogrammable, such as engine controls)
Discrete	Very low	Very low	Very low	Single function (transistors, resistors, capacitors, etc.)

SOURCE: Authors' compilation.

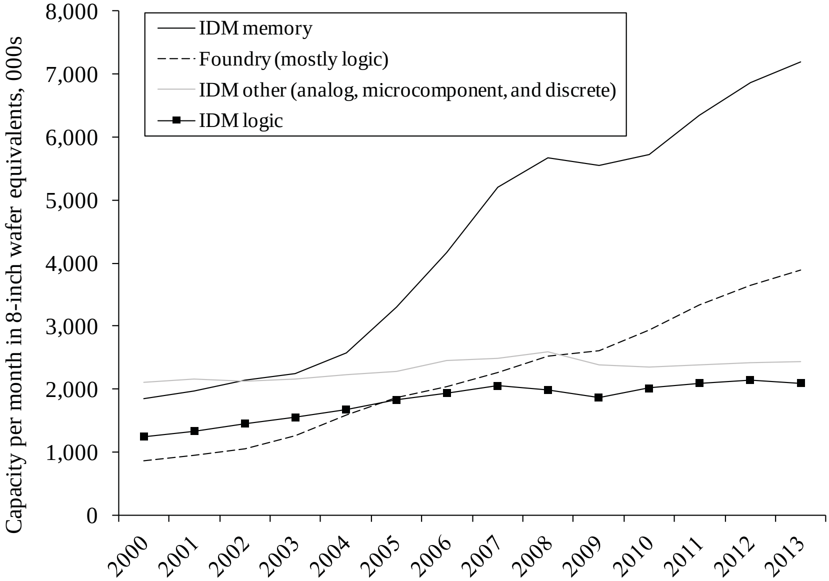
called "logic semiconductors." They include central processing units (CPUs) such as Intel processors, but also a wide variety of application-specific devices that provide functionality for nearly all electronic-based products that can be programmed by users (from mobile-phone handsets to automated factory equipment). While design requirements for logic semiconductors are extremely high because they include millions of microcomponents and multiple technologies in a single chip of silicon, manufacturing requirements, while also high, are not extreme. Computer memory chips, by contrast, contain even greater numbers of microcomponents per area of silicon and are thus extremely demanding to produce, but the circuitry is relatively simple, with information storage grids dominating the design. Other major semiconductors vary in regard to design intensity, but they are generally less demanding to produce and are produced in lower volumes.

Figure 5.9 displays global capacity by product type from 2000 to 2013, along with the U.S. market share by product type in the beginning and at the end of the period. The greatest increase in capacity has occurred in memory chips, which are predominantly produced by IDMs such as Samsung (from Korea). Only one company, Micron Semiconductor, produces memory in the United States. While U.S. memory capacity expanded at a compound annual growth rate of 6 percent, the share fabricated in the United States has declined as production has shifted to Asian countries, notably Taiwan, Japan, South Korea, and China. A large share of analog, microcomponent, and discrete semiconductor products are fabricated in the United States, but these are relatively small segments of the semiconductor market.

Changing patterns in the location of production of logic semiconductors is linked to the rise of the foundry model. So-called fabless semiconductor design companies design and sell logic semiconductors, which are associated with high manufacturing and design requirements as well as high profit margins, and contract out production to foundries. Many dominant fabless design companies, such as Qualcom and Broadcom, are located in the United States, while foundries are concentrated in Taiwan and Singapore. In 2000, 41 percent of the capacity to produce logic semiconductors was in foundries, but by 2013 foundries accounted for 65 percent of logic capacity.

The United States accounted for only 3.1 percent of world foundry capacity in 2013, down from 4.6 percent in 2000 (Table 5.4). Manufac-

Figure 5.9 Global Semiconductor Capacity, by Product Type, 2000–2013



turing of logic semiconductors in the United States is concentrated in the domestic plants of highly successful IDMs, such as Intel and Texas Instruments.[13] While the share of IDM logic semiconductor capacity in the United States has expanded since 2000, the U.S. share of total world logic semiconductor capacity has fallen, from 12.8 percent in 2000 to 9.9 percent in 2013—again, mainly because of the rise of the fabless/foundry model. In sum, a more detailed analysis does not alter the gen-

Table 5.4 U.S. Global Capacity Share by Product Type, 2000 and 2013 (%)

U.S. global capacity share by product type and business model	2000	2013
IDM logic	18.4	22.5
IDM memory	15.5	8.9
IDM other (analog, microcomponent, and discrete)	29.3	33.2
Foundry (mostly logic)	4.6	3.1
IDM logic and foundry, combined	12.8	9.9

SOURCE: IHS Global Inc.

eral picture of decline in the importance of the United States as a location for semiconductor manufacturing, depicted in Figure 5.8.

As with computers, this decline is reflected in trade statistics. Semiconductor exports, in nominal dollars, from the United States (of all types) fell at an average rate of 2.5 percent per year from 2002 to 2012 (from $26.3 billion to $20.5 billion), while worldwide exports increased at a rate of 8.7 percent per year (from $161.9 billion to $371.1 billion). As a result, the U.S. share of world semiconductor exports fell from 16.3 percent in 2002 to just 5.5 percent in 2012. This pattern is similar to export trends in PCs and computer servers.

However, changes in world semiconductor imports show a different pattern. Instead of rising imports, as shown for the United States in PCs and servers, semiconductor imports were stagnant, increasing at an average annual rate of less than 1 percent from 2002 to 2012. Since semiconductors are only of use as components in larger systems, imports have mainly risen for the major producers of PCs, servers, and other electronics-based products. China's semiconductor imports, not surprisingly, grew the most rapidly from 2002 to 2012, at an average annual rate of 21.3 percent, and China's share of total world imports grew from 15.3 percent to 41.6 percent. During this same period, the U.S. share of world semiconductor imports shrank from 8.4 percent to 3.6 percent, reflecting the general decline of the United States as a location for final goods manufacturing in electronics.

The location of production of computer and semiconductor manufacturing has clearly shifted away from the United States toward Asian countries, both overall and within the most important and technologically demanding product types (from a manufacturing perspective). Again, this does not necessarily imply that the U.S.-based computer and semiconductor industries, broadly defined to include research and design functions, have lost global competitiveness. U.S. companies continue to drive innovation and growth in the ITC industry, pioneering and dominating new industry segments such as Internet search and retailing, social media, and cloud computing. However, these software-based systems now run, in large part, on hardware manufactured outside the United States. In semiconductors, the addition of new and acquired U.S. IDM fabs outside the country and the rise of the foundry/fabless design business model have enabled U.S. semiconductor companies to continue to design chips in the United States while shifting production overseas (Brown and Linden 2011). The shift of manufacturing to Asia, however, has important implications for the number and types of jobs located in the United States.

In sum, despite the extraordinary real output growth in the U.S. computer and semiconductor manufacturing industries, as measured in official statistics, the competitiveness of the United States as a manufacturing location for these products has substantially eroded. Exactly how, over the longer term, the shift in the locus of production to Asia will affect research and development activities in the United States remains to be seen.

Interpreting Productivity Growth

The rapid growth in real output, coupled with a sharp drop in employment—39 percent since 1997 compared to 30 percent for all manufacturing—has led to surging labor productivity in the computer and electronic products industry. Analysts often interpret productivity growth to mean that workers are working faster or that automation (the substitution of capital for labor) is driving the growth, as illustrated in a recent White House report on manufacturing, which stated, "Manufacturing workers have paradoxically often been the victims of their sector's own success, as rapid productivity growth has meant that goods can be produced with fewer workers" (Executive Office of the President 2009).

Productivity growth in computer-related industries, however, is largely attributable to rapidly falling price deflators that aim to capture consumer valuation of improvements in product quality. These improvements, we argue, primarily reflect innovations from research and development and innovations in the production processes. While, for example, the typical computer produced in the United States today may in some statistical sense be the equivalent of several computers produced a decade ago, that does not, in and of itself, mean that fewer workers are needed to manufacture a computer today than in the past. For an industry where full automation has reigned for many decades, the notion of capital substituting for labor appears quaint. Indeed, a recent report by the McKinsey Global Institute concluded that all of the large-scale net job losses in U.S. computer and electronic products manufacturing are attributable to the offshoring of production (Roxburgh et al. 2012).

IMPLICATIONS FOR RESEARCH

The outsized effect that the computer and electronic products industry has on real output and productivity measures holds important implications for empirical research. While computer-related industries show extraordinary real GDP growth owing to price deflators that account for improvements in product quality, they registered above-average employment declines and import penetration. Such an outlier may distort relationships between economic variables, result in anomalous findings, and lead researchers to draw incorrect inferences—for example, about the causes of the sharp decline in manufacturing employment or the effects of imports on domestic industry.

In addition to the large effect that computer-related industries have on measured aggregate and state-level manufacturing's real value-added growth, the sizable growth of imported intermediates used in manufacturing has likely imparted a significant bias to real value-added in the published statistics for all manufacturing industries. The BEA estimates that the import share of materials intermediates used in manufacturing rose from 18 percent in 1997 to 25 percent in 2007. Moreover, most of the growth in imported intermediates came from developing countries, most notably China, whose market share increased largely because suppliers from these countries offered lower (quality-adjusted) prices for these intermediate inputs. So-called offshoring bias arises because the price declines associated with the shift in sourcing to low-cost countries are unlikely to be captured in the import and producer price indexes constructed by the Bureau of Labor Statistics and used by the Bureau of Economic Analysis to deflate intermediate inputs in the industry accounts data. As a result, official statistics may substantially understate the quantity of inputs used by U.S. manufacturers and overstate the growth in manufacturing's real valued-added (Houseman et al. 2011).

Although growth in a state's real manufacturing GDP should be a good predictor of a state's manufacturing employment growth, computer-related industries and offshoring bias may substantially weaken the relationship between measured output and employment in manufacturing.[14] Consequently, we expect that a state's real value-added growth in manufacturing, adjusted for the contribution from computer-related industries and for offshoring bias, will be a better predictor of the state's employment growth than published real value-added growth measures.

Here we test that proposition by regressing a state's manufacturing employment growth over the 1997–2007 period on real value-added growth over the same period, measured three ways: first as the published aggregate manufacturing measure, next as the published measure excluding NAICS 334, and finally as a measure that both excludes NAICS 334 and adjusts for offshoring bias.[15]

$$\text{(5.2)} \qquad \ln(E_{s,07} / E_{s,97}) = \alpha + \beta \ln(Q_{s,07} / Q_{s,97}) + \varepsilon_s$$

Ordinary least squares estimates of Equation (5.2) may be subject to simultaneity bias because employment and output growth in a state's manufacturing industry are determined by both demand- and supply-side forces: while overall national demand conditions for an industry's product affect state-level industry demand for labor, a state's supply of workers may affect industry growth in that particular state. For example, industries may expand relatively more in states with higher population growth and hence growth in their supply of labor. In addition, state-level labor productivity shocks may expand output while reducing employment to output ratios. In other words, the ordinary least squares estimates of Equation (5.2) do not correspond to any well-defined structural relationship.

To address possible simultaneity bias and to focus on how demand forces at the national level affect state labor markets, we instrument state-level manufacturing's real GDP growth rates using national industry-level growth rates: the instrument is a weighted average of the national industry-level growth rates, where the weights are the state's nominal shares of value-added in the component industries.[16] This instrument proxies for what would happen to state-level demand for manufacturing output if each of a state's manufacturing industries were to maintain its current competitiveness and hence its market share of national demand. With this instrument, Equation (5.2) estimates a structural relationship showing the effects of national demand shocks to products produced in a state's manufacturing sector on that state's manufacturing employment.

Table 5.5 presents ordinary least squares and two-stage least squares estimates of Equation (5.2). The first two columns of Table 5.5 are based on observations from all 50 states and the District of Columbia. Strikingly, the coefficient estimate on the output growth term more than doubles, from 0.23 to 0.56, in the OLS model when NAICS 334 is omitted from the growth measure. State-level employment growth is much more strongly related to output growth when we omit the information from this industry.

Table 5.5 The Effect of Manufacturing Output Growth on Employment Growth, 1997–2007

	(1) OLS	(2) 2SLS	(3) OLS	(4) 2SLS
Growth in mfg. real value-added	0.227	0.057	0.228	0.084
	(0.066)	(0.106)	(0.050)	(0.080)
Constant	−28.041	−21.907	−27.588	−22.146
	(3.231)	(4.473)	(2.478)	(3.512)
Growth in mfg. real value-added w/o computers	0.560	1.067	0.504	0.692
	(0.095)	(0.741)	(0.069)	(0.338)
Constant	−26.493	−33.353	−25.196	−27.900
	(2.271)	(10.312)	(1.692)	(5.061)
Growth in mfg. real value-added w/o computers, adjusting for offshoring bias	0.559	0.990	0.502	0.700
	(0.095)	(0.621)	(0.068)	(0.299)
Constant	−24.518	−28.839	−23.372	−25.499
	(2.093)	(6.619)	(1.548)	(3.534)
N	51	51	48	48

NOTE: Each panel represents the regression of state employment growth on output growth for the period 1997−2007. Standard errors of the coefficient estimates are reported in parentheses. A weighted average of national-level industry real value-added growth is used as an instrument for state growth measures in the two-stage least squares models. See text for further discussion.

In the 2SLS models reported in column 2, the coefficient on the aggregate manufacturing growth term is 0.06, whereas the coefficient on the manufacturing growth measure that excludes computer-related industries is 1.07. A coefficient estimate of approximately 1 implies that a 1 percent increase in a state's output results in a 1 percent increase in employment, which is a reasonable estimate of the effect of a demand shock. In contrast, the coefficient close to zero on aggregate manufacturing growth implies that demand shocks to a state's industries have little effect on state employment growth, a finding that makes little sense and suggests problems in using the aggregate manufacturing data.

The output measure in the bottom panel of Table 5.5 excludes NAICS 334 and adjusts for offshoring bias. This last output measure is subject to important caveats. As discussed in the appendix, estimates of offshoring bias in real GDP measures of state manufacturing likely significantly understate true variation across states in offshoring bias. Given this fact, it is perhaps not surprising that also adjusting for offshoring bias has little effect on the point estimates. Nevertheless, it does substantially reduce the standard error of the estimate in the 2SLS model: the coefficient estimate of 0.99 in the third panel of column 2 has a *p*-value of 0.12.

In the models reported in columns 3 and 4 of Table 5.5, we omit observations from the District of Columbia, Hawaii, and Alaska, which have the smallest manufacturing sectors and which differ from other states in geographic proximity or size. The patterns of the coefficient estimates are similar to those reported in columns 1 and 2, but excluding these very small states substantially improves the precision of the estimates, particularly in the 2SLS models. In the models that instrument for state output growth, the coefficient on manufacturing real value-added growth is 0.08 and insignificant. The coefficients on the growth measures that either exclude NAICS 334 or exclude NAICS 334 and correct for offshoring bias are 0.69 and 0.70, respectively, and both are significant at conventional levels (*p*-values 0.05 and 0.02).[17]

Although, using state-level data, the results from these regressions show that the computer and electronic products industry breaks the empirical link between real output and employment growth in the manufacturing sector, this analysis does not provide insights into the reasons underlying the sharp trend of decline in U.S. manufacturing employment since 2000. It does, however, underscore the point that the strong output and productivity growth in the aggregate manufacturing statistics is not evidence, in and of itself, that automation caused the decline, as many researchers and analysts have concluded.[18]

The dominance of the computer-related industries in measured real output growth in manufacturing may lead to other perverse research findings, as illustrated in Acemoglu et al. (2014, Appendix Table 2). In an analysis of the effect of import penetration on domestic shipments in manufacturing industries, the study's authors find that an increase in import penetration significantly lowers nominal shipments but has no effect on real shipments in the affected industry. The naïve researcher would conclude, therefore, that imports have had no adverse impact on the quantity of goods manufactured in the United States. This finding, however, is driven by computer-related industries, which are outliers—simultaneously experiencing extraordinary real output growth and high growth in import penetration. Acemoglu et al. show that the coefficient on the import penetration term is negative and significant when computer-related industries are excluded from the regression.

RECOMMENDATIONS FOR STATISTICAL AGENCIES

Statistics play a critical role in informing policymakers and shaping their responses to economic issues. The recent debate over manufacturing policy in the United States, however, illustrates how the numbers can obfuscate as much as enlighten. More transparency in the publication of the data—in particular, making clear to data users the influence the computer and semiconductor industries have on the aggregate manufacturing numbers—could have avoided much of the confusion. The extraordinary growth of real value-added and productivity in the computer and semiconductor industries also naturally raises the question: Are these numbers right? The outsized effect that this small industry has on aggregate statistics is reason for further scrutiny of the data. In addition, the growth of globalization, accompanied by rapid shifts in the location of production, underscores the inadequacy of current price indexes to capture price changes associated with changes in sourcing. In this closing section, we recommend steps the statistical agencies can take to improve communication with data users and highlight several areas for further research.

Improve Transparency and Communication with Data Users

Many influential economists and policy analysts have cited the robust growth in U.S. manufacturing's real value-added and productivity as evidence of the sector's strength (Atkinson et al. 2012). It is unlikely that most citing those statistics understand that one small industry segment largely accounts for the sector's growth, that the output and productivity growth in the computer industry primarily derives from product innovation, or that the manufacturing presence of these industries in the United States appears to be declining. Making these facts more transparent to data users is important. The statistical agencies could easily highlight the influence of computer-related industries by publishing separate tabulations for real value-added in manufacturing excluding these industries. The statistical agencies also should disseminate information to users clarifying how price deflators affect the industry's measured output growth and what the output growth measures mean. Ideally, the statistical agencies would develop better measures of the global competitiveness of domestic industries by generating and publishing systematic comparisons of U.S. manufacturing industries with industries elsewhere in the world.

State policymakers are among the many users who would benefit from more transparent manufacturing data. In seeking to understand how national manufacturing trends might be affecting their state labor markets, state policymakers will not learn much from a naïve use of the official statistics. Adjusting statistics to exclude computer-related industries and to correct for import price biases will result in data that are more sensible and useful for understanding trends in state labor markets.

A proposed change to the industry classification system would put so-called factoryless goods producers (FGPs)—organizations that design and sell products but contract out their production—in the manufacturing sector.[19] Currently, such organizations usually are classified in wholesale trade or research. The proposed change—originally intended to take effect in 2017 but indefinitely postponed—is expected to significantly increase measured manufacturing output in a number of industries, including computers and semiconductors. While their classification in manufacturing has merit, the activities in FGPs (such as fabless semiconductor design firms and computer firms that use contract manufacturers in China) are a far cry from the factories of old. At the very least, extensive education of data users about any change and the publication of separate tabulations on FGPs within manufacturing would be critical to avoid even further misinterpretation of the manufacturing statistics.

Research on Price Deflators

The price deflators for a small number of products within the computer and electronic products industry fundamentally drive growth in the manufacturing sector and have a large influence on aggregate GDP growth as well. Those price deflators, however, are potentially sensitive to methods used to adjust for quality improvements. Existing price indexes for computers and related electronic products, for example, implicitly assume that consumers and businesses derive value solely from the hardware embedded in these products. In practice, however, consumers benefit from the interaction of the hardware with software and from networking with other computer users via the Internet. In the presence of network externalities, the welfare implications for an individual consumer of some change in computer-related hardware characteristics and prices depend upon the hardware and software used by others. When some users upgrade their computers, it may force others to upgrade theirs in order to maintain the same level of interaction. These negative externalities must be taken into account in order to capture real output measures that correspond to changes in consumer well-being. However, current price index procedures do not take these externalities into account. A version of this problem was explored in Ellison and Fudenberg's (2000) article on excessive upgrades in the software industry.[20]

Future research should address this and other critiques that current methodology may significantly overstate the true benefits to consumers and businesses from technological advances in computer and related hardware.

Crediting Gains from R&D

Rapid advances in research and product development in the computer and electronic products industry have resulted in rapid declines in measured quality-adjusted product prices, which in turn have driven rapid measured output and productivity growth in manufacturing. Conversely, recent plant closures and associated downward revisions to shipments in the computer industry have contributed to a substantial downward revision in real GDP growth in manufacturing.[21] And if offshoring of computer and semiconductor production continues, it likely will significantly dampen measured value-added and productivity growth in manufacturing in the future.

But one might ask whether the true economic impact of increased or decreased production in this industry is commensurate with its impact on the manufacturing statistics? Should, for example, the effect on real output and productivity growth in U.S. manufacturing from the closure of a computer assembly plant be an order of magnitude greater than the closure of a similarly sized auto assembly plant, particularly if research and development for the former still takes place in the United States?

Crediting the output and productivity growth from product improvements to production would matter little if firms were vertically integrated—performing tasks from product design to the manufacturing of the products—and if these tasks were all performed in one firm in one country. As the computer and electronic products industry illustrates, however, the United States increasingly is moving away from making things and instead specializing in services and product design (Corrado and Hulten 2010). Research should address distortions to statistics arising from the fact that gains from technical advances are being credited solely to the manufacture of physical products.

Research on Price Index Construction

Finally, research indicates that the rapid shift in sourcing of products to low-cost foreign suppliers is imparting a significant bias to real value-added and productivity statistics in the computer and electronic products industry and in manufacturing overall. The bias is part of a more general problem in the construction of price indexes: the way they are constructed implicitly assumes that the “law of one price” holds, and thus that observed price differences across suppliers reflect differences in the quality of their goods. The entry and market expansion of low-cost suppliers, however, is an important part of the ongoing dynamics in prices facing consumers and businesses. The input price index proposed by Alterman (this volume), which would be based on a survey of input purchasers, represents a first step toward addressing this important gap in price measurement. Research is needed to pilot the index and determine its feasibility.

Notes

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1. McCormack (2013) reports on the status of congressional action on manufacturing policies.
2. Throughout this chapter, we use the terms "real value-added" and "real GDP" interchangeably. Although nominal value-added in manufacturing has declined as a share of GDP in the United States, this decline may be attributed to the fact that prices have risen less quickly for manufactured products than for services.
3. See, for example, Becker (2012), Hassett (2010), and Perry (2012). Atkinson et al. (2012, pp. 24–25) includes citations to many other prominent analysts and policymakers promoting this view.
4. Houseman et al. (2011) originally made this point. Atkinson et al. (2012) also emphasized this fact.
5. NAICS 334 also includes the manufacture of audio and video equipment; navigational, measuring, electromedical, and control instruments; and magnetic and optical media.
6. This information was provided to us by Erich Strassner at the Bureau of Economic Analysis. Detailed industry value-added data are not published by the BEA, and consequently the analysis presented below is based on data aggregated to the three-digit NAICS level.
7. Atkinson et al. (2012, Figure 30) present similar calculations. In the late 1990s, the Bureau of Economic Analysis along with the other U.S. statistical agencies introduced the use of chained aggregates. Although the BEA publishes value-added in "real chained dollars" for all individual manufacturing industries, these industry-level real chained dollars cannot be summed to create a real series for subsets of industries. The BEA publishes annual figures on industry contributions to aggregate real GDP growth.

8. Because of revisions to the data, the compound annual growth rates for the 1997–2007 period reported in Figure 5.3 differ somewhat from those reported in Houseman et al. (2011). The BEA issued additional revisions to the national industry accounts data in January 2014 but had not updated state data at the time of this writing. The analyses in this chapter are based on national and state manufacturing data available as of December 2013. Recent updates to the national manufacturing statistics do not affect the substantive findings of this chapter.
9. The share of manufacturing value-added in NAICS 334 exceeded 20 percent in 1997 in 10 states: Arizona (50%), California (30%), Colorado (28%), Idaho (29%), Massachusetts (28%), New Hampshire (43%), New Mexico (81%), Oregon (44%), South Dakota (22%), and Vermont (27%).
10. At the time of this writing, 2011 is the last year for which shipments data are available. Data on industry value-added are not published at the six-digit NAICS level.
11. It is possible that the semiconductor industry includes some fabless (that is, without fabrication plants) entities, which design integrated circuits but contract out production, typically to overseas foundries.
12. According to Gartner, U.S. PC brands Hewlett-Packard and Dell ranked number two and number three in unit sales worldwide in the third quarter of 2013, with market shares of 17.1 percent and 11.6 percent, behind China's Lenovo, which held a 17.6 percent market share. See http://www.gartner.com/newsroom/id/2604616. Although little computer assembly takes place in the United States, the United States remains an important location for PC design. Even Lenovo, the Chinese company that purchased IBM's PC division in 2005, maintains a large design center in North Carolina.
13. According to IHS Global Inc., five of Intel's nine logic fabs are located in the United States, along with two in Ireland, one in Israel, and one in China. Four of Texas Instruments' five logic fabs are in the United States, with the additional fab in Japan. Besides these logic fabs, Intel has seven fabs producing microcomponents, all in the United States, and Texas Instruments has 14 smaller fabs producing analog semiconductors, half of which are in the United States.
14. This is particularly true if a state's real output growth results from increased demand for a state's products, rather than from state-level productivity shocks, as we would expect demand would have only modest effects on productivity.
15. In the second and third measures, we exclude employment in NAICS 334 from the manufacturing employment measure, but doing so has little effect on our estimates. The appendix to this chapter provides details on our adjustment of state manufacturing's real GDP growth for offshoring bias, which is based on estimates in Houseman et al. (2011).
16. Specifically, we generate a new annual quantity index series for each state so that the rate of real value-added change between years for the state s is $\ln(q_{s,t} / q_{s,t-1}) = \sum_t w_{i,s,t} \ln(q_{i,US,t} / q_{i,US,t-1})$, where the weight for industry i is the average of industry i's nominal share of value-added in years t and $t-1$. See Bartik (1991) for further discussion of the instrument.

17. These coefficient estimates of about 0.7—though not significantly different from 1—imply that long-run demand shocks to a state's industries may boost labor productivity somewhat. Such a boost to labor productivity could occur if healthy demand conditions allow greater investment and hence increased use of newer technologies and vintage capital. Healthy demand conditions also may permit greater exploitation of scale economies. However, because technology innovations can be shared nationwide, these productivity effects should be limited, and indeed, point estimates of 0.7 indicate that output demand shocks do considerably boost state labor demand. In contrast, the point estimate of 0.08 on the aggregate manufacturing growth term reported in column 4, panel 1, implies that almost all of a demand shock to state output growth is manifested in productivity growth rather than in employment growth, which is hard to believe.
18. Autor, Dorn, and Hanson (2013) and Acemoglu et al. (2014) provide the most rigorous analysis to date of the causes of the recent decline in manufacturing employment and its associated impacts on regional employment and labor force participation. They find strong evidence that the growth of imports from China caused a substantial share—potentially most—of the large decline in manufacturing employment in the years leading up to the Great Recession.
19. Three chapters in the second conference volume—those by Doherty; Kamal, Moulton, and Ribarsky; and Bayard, Byrne, and Smith—provide extensive analyses of the proposed change in classification of factoryless goods producers.
20. Feenstra and Knittel (2004) consider a related problem: that individuals purchase computer hardware beyond its current usefulness because they anticipate future changes in software that will make it necessary to have better computer hardware. As a result, short-run changes in consumer well-being are overstated by the measured decline in computer hardware prices for constant-quality models.
21. For a discussion of the revision, see Mandel (2012).

Appendix 5A

Biases to Real Growth from Offshoring Background on Offshoring Bias

The potential bias from the shift in sourcing to a low-cost foreign supplier occurs because of the methodologies the BLS uses in constructing its price indexes. The BLS samples the prices paid by importers for the import price index and the prices received by producers for the producer price index. Each observation used in the construction of a particular price index represents the period-to-period price change of an item as defined by very specific attributes and reported by a specific importer or domestic producer. These price changes will not necessarily capture price changes purchasers experience when they shift from one supplier to another.

Consider the case where a low-cost foreign supplier enters the U.S. market and captures market share from high-cost domestic suppliers of intermediates used by U.S. manufacturers. Hypothetically, the price drops that U.S. manufacturers realize when they shift to the foreign supplier could be fully captured in the import and input price indexes if three conditions hold: 1) the foreign supplier initially offers the same (quality-adjusted) price as the domestic suppliers; 2) markets instantaneously clear, and thus any expansion of the foreign supplier's market share reflects contemporaneous price declines relative to the domestic supplier that occur *after* entry; and 3) the new foreign supplier is picked up in the import price sample prior to any decline in its relative price. In practice, however, these conditions are likely to be violated: The lag between the time when a new supplier enters the market and its products are integrated into the BLS price sample can be considerable; new suppliers often enter the market with a lower price than incumbent suppliers, and because of information and other adjustment costs that decline over time, businesses may not immediately switch to the low-cost supplier, and thus price differentials between low- and high-cost suppliers may persist (see, for example, Griliches and Cockburn [1994]; Foster, Haltiwanger, and Syverson [2008]; Byrne, Kovak, and Michaels [2013]; and Kovak and Michaels [Chapter 3, this volume]). Diewert and Nakamura (2009) formally show that the bias to the input price index from shifts in sourcing, which is analogous to outlet substitution bias in the Consumer Price Index, is proportional to the growth in the low-cost supplier's market share and to the percentage discount offered by the low-cost supplier.[1]

In the case of shifts in sourcing from high-cost domestic to low-cost foreign suppliers, import and intermediate input price deflators—which are weighted averages of the domestic and import price indexes—are upwardly biased. This, in turn, results in an underestimation of the real growth in imports and an overestimation of the growth in real value-added produced domestically (Diewert and Nakamura 2009; Houseman et al. 2010, 2011; Mandel 2007; Nakamura et al., this volume; Reinsdorf and Yuskavage 2009).

Biases to the input price index may occur whenever a producer shifts from a high-cost to a low-cost supplier, irrespective of whether the low-cost supplier is domestic or foreign. However, the rapid growth of imported intermediates from emerging economies raises concerns that biases in the data from offshoring have been empirically important. Houseman et al. (2010, 2011) estimate the size of the potential bias to the growth of real value-added and multifactor productivity in U.S. manufacturing from the growth in imported materials intermediates over the 1997–2007 time period. Because the size of the price decline associated with the offshoring of an intermediate good to a low-cost foreign supplier is not observed, it is necessary to make some assumptions about the size of the discount. Houseman et al. compute offshoring bias at the three-digit NAICS level under a variety of assumptions about the size of the price differentials, drawing on information from case studies and micro import price data collected by the BLS.

In addition, U.S. statistical agencies do not track the destination of imports and consequently do not know which industries use imported intermediates. In generating the industry-level data used in Houseman et al. (2010, 2011), the BEA assumes that all industries use imported inputs in proportion to their overall use of the input in the economy. For example, if an industry accounts for 20 percent of the use of an intermediate product economy-wide, then, under the so-called import proportionality assumption, it is assumed the industry uses 20 percent of the imports of this intermediate product. While certain inputs are specific to an industry, often products are inputs to a wide variety of industries. If manufacturers more intensively (less intensively) engage in offshoring than businesses in other sectors, the estimates in Houseman et al. will understate (overstate) the degree of offshoring bias in manufacturing. Similarly, within manufacturing there may be considerable variation in the intensity with which industries offshore specific intermediate inputs; the import comparability assumption will dampen any differences in estimates of offshoring bias among manufacturing industries.

Houseman et al. (2010, 2011) estimate that the substitution of imported for domestic material inputs used by U.S. manufacturers resulted in an overstatement of the annual growth in real value-added by between 0.2 and 0.5 percentage points per year from 1997 to 2007. Estimates of the bias to real value-added growth from the offshoring of material intermediates were the largest in the computer and electronic products industry—ranging from 0.5 to

1.4 percentage points per year—although because the average annual growth rate in NAICS 334 exceeded 20 percent, adjusting for the bias lowers that growth by only 4 to 7 percent. For manufacturing excluding NAICS 334, Houseman et al. estimate that the growth in real value-added was upwardly biased by 0.2 to 0.4 percentage points per year, implying that real value-added growth was upwardly biased by as much as 50 percent over the period in the rest of manufacturing.

Estimates of the bias from materials offshoring to multifactor productivity ranged from about 0.1 to 0.2 percentage points per year for all manufacturing and from about 0.2 to 0.4 percentage points per year for the computer and electronic products industry.

Offshoring Bias in State Manufacturing Real GDP

The adjustments to state manufacturing real GDP growth for offshoring bias, which are used in the regressions reported in Table 5.5, are based on estimates generated in Houseman et al. (2010). A couple of caveats should be made about these state-level adjustments. First, and perhaps most importantly, as noted above, imports are imputed to industries using the import proportionality assumption, and thus differences across states in their industry mix generate cross-state differences in our estimates of biases to real value-added growth from offshoring. Because the import proportionality assumption minimizes measured variation in import use across industries, it also minimizes measured cross-state variation in offshoring bias.

In addition, the BEA has revised the manufacturing GDP numbers since the estimates in Houseman et al. (2010) were generated. We use the revised manufacturing real GDP figures and assume that the bias from offshoring affects measured growth rate in the same proportion as estimated in that paper:

$$\text{(5A.1)} \qquad \frac{AdjQ_{i,s,t}}{Q_{i,s,t}} = \left[\frac{1 + r_{a,i}}{1 + r_{m,i}}\right]^t .$$

The left-hand expression is the ratio of adjusted to unadjusted manufacturing real value-added in industry *i*, state *s*, and year *t*; r_{ai} is the growth rate in industry *i* adjusted for offshoring bias; r_{mi} is the measured or baseline growth rate of real value-added in industry *i* as estimated in Houseman et al. (2010); and *t* is an index for year, 1997 = 0.[2]

We estimate the effect of offshoring bias on state manufacturing growth rates under two assumptions about the quality-adjusted price differences of products between developing countries (e.g., China) and the United States and the quality-adjusted price differences between countries with an intermediate level of development (e.g., Mexico) and the United States: 1) the developing country discount is 30 percent, and the intermediate country discount is 15 percent; and 2) the developing country discount is 50 percent, and the intermediate country discount is 30 percent. These two assumptions yield estimates of offshoring bias on the low and high end of those presented in Houseman et al. (2010) (see Table 5A.1).

Compared to real value-added growth measures that exclude NAICS 334, measures that also adjust for biases to the input price index from the growth of imported material intermediates result in an additional downward adjustment of 0.1–0.7 percentage points. The largest adjustments occur in Michigan (a 0.3–0.7 percentage-point reduction), followed by Kentucky (a 0.3–0.5 percentage-point reduction) and Ohio and Indiana (a 0.2–0.5 percentage-point reduction). Our estimates of the bias for another 20 states fall in the 0.2–0.4 percentage-point range. As previously noted, however, the import comparability assumption used to allocate imports to user industries tends to minimize cross-state differences in offshoring bias and consequently may introduce considerable error into these estimates.

The state manufacturing real GDP figures utilized in the regressions reported in Table 5.5 assume a price discount of 50 percent with developing countries and 30 percent with intermediate countries. Corrections based on these assumptions performed somewhat better in regressions than those based on smaller discount assumptions.

Appendix Notes

1. Outlet substitution bias is an example of a shift in sourcing from high- to low-cost domestic suppliers. Diewert and Nakamura (2009) show that the characterization of the bias to the input price index that results when producers shift sourcing of intermediates is identical to the characterization of the bias to the CPI from outlet substitution.
2. We do not have access to the detailed data on imported and domestic intermediate inputs needed to generate entirely new estimates. The growth rate r_m for industry i corresponds to column 2, and the rate r_a for industry i corresponds to those in columns 10 or 11 of Table 9 of Houseman et al. (2010). Houseman et al. detail the classification of countries as developing, intermediate, or advanced, as well as the evidence on price discounts.

Table 5A.1 Average Annual Growth of Real Value-Added in Manufacturing, Adjusted for Computer and Electronic Products Manufacturing and Offshoring Bias, by State, 1997–2007 (%)

	All manufacturing	Mfg. less NAICS 334	Mfg. less NAICS 334, adj. for offshoring bias, 15/30[a]	Mfg. less NAICS 334, adj. for offshoring bias, 30/50[a]
Alabama	3.4	2.5	2.3	2.1
Alaska	1.3	1.2	1.1	1.0
Arizona	8.7	2.4	2.2	2.0
Arkansas	0.5	0.1	−0.1	−0.3
California	7.9	2.5	2.3	2.1
Colorado	5.9	1.0	0.8	0.7
Connecticut	2.9	1.9	1.8	1.6
Delaware	2.2	0.7	0.6	0.4
District of Columbia	1.9	−0.9	−1.0	−1.2
Florida	4.6	1.4	1.2	1.1
Georgia	1.5	0.9	0.7	0.5
Hawaii	0.1	0.0	−0.1	−0.2
Idaho	12.8	1.5	1.3	1.2
Illinois	1.1	0.0	−0.2	−0.3
Indiana	3.9	3.4	3.2	2.9
Iowa	2.7	1.8	1.6	1.4
Kansas	3.8	2.9	2.7	2.5
Kentucky	−0.4	−0.9	−1.2	−1.5
Louisiana	3.9	3.8	3.7	3.5
Maine	1.8	0.6	0.4	0.2
Maryland	3.3	−0.1	−0.3	−0.4
Massachusetts	6.3	−0.3	−0.4	−0.6
Michigan	1.4	1.0	0.7	0.3
Minnesota	4.1	1.2	1.0	0.8
Mississippi	2.0	1.6	1.5	1.3
Missouri	0.2	−0.1	−0.3	−0.6
Montana	3.5	3.1	3.0	2.8
Nebraska	3.7	2.6	2.5	2.3
Nevada	9.7	8.7	8.5	8.4
New Hampshire	3.4	−0.4	−0.6	−0.7

Table 5A.1 (continued)

	All manufac-turing	Mfg. less NAICS 334	Mfg. less NAICS 334, adj. for offshoring bias, 15/30[a]	Mfg. less NAICS 334, adj. for offshoring bias, 30/50[a]
New Jersey	−0.2	−1.6	−1.8	−1.9
New Mexico	5.4	−1.4	−1.6	−1.7
New York	2.4	0.2	0.0	−0.2
North Carolina	3.2	1.4	1.3	1.1
North Dakota	6.8	4.6	4.4	4.2
Ohio	0.4	−0.3	−0.5	−0.8
Oklahoma	2.9	2.3	2.1	1.9
Oregon	15.1	1.1	0.9	0.7
Pennsylvania	−0.1	−1.0	−1.2	−1.3
Rhode Island	1.6	0.2	0.0	−0.2
South Carolina	1.2	0.8	0.6	0.3
South Dakota	7.5	4.9	4.7	4.5
Tennessee	2.1	0.6	0.4	0.2
Texas	7.1	4.1	4.0	3.8
Utah	5.4	3.4	3.2	3.0
Vermont	5.4	0.4	0.2	0.0
Virginia	1.6	0.4	0.3	0.1
Washington	3.4	2.0	1.8	1.6
West Virginia	−2.1	−2.3	−2.5	−2.7
Wisconsin	2.0	0.5	0.4	0.2
Wyoming	5.1	5.0	4.8	4.7

[a] Adjustments for offshoring bias use estimates from columns 10 and 11 of Table 9 in Houseman et al. (2010). Offshoring bias adjustments labeled "15/30" assume that the intermediate country discount is 15 percent and the developing country discount is 30 percent, while offshoring bias adjustments labeled "30/50" assume that the intermediate country discount is 30 percent and the developing country discount is 50 percent.

SOURCE: Authors' calculations using BEA data.

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6
Import Sourcing Bias in Manufacturing Productivity Growth

Evidence across Advanced and Emerging Economies

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One of the main features of the current wave of globalization is the rise in outsourcing to emerging economies. Manufacturing industries, especially, are at the forefront of this development, sourcing ever more of their materials from emerging economies.[1] The motive for this development is straightforward enough: from the perspective of advanced economies, materials sourced from emerging economies are often considerably cheaper than those from domestic producers or other advanced economies. The consequences for U.S. productivity of the shift from high-cost domestic producers to cheaper imports is the topic of two separate works by Houseman et al. (2010, 2011).[2] As the authors show, many of the cost savings associated with this offshoring of production are not captured in official statistics, leading to what they label "offshoring bias." This bias results because lower prices for imports from an emerging economy are often fully attributed to differences in quality; such assumptions overlook the possibility of real cost savings.[3] Correcting for this, Houseman et al. conclude that U.S. manufacturing value-added and multifactor productivity growth are considerably biased upwards because input growth is biased downwards.

This chapter provides an international comparative perspective on this topic. In order to achieve such a perspective, I limit the scope of the analysis to the effect on productivity growth of changing the source of imports; thus, I do not take into account shifts from domestic to foreign sources. I will refer to this effect as "import sourcing bias" rather than use Houseman et al.'s (2010, 2011) term of "offshoring bias." While this is a narrower concept than that of Houseman et al., it can be more widely applied, since it relies on unit values of imported products from UN Comtrade. This is in contrast to Houseman et al.'s combination of confidential transaction-level prices used by the Bureau of Labor Statistics (BLS) to compile the U.S. import price indexes and U.S. case study evidence. My analysis of import sourcing bias thus allows for a comparison of the import sourcing bias in manufacturing productivity growth across countries.

The import sourcing bias measure is based on comparing two polar alternatives for treating the same product imported from different countries. A product imported from Country A could be treated as being different from the same product imported from Country B, or it could be considered a perfect substitute. In the first case, any observed price differences would be considered quality differences, while in the second case, observed price differences would be considered actual price differences. These two alternatives were also outlined in Diewert (1995, 1998), in the context of dealing with consumer prices from different outlets. I will assume that official statistics treat imports from A and B as different products. Because of this flawed approach, cost savings from switching to cheaper source countries will be missed, and the import price index will be biased.

Whether this bias estimate is correct depends, first, on whether it accurately reflects price (rather than quality) differences across source countries and, second, on whether the "different products" price index is an accurate reflection of the approach in the official import price statistics. Caution is in order on both grounds. First, the trade unit values are available at the four-digit Standard International Trade Classification (SITC) level, so there is still ample scope for quality differences within these product categories, as shown in Feenstra and Romalis (2012). When some of the price differences are actually quality differences, the true import sourcing bias is likely closer to zero than the bias estimated here. Second, it almost goes without saying that if statistical agencies already accurately distinguish between price and quality differences in estimating their import price indexes, then there is no import sourcing bias.[4] However, there is reason to believe that statistical agencies would sooner err on the side of ascribing too much of price differences to quality differences, although reliable information on statistics methodologies is hard to come by.[5] These considerations suggest that import sourcing bias is certainly possible in official statistics, but also that the current analysis is likely to overstate any true bias. From that point of view, this analysis is more exploratory regarding the potential scope of this problem, rather than a definitive estimate of its precise magnitude.

The impact of import sourcing bias on productivity growth in manufacturing is computed based on input-output tables. I calculate the bias in manufacturing multifactor productivity (MFP) growth for the period from 1995 to 2008 for 38 economies included in the World Input-Output Database (WIOD).[6] Results show that MFP growth in manufacturing, on average, is overstated by between 0.18 and 0.34 percentage points in advanced economies. Bias estimates for emerging economies are more mixed and include many negative bias estimates as well, which imply shifts toward higher-priced imports. As it would be highly unlikely that manufacturers would willingly switch to higher-cost sources of materials, this suggests that these are actually shifts toward higher-quality products. In the case of the United States, the import sourcing bias found here is between 14 and 33 percent of the offshoring bias of Houseman et al. (2010, 2011). The fact that it is lower comes as no surprise, as import sourcing bias ignores the shifts of sourcing from domestic to foreign suppliers. Even so, it still represents a notable fraction. Howells et al. (2013) have taken a similar approach for the United States as the one I discuss here. Theirs is based on more detailed unit value data, and they find import sourcing bias estimates that are similar to those presented here.

My estimates indicate that import sourcing bias is larger in Western Europe than in the United States. This may be due to the integration of many central and eastern European countries into European supply chains, following their accession to the European Union (EU). Sinn (2006) questioned the apparent solidity of Germany's growth in light of increased offshoring. My findings of lower bias-corrected productivity growth in Germany would seem in line with his argument. But while productivity growth is quite noticeably affected by import sourcing bias, the impact is also not so large that it materially affects cross-country growth patterns. So productivity growth in Germany, after correcting for import sourcing bias, is still quite healthy.

From the perspective of the quality of statistics, my results indicate that import sourcing bias should also be of concern in advanced economies outside the United States. This is certainly not to argue that my unit-value approach would be a superior alternative to import price surveys. Instead, surveying prices of inputs directly from firms, as suggested by Alterman (2009 and Chapter 10 of this volume), would be an approach that would solve import sourcing bias as well as the broader offshoring bias.

METHODOLOGY

Import Sourcing Bias

The bias this chapter aims to quantify can best be illustrated using a stylized example, adapted from Houseman et al. (2010, 2011) to the case of switching between importers. Table 6.1 compares the price of a television in two periods from two foreign suppliers. Both suppliers—Sri Lanka and Switzerland—export televisions, and we assume the product is identical. Given the lower price and identical nature of the product, the number of televisions that is imported from Switzerland drops from 75 to 50 units, while Sri Lanka supplies 25 units in the first period and 50 in the second period. For simplicity's sake, we assume that the price of both suppliers remains unchanged between the two periods, so the price change, shown in the final column, is equal to zero.

We distinguish between two cases: Case 1, where the two suppliers are treated as supplying a different product from each other, and Case 2, where they are treated as supplying the same product. Case 1 is assumed to correspond to current statistical practice (more on that

Table 6.1 Hypothetical Import Switching Example—Sri Lankan and Swiss Televisions

	t	$t + 1$	Change ($t + 1/t - 1$) (%)
Swiss price	10	10	0
Sri Lankan price	5	5	0
Swiss quantity	75	50	−33
Sri Lankan quantity	25	50	+50
Import price			
Case 1: measured			0
Case 2: true	8.75	7.5	−14

SOURCE: Author's construction.

below), while Case 2 is the true input price, given that we are dealing with identical products. Using a Törnqvist price index, the import price change in Case 1 is calculated as

(6.1)

$$\begin{aligned}\log\left(P_t^M / P_{t-1}^M\right) &= \tfrac{1}{2}\left(sl_t + sl_{t-1}\right)\log\left(P_t^{SL} / P_{t-1}^{SL}\right) + \tfrac{1}{2}\left(sw_t + sw_{t-1}\right)\log\left(P_t^{SW} / P_{t-1}^{SW}\right)\\ &= \tfrac{1}{2}\left(sl_t + sl_{t-1}\right)\log\left(5/5\right) + \tfrac{1}{2}\left(sw_t + sw_{t-1}\right)\log\left(10/10\right)\\ &= 0,\end{aligned}$$

where superscript ^{SL} refers to the price of televisions from Sri Lanka, *sl* is the share of Sri Lankan televisions in the total value of imports, and ^{SW} and *sw* refer to the price and import value share for Switzerland. Since the price of both suppliers is constant over time, the weighted average price change is zero.

In Case 2, the input price in period *t* is a weighted average of the price of the two suppliers, so (25 × 5 + 75 × 10) / 100 = 8.75. Here the (correct) assumption is made that these products are substitutes, and the true import price change is thus a 14 percent drop. This drop will be missed by standard statistical methods, even if all the relevant information is available, simply because the products from the two suppliers are assumed to be different even though they are the same. So if the statistical agency decides (mistakenly here) that the price difference reflects a difference in quality, there will be an import sourcing bias.

In this example, it is assumed that the two suppliers sell an identical product. If this is not the case—because, for instance, the quality of the domestic supplier's product is higher—then the quality-adjusted price difference is smaller. Adjusting trade-unit values for quality differences is not straightforward, but it is feasible, as shown by Hallak and Schott (2011) and Feenstra and Romalis (2012). However, such adjustments rely on a specific underlying theoretical model. Furthermore, even when adjusting for quality differences, Mandel (2010); Byrne, Kovak, and Michaels (2013); and Feenstra and Romalis (2012) still find substantial deviations from the law of one price. This implies that there is certainly scope for import sourcing bias.

The main analysis compares import prices for individual products according to the two cases outlined in Table 6.1. The main difference is that many different foreign suppliers are compared, rather than the simple two-supplier case. For Case 1, the price change for product *i* from $t-1$ to t can be written as

$$(6.2) \quad dP_{it}^{1} \equiv \log\left(P_{it}/P_{it-1}\right)^{1} = \sum_{j} \bar{v}_{ijt} \log\left(P_{ijt}/P_{ijt-1}\right),$$

where $v\,\bar{v}_{ijt} = \tfrac{1}{2}\left(V_{ijt}\Big/\sum_{j} V_{ijt} + V_{ijt-1}\Big/\sum_{j} V_{ijt-1}\right)$ is the two-period average share of imports from country *j* in the total value of imports of product *i*. The subscript for the importing country is omitted to avoid notational clutter. The price of each product is computed using import quantities and values as $P_{ijt} = V_{ijt}/Q_{ijt}$; see also the next section for more details about the data and implementation. The price change for Case 2 is defined as

$$(6.3) \quad dP_{it}^{2} \equiv \log\left(P_{it}/P_{it-1}\right)^{2} = \log\left(\frac{\sum_{j} V_{ijt}\Big/\sum_{j} Q_{ijt}}{\sum_{j} V_{ijt-1}\Big/\sum_{j} Q_{ijt-1}}\right),$$

so the weighted average unit value of imports is calculated by summing import values and quantities across all source countries.

If the example from Table 6.1 is the typical case, we would expect to see that P_{ijt}, used in Case 1, would be lower for emerging economies compared with advanced economies and that the share of imports from those countries, $\bar{v}_{ijt}$, would increase over time. As a result, the import price dP_{it}^{2} (Equation 6.3) would typically increase by less than dP_{it}^{1} (Equation 6.2). The difference between the two price changes, $\Delta_{it} = dP_{it}^{1} - dP_{it}^{2}$, is used to determine the import sourcing bias in manufacturing value-added growth.

What is specifically included in this difference, Δ_{it}, is not immediately obvious when comparing Equations (6.2) and (6.3). However, Diewert and Nakamura (2010) have shown that it is possible to write the true index, dP_{it}^{2} here, as a function of the typically observed index dP_{it}^{1} and a bias term. In their simplest case, with a new, lower-priced product entering in the second of a two-period example, the bias is equal to the price discount of the lower-priced entrant times the quantity share that this entrant captures in the second period. In the more general case, with many products and arbitrary quantity shares, the expression for the bias becomes more complicated, but it still only depends on the shifts in imports and the price difference between different source countries.[7] This implies that the difference, Δ_{it} , captures only import sourcing bias and would not be affected by other measurement problems.

There will be a bias if Δ_{it} is different from zero, since in that case the import price measure used by the statistical office, which I assume is well-proxied by dP_{it}^{1}, is not the same as the true import price measure, which I assume is well-proxied by dP_{it}^{2} . In general, I would expect Δ_{it} to be positive, which implies that the price index used to deflate imports is increasing too fast, and thus the quantity of imports increases too slowly.

The "true" import sourcing bias is likely to be smaller (closer to zero) than the bias I estimate here. This is because all true quality differences are considered to be price differences, and it seems likely that sellers of a high-quality product would not charge a lower (true) price than sellers of a low-quality product. To see this, consider a modification of the example in Table 6.1. The assumption in that example is that the Swiss television and the Sri Lankan television are identical, but say that the Sri Lankan product is of lower quality. For instance, assume that 20 percent of the Sri Lankan product is defective, compared with no defects for the Swiss product. The quality-adjusted price of the Sri Lankan product is then 6 rather than 5 because you have to buy 20 percent more of the product to get the same amount of nondefective units. The true price change would then be −11 rather than −14 percent.[8]

The same logic holds for a shift of imports toward higher-quality imports. Bias estimate Δ_{it} would then be negative because quality differences are assumed away. Accounting for quality differences would reduce the observed price differences and thus bring Δ_{it} closer to zero. The estimated Δ_{it} could also be *under*stated if the high-quality product has a lower price than the low-quality product. While this cannot be ruled out, it seems less likely a priori. For instance, the results of Feenstra and Romalis (2012) indicate that estimates of quality and prices based on their model are positively correlated.

The Impact on Value-Added and Productivity Growth

Value-added growth is calculated as a residual, in a process called "double deflation": the growth in output that is not accounted for by growth in intermediate inputs. Imports make up part of intermediate inputs, so if growth in the quantity of imports is too low, then growth in value-added is too high. To be more precise, the price of imported materials used in manufacturing will be biased to the following degree:

$$(6.4) \qquad \Delta_t^{MM} = \sum_i \overline{w}_{it}^{m} \Delta_{it} \,,$$

where $\overline{w}_{it}^{MM}$ is the two-period average share of product i in the total value of imported materials used in manufacturing. Imported materials are, in turn, part of total materials used, which together with energy and services make up total intermediate inputs. Nominal gross output, $P^Y Y$, can thus be written as the following accounting identity:

$$(6.5) \quad P_t^Y Y_t = P_t^{VA} VA_t + P_t^I I_t = P_t^{VA} VA_t + \left(P_t^{MM} MM_t + P_t^{DM} DM_t + P_t^{OI} OI_t \right),$$

where VA is value-added, I stands for total intermediate inputs, MM signifies imported materials, DM stands for domestically sourced materials and OI for other intermediate inputs, and P^X is the price of X. In national accounts, prices are available for gross output and the different intermediate inputs, and the price of value-added is solved for implicitly. The Törnqvist index for the change in the value-added price is defined as

(6.6)

$$\log\left(\frac{P_t^{VA}}{P_{t-1}^{VA}}\right) = \frac{1}{\overline{va}_t}\left(\log\left(\frac{P_t^{Y}}{P_{t-1}^{Y}}\right) - \overline{mm}_t \left(\frac{P_t^{MM}}{P_{t-1}^{MM}}\right) - \overline{dm}_t \left(\frac{P_t^{DM}}{P_{t-1}^{DM}}\right) - \overline{oi}_t \left(\frac{P_t^{OI}}{P_{t-1}^{OI}}\right) \right),$$

where an upper bar denotes a two-period average and a lowercase variable is the share of that variable in gross output—thus, for example,

$$\overline{va}_t = \tfrac{1}{2}\left(P_t^{VA} VA_t / P_t^Y Y_t + P_{t-1}^{VA} VA_{t-1} / P_{t-1}^Y Y_{t-1} \right).$$

Based on the argument above, the price of imported materials, P^{MM}, is biased by Δ_{mm} , so using Equation (6.6), the bias in the price of value-added is

$$(6.7) \qquad \Delta_t^{PVA} = -\frac{\overline{mm}_t}{\overline{va}_t} \Delta_t^{MM} = -\tfrac{1}{2}\left(\frac{P_t^M MM_t}{P_t^{VA} VA_t} + \frac{P_{t-1}^M MM_{t-1}}{P_{t-1}^{VA} VA_{t-1}} \right) \Delta_t^{MM} \,.$$

Since the bias in prices has no bearing on the growth of nominal value-added, the bias in the growth of the quantity of value-added is equal to the negative of the bias in the growth of the price of value-added, $\Delta_t^{VA} = -\Delta_t^{PVA}$. As the bias in the growth of imported materials has no effect on the growth of labor or capital, the growth bias of value-added translates one-for-one into a bias in MFP growth, $\Delta_t^{MFP} = \Delta_t^{VA}$.

DATA SOURCES AND IMPLEMENTATION

To implement the bias calculation in Equation (6.7), two data sources are used, one with data on import prices and the other with data on the economies' input-output structure. The import prices are based on the UN Comtrade database, which provides information on the quantity and value of imports by product, importing country, and source countries for each year in the period 1995–2008. There are data for up to 804 products, classified according to the four-digit level of the SITC Revision 2 (SITC Rev. 2) system. The valuation concept for the import value is CIF (cost, insurance, and freight), so it reflects the full price the importer has to pay to get the product into the country.

I undertake two processing steps before implementing Equations (6.2) and (6.3). First, I only keep observations for which the quantity unit is kilograms. This is done to ensure that the unit values are comparable across source countries.[9] Second, I compute the median unit value of a product across all 38 importers and 139 source countries and drop observations for which the unit value is either smaller than 1 percent or larger than 100 times the median unit value, as these are more likely to reflect data errors. (The sensitivity of the results to these trimming criteria is discussed below.) Also included in the data error category are observations for which the quantity is equal to zero while the value is positive. Around 1 percent of observations are dropped as a result. Based on the resulting price and value data, Equations (6.2) and (6.3) are implemented and the price change difference, Δ_{it}, is computed.

The price change difference for each imported product then needs to be weighted by the share of that product in imported materials used in manufacturing, as discussed in Equation (6.4). From the World Input-Output Database (WIOD), I have annual data on the composition of imported intermediates for the 38 countries that are analyzed. However, this composition is only available at a higher level of aggregation, namely, for 14 manufacturing industries that deliver materials to manufacturing.[10] So I first use a concordance of SITC Rev. 2 to the International Standard Industrial Classification Revision 3 (ISIC Rev. 3) industrial classification to aggregate product-level price-change differences to the level of these 14 manufacturing industries, using the share of each product in total imports by each country. Then Equation (6.4) is applied as described, and the outcome is used in Equation (6.7) to arrive at the estimate of the bias in manufacturing productivity growth.

I use the Socio-Economic Accounts (SEAs) that are part of WIOD to compute the growth of manufacturing MFP:[11]

(6.8)

$$\log\left(\frac{MFP_t}{MFP_{t-1}}\right) = \log\left(\frac{VA_t}{VA_{t-1}}\right) - \sum_i \bar{\alpha}_{it} \log\left(\frac{H_{it}}{H_{it-1}}\right) - \left(1 - \sum_i \bar{\alpha}_{it}\right) \log\left(\frac{K_t}{K_{t-1}}\right).$$

Based on the SEAs, there is information for manufacturing on value-added at constant prices (*VA*), employment by skill type (H_{it}), the total capital stock (K_t), and the share of labor compensation going to each skill type in value-added (α_{it}). Ideally, there should be data on capital stocks by asset type, but this is not available for all countries. As a result, the contribution to growth from changes in the composition of the capital stock is included in this measure of MFP growth.

For my analysis, I assume that statistical agencies treat imports of the same product from different countries as different products. Establishing whether this is actually the case is a much harder challenge. As a general principle, the main concern in official statistics is to avoid ignoring quality differences, and statistical agencies would thus be likely to treat products from different countries as having a different quality, rather than a different price—see, e.g., Eurostat (2001) and IMF (2009). How U.S. statisticians deal with this issue is discussed in detail in Houseman et al. (2010, 2011).[12] Put briefly, unless it is clear that a “new” product imported from a different country is identical to the “old” product, price differences are assumed to be due to quality differences. European countries would have to follow a similar approach as the United States to be in line with Eurostat requirements. Since separate import price indices are published for imports from euro-area countries and for imports from non-euro-area countries, this suggests that products from different countries are not treated as close substitutes. For other countries, information on import prices and the estimation methodology is even harder to establish. For instance, the Reserve Bank of India (2012) shows import prices for India based on unit values, but it is unclear what level of detail these are constructed from. If they distinguish import unit values by source country, then there would be scope for import sourcing bias, but otherwise, their measure may be similar to my dP_{it}^2 . This paucity of methodological documentation presents a challenge in gauging the possible scope for import sourcing bias for most countries outside the United States.[13]

This might not be a major problem if dP_{it}^1 from Equation (6.2) were close to official import prices. Using data provided by Eurostat, a comparison can be made for nine European countries, and the results actually show substantial differences. Indeed, dP_{it}^1 is much more similar to dP_{it}^2 (a correlation of 0.93) than to the official import prices (0.18). The standard deviation of dP_{it}^1 and dP_{it}^2 is also about three times larger than that of the official indices. To some extent, this is unsurprising, as dP_{it}^1 will capture many changes that official import prices are designed to ignore. While both capture the changes in price of individual products by a specific producer in a particular country, dP_{it}^1 will also capture shifts between producers of the same product in the same country, shifts between products within the SITC four-digit category, and changes in the importance of individual products in the broader category.

However, as discussed above, Diewert and Nakamura (2010) show that it is possible to express the true price index, dP_{it}^2 , as a function of the typically observed price index dP_{it}^1 and a bias term. This bias term, Δ_{it} , the difference between dP_{it}^1 and dP_{it}^2 , depends only on the price difference and shifts in imports across source countries. In other words, even when dP_{it}^1 is a poor approximation of official import prices, the import sourcing bias estimate Δ_{it} is not "contaminated" by factors unrelated to import price differences and sourcing patterns.

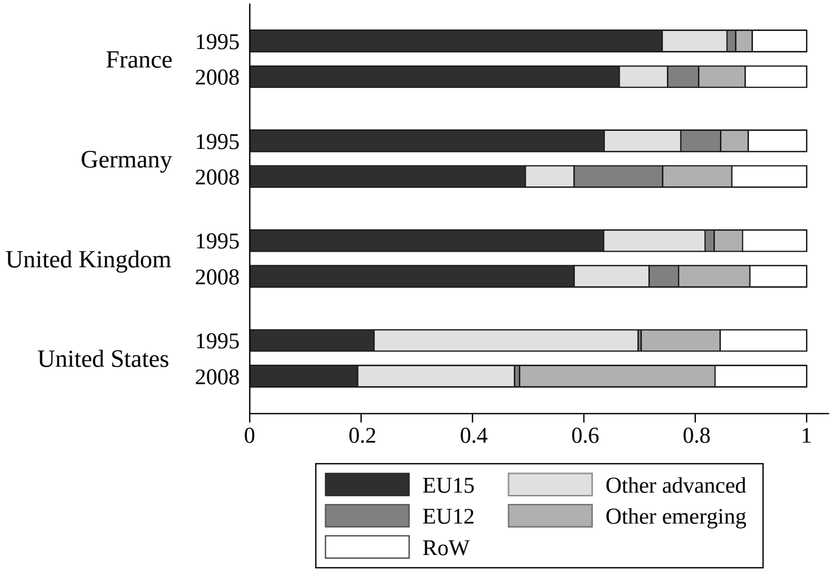
This discussion implies that caution is in order in interpreting the results on two counts. First, if statistical agencies adequately account for price and quality differences across source countries, the method employed here would incorrectly ascribe a bias to the import price index of that country. A bias would only occur if the statistical agencies ascribe too much of the price differences across source countries to quality differences. Second, our trade unit values are available at a level of detail at which quality differences will still be a notable factor. As long as the correlation between (true) prices and quality is not negative, the bias estimates are likely to be too large. Given these caveats, the results should be regarded more as indicative of the likely scope of this problem than as the final word on the precise magnitude.

RESULTS

The increased sourcing of materials from lower-cost countries is shown in Figure 6.1 for the three largest European countries and the United States. Between 1995 and 2008, each of these countries considerably increased the share of imported materials from emerging economies. I define two groups of emerging economies. The first group consists of the (mostly) central and eastern European countries that have joined the European Union since 2004, the EU12.[14] The second group, “Other emerging,” includes Brazil, China, India, Indonesia, Mexico, Russia, and Turkey. The advanced economies are the EU15[15] and the group labeled “Other advanced,” which includes Australia, Canada, Japan, Korea, Taiwan, and the United States.[16] This grouping is informative, as the share of imports from advanced economies went down considerably over this period, while both groups of emerging economies gained considerably in import market share.[17]

This shift in import market share toward emerging economies is an indication that imports from these economies are cheaper. To illustrate this, we can compare the import price for the same product across countries. To make this more straightforward to visualize, I first compute the median unit value by source country group (advanced/emerging, EU/other), importer, product, and year. These median unit values are then compared with the median unit value of imports from the EU15. Figure 6.2 plots the median price difference relative to the EU15 for each country group over time. The median price for imports from other advanced economies[18] was about 20 percent higher than the price for imports from the EU15 throughout the period. To give an indication of the distribution around the median price difference, the percentage of

Figure 6.1 Share of Source Country Groups in Imported Materials Used in Manufacturing, Selected Countries for 1995 and 2008

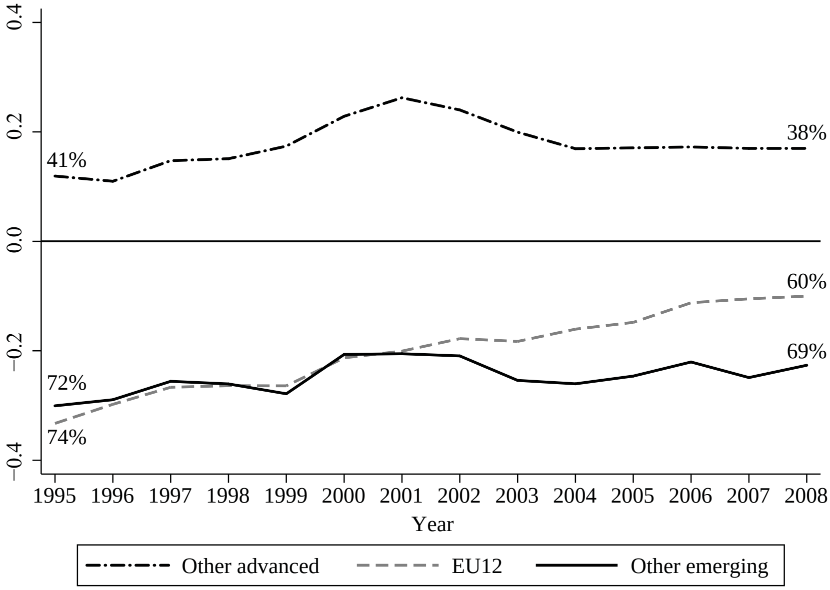


NOTE: RoW = rest of world.
SOURCE: Computations based on WIOD, see www.wiod.org.

products that had a lower price than imports from EU15 countries is also indicated. For imports from other advanced economies, only about 40 percent of products are cheaper than imports from EU15 countries. The generally higher prices of imports from other advanced economies could be a "Washington apples" effect (Alchian and Allen 1964). Since most countries in the analysis are EU countries (27 out of 38 countries), imports from other advanced economies tend to come from farther away and would thus need to be of higher quality to overcome higher trade costs.

Throughout the period, and for most countries, importing from emerging economies was much cheaper than importing from EU15 countries. The median difference in 1995 was around 30–35 percent for imports from the EU12 and other emerging economies. The price advantage shrank over this period to about 20 percent for other emerging economies and to about 10 percent for EU12 countries. Most prod-

Figure 6.2 Median Price Difference Relative to EU15 Imports and Percentage of Products That Have Lower Prices than EU15 Imports, by Country Grouping, 1995–2008



NOTE: The lines show the median price difference of imports from a specific country grouping relative to imports from EU15 countries. The percentages indicate the percentage of products with lower prices.
SOURCE: Author's computations.

ucts from both groups of countries had lower prices than when imported from EU15 countries. This figure, though, treats all products identically even if they represent only a small part of imports.

We therefore turn to the results from estimating import sourcing bias, where products are weighted by their share in the value of imports. In these results, we focus on how the difference in price levels translates to a different rate of import price change, rather than on the price-level differences in themselves. Table 6.2 illustrates the products and country groups for which the import sourcing bias is most relevant. For each traded product, I calculate the difference between a price index under the assumption products are different when imported from a different country (Equation [6.2]) and a price index under the assumption prod-

Table 6.2 Offshoring Bias across Product Groups and Country Groups, 1995–2008

Type of product	Differentiated		Reference-priced		Exchange-traded	
	Conservative	Liberal	Conservative	Liberal	Conservative	Liberal
Overall	0.33	0.29	−0.01	0.03	−0.06	−0.06
EU15	0.51	0.44	0.02	0.08	−0.04	−0.04
Other advanced	0.53	0.51	0.07	0.09	0.02	0.03
EU12	0.26	0.15	−0.06	0.05	−0.06	−0.06
Other emerging	−0.08	0.04	−0.04	−0.15	−0.18	−0.18

NOTE: The table shows the weighted average difference between the price change for a "different products" price index versus a "perfect substitutes" price index over the period from 1995 to 2008. The "different products" price index is defined in Equation (3.2), and the "perfect substitutes" index is defined in Equation (3.3). The price changes for each product are multiplied by the two-period average share of that product in country imports and summed across product groups. The product groups are defined by Rauch (1999) and are used to indicate the extent to which products are homogenous (exchange-trade) or differentiated; both Rauch's conservative and liberal groupings of products are shown. The differences in price changes for each group are then averaged across countries.

SOURCE: Author's computations.

ucts imported from different countries are perfect substitutes (Equation [6.3]). This difference is then weighted by the share of each product in the total imports of each country and summed across three groups of products.

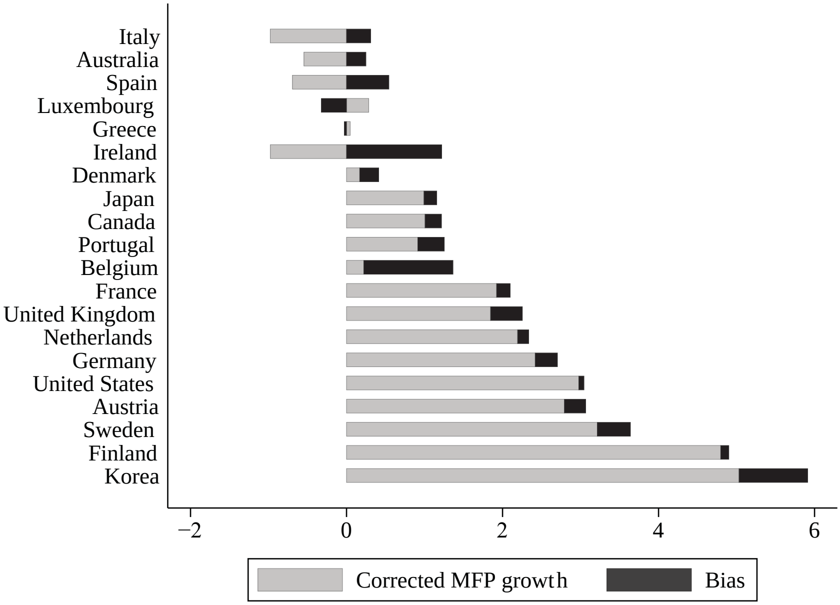
This product grouping, introduced by Rauch (1999), distinguishes between homogenous and differentiated products. Some products, typically commodities such as oil or lead, are traded on exchanges and are thus considered homogenous. For a second category of products, it is possible to find so-called reference prices in trade journals, such as for chemicals. The remainder of products—i.e., those for which no "standard" prices are available—are considered to be differentiated. This determination is made at the five-digit SITC level, and in translating this to the four-digit SITC level (which is used here), Rauch formulates two alternative classifications, a "conservative" and a "liberal" one. In the conservative classification, products are labeled as "differentiated" when the four-digit category also consists (in part) of "reference-priced" or "exchange-traded" products. In the liberal classification, the alternate choice is made, thus allocating a product to the "reference-priced" or "exchange-traded" categories, rather than the "differentiated" category. The final step is to compute an (unweighted) average of the price-change differences across countries.

The top row of Table 6.2 shows that, across all countries, there is only evidence of a (positive) import sourcing bias for differentiated products.[19] For reference-priced and exchange-traded products—i.e., the more homogenous products—there is little indication that a shift toward low-cost sources is biasing import price indexes, especially in Rauch's (1999) conservative product grouping (which uses a stricter rule for classifying products as homogenous). Indeed, the negative import sourcing bias numbers for some product and country groups imply shifts toward higher-cost sources. Across country groups, only advanced economies show notable positive import sourcing bias numbers, and then only for differentiated products. This group of products is where one would expect products of different prices—but also of different quality levels—to be able to coexist. The positive import sourcing bias numbers in Table 6.2 could then imply that advanced economies are shifting toward lower-quality imports or toward lower-cost imports (at a given quality level). In that regard, the import sourcing bias estimates in Table 6.2 and those that follow are likely to be an overestimate of the true bias.

Figure 6.3 moves to the country level and shows the import sourcing bias in combination with average annual growth in manufacturing MFP for the 20 advanced economies between 1995 and 2008 (ordered by measured MFP growth). The total bar equals manufacturing MFP growth as computed from the SEA (Equation [6.8]), which is divided into the bias calculated from Equation (6.7) and the corrected MFP growth. This illustrates how the bias is substantial in most countries and positive in all but Luxembourg and Greece. For this set of countries, the average bias is 0.34 percentage points, which is 25 percent of the (corrected) average annual MFP growth of 1.38 percent. In other words, measured MFP growth in advanced economies could very well substantially overstate actual growth. At the same time, the cross-country pattern of MFP growth is not much distorted: Though the growth rates are lower, the measured MFP growth and corrected MFP growth rates are very highly correlated across countries (0.98).

The import sourcing bias found for the United States of 0.07 percentage points is smaller than the offshoring bias found by Houseman

Figure 6.3 Average Annual Manufacturing MFP Growth in Advanced Economies, Bias and Bias-Corrected Measures, 1995–2008



SOURCE: Author's computations.

et al. (2010, 2011), whose estimates range from 0.21 to 0.51 percentage points over mostly the same period.[20] Since any bias from shifting from domestic to foreign suppliers is not included in my import sourcing bias, this is as expected. It does suggest that import sourcing bias captures a notable share (14–33 percent) of the overall offshoring bias. In countries with smaller, more open economies than that of the United States, my import sourcing bias is likely to be an even larger part of the overall offshoring bias.

To gauge the robustness of these bias estimates, I repeated the analysis with more restrictive criteria for removing outliers in the unit value data. Rather than removing unit values that were 100 times larger or 0.01 times as large, I used parameters of 20 times larger or 0.05 times as large, as well as 10 times larger or 0.1 times as large. The resulting bias estimates are noticeably smaller, indicating that mostly small unit values are dropped from the data set. For advanced economies, the average bias drops from 0.34 in the 100–0.01 case to 0.28 in the 20–0.05 case and 0.18 in the 10–0.1 case.[21] The cross-country pattern is very similar, though, confirming the finding that the cross-country pattern of MFP growth is not affected by import sourcing bias.

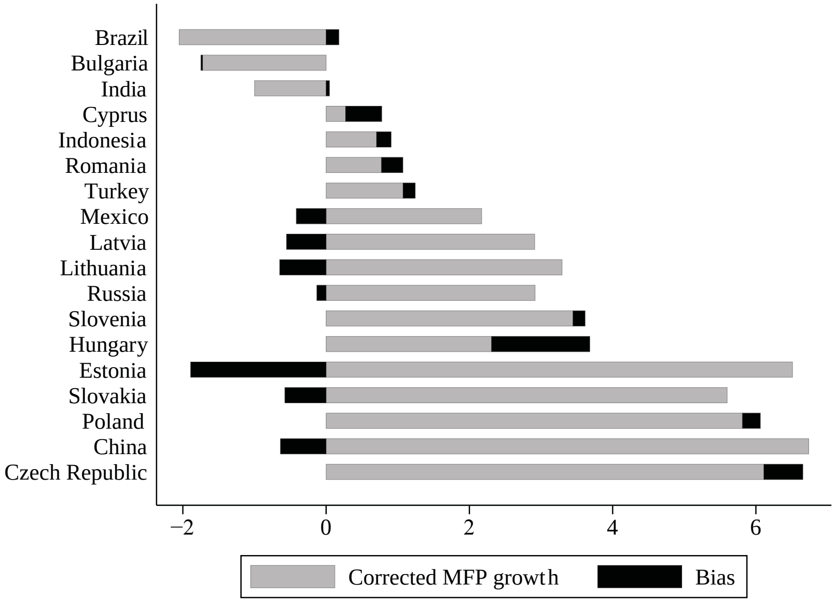
Figure 6.4 shows the bias estimates for the 18 emerging economies. As already shown in Table 6.2, there is no clear positive import sourcing bias: the average bias is −0.06 and varies between −1.89 (Estonia) and +1.37 (Hungary). Taken at face value, the negative bias estimates suggest that measured productivity growth is understated because manufacturers are shifting toward imports of higher-cost materials. This is hard to fathom unless these materials are also of higher quality. These negative biases could reflect an increasing integration of emerging economies into advanced economies' supply chains, with, for instance, (high-quality) car parts arriving from western European manufacturers for assembly in countries such as Slovakia. From the perspective of productivity measurement, import sourcing bias seems to be less of a problem in these emerging economies.

CONCLUSION

While manufacturers increasingly buy their materials from lower-cost countries, official statistics lag behind this trend. Methods to measure the price change of imported materials miss out on cost-savings that manufacturers achieve by sourcing from lower-cost countries. By overestimating price changes of imports, statisticians underestimate the growth in the quantity of imports, leading to an upward bias in growth of productivity. In this chapter, I quantify this import sourcing bias for 38 advanced and emerging economies and estimate bias-adjusted growth of manufacturing value-added for the period 1995–2008. This relies on data for import unit values across importing countries, so that price changes of import products can be calculated under the assumption that imports from different countries are either different products or perfect substitutes. Treating imports from different countries as substitutes allows for cost savings to be registered in the statistics.

The analysis for advanced economies shows that there is a shift toward imports with lower unit values for the group of differentiated

Figure 6.4 Average Annual Manufacturing MFP Growth in Emerging Economies, Bias and Bias-Corrected Measures, 1995–2008



SOURCE: Author's computations.

products. As a result, manufacturing MFP growth in advanced economies is biased upwards by, on average, 0.18 to 0.34 percentage points, or 10 to 20 percent of measured growth. In emerging economies, there is no clear bias in either direction. The true import sourcing bias is likely to be closer to zero than these estimates, as the method used here ascribes none of the price differences to differences in quality. Furthermore, if statistical agencies already deal well with price and quality differences across source countries, then there is no bias to begin with. From that perspective, it is reassuring to discover that even with the larger estimate of import sourcing bias, the cross-country pattern of productivity growth is not affected. On the other hand, this analysis is limited to analyzing import sourcing bias, and any bias stemming from shifts between domestic and foreign suppliers is not accounted for.

Yet even the current estimates have implications for the reliability of output and productivity statistics. These questions cannot easily be resolved in the standard statistical framework, where price changes are measured separately for inputs from domestic and different foreign sources. Instead, surveying an input price index, as discussed by Alterman (2009 and Chapter 10 of this volume), may hold greater promise, since for such an index firms would provide the overall input price, regardless of source. The earlier experiences of the Bureau of Labor Statistics in surveying margin prices (i.e., the sales price minus the purchase price of the product) in wholesale and retail trade suggest that this would be feasible. Those new prices led to much lower productivity growth, particularly in retail trade (Harchaoui 2012), which points to the importance of accurately measuring not only output but also input prices. From a policy perspective, these findings suggest that some of the offshoring of activities, in particular from western Europe to central and eastern European countries, has led to an overestimation of productivity growth. However, import sourcing bias by itself is not a large enough factor that the cross-country productivity growth patterns are materially affected.

Notes

The author would like to thank the participants at the “Measuring the Effects of Globalization” conference, held February 28–March 1, 2013, in Washington, D.C., and in particular Susan Houseman and Ana Aizcorbe, for helpful comments and discussions.

1. See, e.g., OECD (2010).
2. There has also been earlier work on this; see, e.g., Schott (2004) and Reinsdorf and Yuskavage (2009).
3. In the literature on bias in consumer prices, this is known as outlet substitution bias; see, e.g., Reinsdorf (1993), Diewert (1998), and Hausman (2003).
4. There would still be offshoring bias until prices of domestic and foreign sources of inputs were compared and any price differences accounted for.
5. See IMF (2009) for international measurement guidelines, but also Inklaar, Timmer, and van Ark (2008) on the topic of the measurement of industry output prices across Europe in relation to measurement guidelines.
6. See http://www.wiod.org. Taiwan is excluded because of missing trade data, and Malta because of highly erratic unit values.
7. Diewert and Nakamura (2010) show this for a Fisher index, whereas here a Törnqvist index is used. Given the similarity in the structure of these two indexes, there is likely a similar decomposition for the Törnqvist as for the Fisher. Furthermore, import sourcing bias estimates based on the Fisher index are similar in size to the Törnqvist estimates shown in the chapter.

8. The first-period price is now 25% × 6 + (1 − 25%) × 10 = 9, and the second-period price is 8, so the price decline between the two periods is 11 percent.
9. More than 90 percent of the unit values are based on quantities in kilograms. Furthermore, the same product could be reported in kilograms by some countries and in another unit (e.g., number of items) by other countries. To avoid mixing prices per kilogram and prices per unit for the same product, only prices per kilogram are used.
10. WIOD distinguishes inputs from 35 industries, but these also include nonmanufacturing inputs.
11. See, e.g., Timmer et al. (2010) for more detail on (industry-level) growth accounts and MFP growth estimates.
12. See also Nakamura and Steinsson (2012) and BLS (1997).
13. See, for instance, Inklaar, Timmer, and van Ark (2008) on price measurement of industry output across Europe.
14. These are Bulgaria, Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, and Slovenia.
15. The EU15 consists of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom.
16. We could not include Taiwan in our full analysis because of missing trade price data.
17. Note that the share of imported materials in total material use also increased, so imports from advanced economies did not decline in the absolute sense.
18. The import price data cover more countries than the input-output data, so there are more advanced economies. All non-EU countries with a 2008 GDP per capita level exceeding 55 percent of the U.S. level are labeled “advanced.” This threshold was chosen because it is the dividing line between the EU15 and the EU12.
19. Results based on unweighted average price changes are very similar.
20. The bias in value-added-based MFP growth is identical to the bias in value-added growth, as was noted in the discussion of Equation (6.7), so I use Houseman et al.’s (2010, 2011) estimate of the bias in value-added growth here.
21. In the 10–0.1 case, the import sourcing bias for the United States drops almost to zero, which would imply that all of the offshoring bias is due to switching from domestic to foreign suppliers.

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7
Biases to Manufacturing Statistics from Offshoring

Evidence from Japan

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As manufacturing sectors of developed economies outsource more and more to developing economies, this may give rise to a serious measurement problem. If a manufacturing industry (or firm) procures a lot of parts and components from developing economies at exceptionally low prices and we do not correctly take account of these low prices, we will overestimate the productivity of this industry (or firm).

In this chapter, we investigate two types of biases to manufacturing statistics from the growth in manufacturers' use of imported intermediates—commonly known as offshoring.

The first type of bias concerns measuring the use of imported products in the economy. Most countries, including the United States, do not track whether imports are destined for final demand or intermediate uses but instead assume that industries use imports in proportion to their overall use of these products in the economy—this is the so-called import proportionality assumption. Measures using the import proportionality assumption will differ from measures based on actual input use if two conditions occur: 1) industries' use of imports differs significantly from that assumed under the import proportionality assumption, and 2) the price movements of imported and domestic intermediates within commodity classes differ significantly.[1] In this study, we call these types of biases the bias caused by the import proportionality assumption.

The second type of bias concerns the price gap between domestically produced inputs and imported inputs. If manufacturers shift sourcing from a high-cost domestic supplier to a low-cost foreign supplier and statisticians do not take account of this price gap, statisticians' estimates of the inputs of these manufacturers will be downwardly biased, and estimates of the total factor productivity (TFP) will be upwardly biased. This has been referred to as "offshoring bias" in the literature (Diewert and Nakamura 2011; Houseman et al. 2011).

Japan presents an ideal case study to examine both the bias caused by the import proportionality assumption and the bias caused by offshoring. The reason is that every five years, the Ministry of Internal Affairs and Communications publishes the Input-Output Tables for Japan (I-O tables), in which domestically produced intermediate inputs and imported intermediate inputs are treated separately. The Japanese government estimates the input structure by conducting a special survey, implemented by the Ministry of Economy, Trade, and Industry (METI), on the sources of each industry's procurements. Moreover, because of Japan's location, imports of intermediate inputs from China and other developing economies in East Asia have increased rapidly in recent decades. Against this background, using Japan's I-O tables and price indices for imported and domestic products, one of the major aims of this study is to estimate the bias from the import proportionality assumption by examining differences in estimates of import use in the I-O tables based on actual data and estimates based on the import proportionality assumption.

In order to estimate offshoring bias, we need—in addition to data on import use in the economy and price indices for imported and domestic products—data on the price gap between domestically produced inputs and imported inputs. In Japan, such data are available from the *Survey on Foreign and Domestic Price Differentials for Industrial Intermediate Input*, conducted by METI every year. This survey provides information on differentials in customer delivery prices among Japan, China, the United States, Germany, South Korea, Taiwan, and Hong Kong for about 180 commodities and 40 services. Using these data, we estimate the price gap between domestically produced inputs and imported inputs by country of origin.

The structure of the article is as follows. In Section Two, "Approach to Measuring the Two Types of Biases," we explain our methodology to estimate the two types of biases using data on Japan. We then explain our data in Section Three, "Data Used." We also detail what data METI collects and how it collects these data. In Section Four, "Estimation of Bias Caused by the Import Proportionality Assumption," we report our results on bias created by the import proportionality assumption. In Section Five, "Estimation of Offshoring Bias," we report our results on the second type of bias. Section Six concludes.

APPROACH TO MEASURING THE TWO TYPES OF BIASES

This section presents the approach we use to measure the two types of bias: 1) bias caused by the import proportionality assumption and 2) offshoring bias.

We start by explaining our approach to measuring the bias caused by the import proportionality assumption.

In Japan, input-output tables, in which domestically produced intermediate inputs and imported intermediate inputs are treated separately, are constructed every five years. Therefore, data on the nominal value of imported intermediate inputs from sector *i* to sector *j*, $X_{i,j}^{M}(t)$, and data on the nominal value of domestically produced intermediate inputs from sector *i* to sector *j*, $X_{i,j}^{H}(t)$, are available separately. Here, superscript ^{M} stands for imported intermediate inputs and superscript ^{H} stands for domestically produced intermediate inputs. In the United States, only data on the total value of intermediate inputs from sector *i* to sector *j*, $X_{i,j}^{M}(t)+X_{i,j}^{H}(t)$, are available to construct input-output tables; the extent to which the intermediate inputs used in sector *j* are imported or domestically produced is unknown.

Let us theoretically examine biases caused by this shortcoming of U.S.-type input-output tables based on the import comparability assumption.

Assume that imported intermediate inputs from sector *i* to sector *j* and domestically produced intermediate inputs from sector *i* to sector *j* are different products and the cost share of each product reveals its marginal contribution to production in sector *j*.

In Japan, as in the United States, data on the absolute price levels of imported products and domestic products are not available. In both countries, only the price indexes of imported products and domestic products are available. Let $P_i^M(t) / P_i^M(0)$ denote the price change of imported product i from year 0 to year t and $P_i^H(t) / P_i^H(0)$ denote the price change of domestically produced product i from year 0 to year t.[2]

For our estimation of the bias, which would be caused by a lack of information on imports, we first prepared nominal and real import input-output tables for 1995, 2000, 2005, and 2008 in Japan using data on import use in the economy. As we will explain in detail in the next section, the main sources of our I-O tables are the 1995-2000-2005 Linked Input-Output Tables, published by the Statistics Bureau of the Ministry of Internal Affairs and Communications (MIAC), and the 2008 Updated Input-Output Tables, published by METI. Both of the statistics set 2005 as their benchmark year.

The key variables we would like to estimate are the real input indexes for each sector. For the calculation of these quantity indexes, we use 2005 as the base year. That is, we weight input quantity changes by the nominal input values of 2005. Using Japan's I-O tables, which incorporate information on the use of imports in the economy, we derive the real input index for sector j for year t (t = 1995, 2000, 2005, 2008), $x_j^J(t)$, as follows:

(7.1)
$$x_j^J(t) = \frac{\sum_i \left(X_{i,j}^M(T) \dfrac{\dfrac{X_{i,j}^M(t)}{P_i^M(t)}}{\dfrac{X_{i,j}^M(T)}{P_i^M(T)}} + X_{i,j}^H(T) \dfrac{\dfrac{X_{i,j}^H(t)}{P_i^H(t)}}{\dfrac{X_{i,j}^H(T)}{P_i^H(T)}} \right)}{\sum_i \left(X_{i,j}^M(T) + X_{i,j}^H(T) \right)}$$

$$= \frac{\sum_i \left(X_{i,j}^M(t) \dfrac{P_i^M(T)}{P_i^M(t)} + X_{i,j}^H(t) \dfrac{P_i^H(T)}{P_i^H(t)} \right)}{\sum_i \left(X_{i,j}^M(T) + X_{i,j}^H(T) \right)} \quad ,$$

where the superscript ^{J} means that this index is based on noncompetitive import-type I-O tables like Japan's. T denotes the base year, 2005.[3]

In most countries, data on the destination of imports in the economy are not regularly available, and the ordinary approach is to assume that a sector's imports of each input, relative to its total demand, are the same as the economy-wide imports relative to total demand (as is assumed in the I-O tables for the United States)—the so-called import proportionality assumption.

That is, an industry's imports are calculated as follows: let $m_i(t)$ denote the economy-wide imports of product *i* relative to total demand for product *i*:

$$(7.2) \quad m_i(t) = \frac{\sum_j X_{i,j}{}^M(t) + \sum_k F_{i,k}{}^M(t)}{\sum_j \left(X_{i,j}{}^M(t) + X_{i,j}{}^H(t)\right) + \sum_k \left(F_{i,k}{}^M(t) + F_{i,k}{}^H(t)\right)},$$

where $F_{i,k}{}^M(t)$ and $F_{i,k}{}^H(t)$ denote the value of imports of product *i* used to satisfy final demand *k* and the value of domestic output of product *i* used to satisfy final demand *k*.

In this shortcut approach, growth of real inputs from sector *i* to sector *j* is estimated by

$$m_i(t)\frac{\dfrac{X_{i,j}{}^M(t)+X_{i,j}{}^H(t)}{P_i^M(t)}}{\dfrac{X_{i,j}{}^M(T)+X_{i,j}{}^H(T)}{P_i^M(T)}} + (1-m_i(t))\frac{\dfrac{X_{i,j}{}^M(t)+X_{i,j}{}^H(t)}{P_i^H(t)}}{\dfrac{X_{i,j}{}^M(T)+X_{i,j}{}^H(T)}{P_i^H(T)}}.$$

Moreover, the real input index for sector *j* for year *t*, $x_j{}^U(t)$, is defined by

(7.3)

$$x_j{}^U(t) = \frac{\sum_i \left(X_{i,j}{}^M(T)+X_{i,j}{}^H(T)\right)\left(m_i(t)\dfrac{\dfrac{X_{i,j}{}^M(t)+X_{i,j}{}^H(t)}{P_i^M(t)}}{\dfrac{X_{i,j}{}^M(T)+X_{i,j}{}^H(T)}{P_i^M(T)}} + (1-m_i(t))\dfrac{\dfrac{X_{i,j}{}^M(t)+X_{i,j}{}^H(t)}{P_i^H(t)}}{\dfrac{X_{i,j}{}^M(T)+X_{i,j}{}^H(T)}{P_i^H(T)}}\right)}{\sum_i \left(X_{i,j}{}^M(T)+X_{i,j}{}^H(T)\right)}$$

$$= \frac{\sum_i \left(X_{i,j}{}^M(t)+X_{i,j}{}^H(t)\right)\left(m_i(t)\dfrac{P_i^M(T)}{P_i^M(t)} + (1-m_i(t))\dfrac{P_i^H(T)}{P_i^H(t)}\right)}{\sum_i \left(X_{i,j}{}^M(T)+X_{i,j}{}^H(T)\right)},$$

where the superscript ^{U} means that this index is drawn from U.S.-type input-output tables based on the import proportionality assumption.

Equation (7.3) shows that when the price of imports relative to that of domestic output declines ($P_i^M(T) / P_i^H(T) > P_i^M(t) / P_i^H(t)$) from T to t for most inputs i, we will underestimate the increase in intermediate inputs in sectors where imports of product i relative to the sector's total demand is higher than the economy-wide imports/domestic output ratio ($(X_{i,j}^M(t) / (X_{i,j}^M(t)+ X_{i,j}^H(t)) > m_i(t)$) for these inputs. As a result, we will overestimate the TFP growth of such sectors.

This type of bias is caused by the assumption that an industry's imports of each input, relative to its total demand, are the same as the economy-wide imports relative to total demand. This bias will be large if imports of each input, relative to the total demand for that input, are quite different across sectors, and if changes in the relative prices of imports and domestic products are large.

Biases caused by the import proportionality assumption have zero-sum characteristics. In some sectors, the imports-total demand ratio is higher than the economy-wide average, while in others, the ratio is lower. Therefore, these biases will tend to cancel each other out when we calculate macro-level TFP growth. However, if imports tend to be used more as intermediate inputs and domestic output tends to be used more for satisfying final demand, we will overestimate TFP growth of the macroeconomy when the prices of imports relative to those of domestic output decline.

Using Japan's I-O data from 1995 to 2008, we will analyze how the intermediate input index based on Equation (7.1) moves differently from the intermediate input index based on Equation (7.3).

Next, let us explain our methodology for measuring offshoring bias. The offshoring bias concerns an important caveat regarding our real input index $x_j^J(t)$, which is defined by Equation (7.1) and is based on import I-O tables like Japan's. If quality-adjusted prices of imports i and that of domestic output i are different, then our intermediate input index defined by Equation (7.1) is not appropriate for measuring true intermediate input growth. This issue was first pointed out by Diewert and Nakamura (2011) and empirically examined by Houseman et al. (2011).

If we express the (quality-adjusted) absolute price level of imported products by $P_i^M(t)$ and the (quality-adjusted) absolute price level of domestically produced products by $P_i^H(t)$, then the appropriate input index of sector j for year t is defined by

(7.4)
$$x_j^{\,O}(t) = \frac{\sum_i \left\{ \left(X_{i,j}^{\;M}(T) + X_{i,j}^{\;H}(T) \right) \dfrac{\dfrac{X_{i,j}^{\;M}(t)}{P_i^M(t)} + \dfrac{X_{i,j}^{\;H}(t)}{P_i^H(t)}}{\dfrac{X_{i,j}^{\;M}(T)}{P_i^M(T)} + \dfrac{X_{i,j}^{\;H}(T)}{P_i^H(T)}} \right\}}{\sum_i \left(X_{i,j}^{\;M}(T) + X_{i,j}^{\;H}(T) \right)},$$

where the superscript ^{O} means that this index is based on information on price gaps between domestically produced inputs and imported inputs and is free from offshoring bias.

Assume that imports are cheaper than domestically produced inputs and that both prices, $P_i^M(t)$ and $P_i^H(t)$, are constant over time. Also assume that firms in sector j substitute imports for domestically produced inputs by the same amount, and that imports and domestically produced inputs make the same marginal contribution to production. Then the true intermediate input index must remain constant. Input index $x_j^O(t)$, which is defined by Equation (7.4), satisfies this condition. But both the input index $x_j^J(t)$, which is defined by Equation (7.1), and the input index $x_j^U(t)$, which is defined by Equation (7.3), decline. When we use $x_j^J(t)$ or $x_j^U(t)$, we will judge incorrectly that the intermediate input in sector i has decreased. Thus, we will overestimate the TFP growth of sector i.

Using METI's *Survey on Foreign and Domestic Price Differentials for Industrial Intermediate Input* (METI 1999) and Japan's I-O data, we will evaluate offshoring bias by comparing the intermediate input index $x_j^U(t)$ defined by Equation (7.3) and the intermediate input index $x_j^O(t)$ defined by Equation (7.4).

DATA USED

In this section we explain the data we use for our analysis. For information on the nominal use of imports in the Japanese economy in 1995, 2000, and 2005, we use the Input-Output Tables for Japan for each of these years, published by the Statistics Bureau of the Ministry of Internal Affairs and Communications (MIAC). For these years, tables of imports reporting the nominal value of imports used as inputs in sector j, $X_{i,j}^{M}(t)$, and the nominal value of imports used to satisfy final demand k, $F_{i,k}^{M}(t)$, for each product i are available.

In order to construct these tables on imports, METI, which collaborates with MIAC to compile the I-O tables, conducts its survey on the use of major imports at the HS nine-digit level.[4] Online Appendix Table 7A.1 provides an outline of the questionnaire form, which has been partially filled out by the authors with made-up industry names to illustrate the conceptual framework of the METI survey.[5] About 200 trading companies and producer associations are interviewed; the latter, such as the association of electronics parts producers and the association of automobile parts producers, make up the majority. This means that METI mainly asks the Japanese producers of each commodity about the destination industries for imports of these commodities, most of which are produced by their rivals abroad. (Of course, some Japanese producers are now multinationals and import from their own affiliates abroad.)

To extend our analysis to more recent years, we estimate import input-output tables for 2008 using the 2008 Updated Input-Output Tables and the 2005 Input-Output Tables for Japan. The updated I-O Tables do not contain tables on imports, so we therefore estimate tables on imports by extrapolating data in import tables for 2005 using import data for 2008.

We obtain deflators for imports and domestic output separately for each sector i from the 1995-2000-2005 Linked Input-Output Tables, published by the Statistics Bureau of MIAC, and the 2008 Updated Input-Output Tables. In these I-O tables, the major original sources of deflators for commodities are the Domestic Corporate Goods Price Index (DCGPI) and the Import Price Index (IPI), taken from the Corporate Goods Price Index, published by the Bank of Japan.

Using these various sources, we prepared nominal and real import input-output tables for 1995, 2000, 2005, and 2008. The endogenous sector table for each year has 514 rows and 401 columns. In our analysis, we set 2005 as our benchmark year for our calculation of the quantity and the price index before and after 2005.

Moreover, for data on price gaps necessary for our analysis we use the *Survey on Foreign and Domestic Price Differentials for Industrial Intermediate Input* (METI 1999). This survey has been conducted every year since 1993 and reports differences in the customer delivery price for about 150 intermediate goods and 30 services between Japan on the one hand and the United States, China, Germany, and the newly industrializing economies (NIEs, consisting of South Korea, Hong Kong, Taiwan, and Singapore) on the other. The survey specifies each commodity and service in great detail. In the case of commodities, the survey in principle follows the commodity specification of the Corporate Goods Price Index.

As we will report in detail in Section Five, "Estimation of Offshoring Bias," unit prices in the developing economies included in the survey (i.e., China and the NIEs) for many products tend to be much lower than unit prices in the developed economies (i.e., Japan, the United States, and Germany). This implies that it would be inappropriate to assume, as is done in Equation (7.4), that the unit prices of Japanese imports are identical regardless of the country of origin. We therefore distinguish between imports from developed and from developing economies.

The number of goods and services covered by the survey differs across countries and across years. Data are relatively abundant for U.S.-Japan and China-Japan price differences from 2000, and we therefore use data for the two pairs for 2000 and 2008.[6]

We grouped Japan's trade partners into two groups: 1) developed economies, consisting of the United States and countries that were members of the European Union in 2000, and 2) developing economies, consisting of China and the rest of the world. We assume that price differentials between Japan and the developed economies are the same as the U.S.-Japan price differentials, and that price differentials between Japan and the developing economies are the same as the China-Japan price differentials.

A potential problem is that customer delivery prices in the United States and China reported in METI's survey may include prices of goods imported into the United States and China, but what we would like to know is the price gaps between domestically produced goods and imported goods from China and the United States in Japan. However, because we have no way of knowing whether the customer delivery prices in the United States and China reported in the METI survey include imported goods, we assume that the price gaps reported in the survey are good indicators of the price gaps between domestically produced goods and imported goods in Japan.

Another, related issue is that in Japan's I-O tables, the value of domestic products is given on a producer price basis, while the value of imported products is on a CIF (cost, insurance, and freight) basis. On the other hand, METI's survey reports price gaps between customer delivery prices in Japan and customer delivery prices in other countries. Because of trade costs, it is likely that the ratio of the price of imported products on a CIF basis over the price of domestic products will tend to be higher than the ratio of customer delivery prices in other countries over customer delivery prices in Japan. In order to adjust for this factor, we assume for each commodity that the ratio of the price of imported products on a CIF basis over the price of domestic products is 10 percent higher than the ratio of customer delivery prices in other countries over customer delivery prices in Japan.

In our analysis of offshoring bias, we use 2000 as the base year and set the producer prices of domestic product *i* in year 2000, $P_i^H(2000)$, equal to one for all *i*. We derive the CIF price of product *i* in year 2000 imported from developed economies, $P_i^D(2000)$, and the CIF price of product *i* in year 2000 imported from developing economies, $P_i^L(2000)$, for each *i* using the following equations:

$$(7.5) \quad P_i^D(2000) = 1.1 \frac{\Pi_i^D(2000)}{\Pi_i^H(2000)} P_i^H(2000)$$

and

$$(7.6) \quad P_i^L(2000) = 1.1 \frac{\Pi_i^L(2000)}{\Pi_i^H(2000)} P_i^H(2000) \ ,$$

where $\Pi_i^H(2000)$, $\Pi_i^D(2000)$, and $\Pi_i^L(2000)$ respectively denote the customer delivery price of product *i* in year 2000 in Japan, the United States, and China, which we take from the *Survey on Foreign and Domestic Price Differentials for Industrial Intermediate Input* (METI 1999).

As for the CIF prices of product *i* in Year 2008 imported from developed and developing economies (both developed and developing measured in terms of the producer price of domestic product *i* in Year 2000 in Japan), one way to estimate this is to use the customer delivery price in Year 2008 in Japan, the United States, and China and sectoral deflators in the I-O tables. That is, we can derive the CIF price of product *i* in Year 2008 imported from developed economies, $P_i^D(2008)$, and the CIF price of product *i* in Year 2008 imported from developing economies, $P_i^L(2008)$, for each *i*, as well as the producer price of domestic product *i* in year 2008, $P_i^H(2008)$, for each *i*, using the following equations:

$$(7.7) \quad P_i^D(2008) = 1.1 \frac{\Pi_i^D(2008)}{\Pi_i^H(2008)} \frac{P_i^H(2008)}{P_i^H(2000)} P_i^H(2000),$$

$$(7.8) \quad P_i^L(2008) = 1.1 \frac{\Pi_i^L(2008)}{\Pi_i^H(2008)} \frac{P_i^H(2008)}{P_i^H(2000)} P_i^H(2000), \text{ and}$$

$$(7.9) \quad P_i^H(2008) = \frac{P_i^H(2008)}{P_i^H(2000)} P_i^H(2000),$$

where $\Pi_i^H(2008)$, $\Pi_i^D(2008)$, and $\Pi_i^L(2008)$ denote the customer delivery price of product *i* in Year 2008 in Japan, the United States, and China, respectively. We obtain $P_i^H(2008) / P_i^H(2000)$ from the sectoral deflators in the 1995-2000-2005 Linked Input-Output Tables and the 2008 Updated Input-Output Tables.

We should note that there is another important source of import price change in addition to the combined data of the *Survey on Foreign and Domestic Price Differentials for Industrial Intermediate Input* (METI 1999) and the sectoral deflators in the 1995-2000-2005 Linked Input-Output Tables and the 2008 Updated Input-Output Tables—namely, the import deflators in the I-O tables. The import deflators in the I-O tables are mainly based on the Bank of Japan–published Corporate Goods Price Index, which covers many more commodities and countries of origin than METI's survey. The import deflators in the I-O tables therefore likely are more reliable than our estimates using Equations (7.7), (7.8), and (7.9), but the I-O tables do not contain data on import prices by country of origin or on absolute price gaps. Taking these advantages and disadvantages of the import deflator in the I-O tables into account, we use these deflators as a kind of a control total, as we shall explain below.

The CIF price of product *i* in year 2008 imported from developed economies, $P_i^D(2008)$, and the CIF price of product *i* in year 2008 imported from developing economies, $P_i^L(2008)$, are expected to satisfy the following equation:

$$(7.10)\quad \frac{P_i^M(2008)}{P_i^M(2000)} = m_i^D(2008)\frac{P_i^D(2008)}{P_i^D(2000)} + \left(1 - m_i^D(2008)\right)\frac{P_i^L(2008)}{P_i^L(2000)},$$

where $P_i^M(t)$ denotes Japan's import price of product *i* from the rest of the world in year *t*, and $m_i^D(t)$ denotes the percentage of Japan's imports of product *i* from developed economies in Japan's total imports in 2008. We obtain these data from the Trade Statistics of Japan, published by the Ministry of Finance.

Because of the differences in data sources and other factors (such as the fact that we use price difference data only for the U.S.-Japan and China-Japan pairs, whereas the import deflators in the I-O tables cover all of Japan's imports from the world), $P_i^D(2008)$ and $P_i^L(2008)$, derived from Equations (7.8) and (7.9), do not necessarily satisfy Equation (7.10). To make $P_i^D(2008)$ and $P_i^L(2008)$ consistent with Equation (7.10), we add an adjustment term γ on the right-hand side of Equations (7.8) and (7.9) and redefine $P_i^D(2008)$ and $P_i^L(2008)$ as follows:

$$(7.11)\quad P_i^D(2008) = 1.1\gamma \frac{\Pi_i^D(2008)}{\Pi_i^H(2008)} \frac{P_i^H(2008)}{P_i^H(2000)} P_i^H(2000)$$

and

$$(7.12)\quad P_i^L(2008) = 1.1\gamma \frac{\Pi_i^L(2008)}{\Pi_i^H(2008)} \frac{P_i^H(2008)}{P_i^H(2000)} P_i^H(2000),$$

where γ is defined by

$$\gamma = \frac{\dfrac{P_i^M(2008)}{P_i^M(2000)}}{m_i^D(2008)\dfrac{\dfrac{\Pi_i^D(2008)}{\Pi_i^H(2008)}\dfrac{P_i^H(2008)}{P_i^H(2000)}}{\dfrac{\Pi_i^D(2000)}{\Pi_i^H(2000)}} + \left(1 - m_i^D(2008)\right)\dfrac{\dfrac{\Pi_i^L(2008)}{\Pi_i^H(2008)}\dfrac{P_i^H(2008)}{P_i^H(2000)}}{\dfrac{\Pi_i^L(2000)}{\Pi_i^H(2000)}}}.$$

It can be easily confirmed that $P_i^D(2008)$ and $P_i^L(2008)$, defined by Equations (7.11) and (7.12), satisfy Equation (7.10).

Our input index for sector j for year t, which is based on information on price gaps between domestically produced inputs and imported inputs and is free from offshoring bias, is defined by the following equation:

(7.13)

$$x_j^O(t) = \frac{\sum_i \left\{ \left(X_{i,j}^M(T) + X_{i,j}^H(T) \right) \dfrac{\dfrac{m_i^D(t) X_{i,j}^M(t)}{P_i^D(t)} + \dfrac{\left(1 - m_i^D(t)\right) X_{i,j}^M(t)}{P_i^L(t)} + \dfrac{X_{i,j}^H(t)}{P_i^H(t)}}{\dfrac{m_i^D(T) X_{i,j}^M(T)}{P_i^D(T)} + \dfrac{\left(1 - m_i^D(T)\right) X_{i,j}^M(T)}{P_i^L(T)} + \dfrac{X_{i,j}^H(T)}{P_i^H(T)}} \right\}}{\sum_i \left(X_{i,j}^M(T) + X_{i,j}^H(T) \right)}$$

for $t = 2000, 2008$, and $T = 2000$. This is a modified version of Equation (7.4).

Two additional caveats with regard to our data should be pointed out. First, METI's survey on price differentials does not cover food processing and agricultural, fishery, and forestry output, while the coverage of service output is very limited. Therefore, we calculate price gaps only for the output of the mining and manufacturing sectors other than processed food, and we assume that there are no price differentials in the case of agricultural, forestry, and fishery products; food processing; and services. Moreover, because of this limitation in the data, we excluded the food processing sector from our analysis of the offshoring bias.

Second, even in the case of nonfood commodities, the number of commodities reported in the survey (about 180) is not sufficient for the estimation of price gaps for our disaggregated three-digit-level I-O tables in which we have 285 rows, consisting of the mining sector and of manufacturing sectors other than processed food. Therefore, for industries in the I-O tables that we could not match at the three-digit level, we assumed that the price gap was the same as at the more aggregated two-digit industry level. Moreover, when the METI survey provides price gap data on multiple commodities that correspond to one of the 285 industry rows, we calculate the industry average price gap for that industry by employing the weights used in the METI survey. The original source of the weights is the Corporate Goods Price Index.

ESTIMATION OF BIAS CAUSED BY THE IMPORT PROPORTIONALITY ASSUMPTION

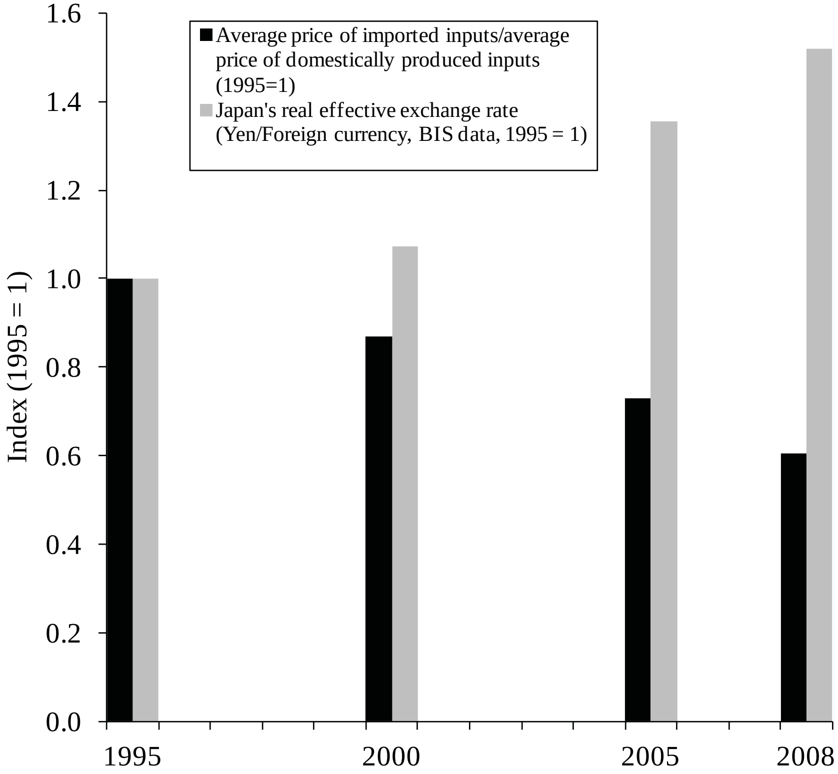
Using our data, we analyze how the prices of imported inputs relative to domestically produced inputs changed between 1995 and 2005, as well as how much the share of imported inputs in total inputs differs across sectors and how this share changed between 1995 and 2005. In addition, we estimate the bias from the import proportionality assumption by comparing the intermediate input index based on information from the tables on imports. We estimate the index based on the assumption that an industry's imports of each input, relative to its total demand, are the same as the economy-wide imports relative to total demand (as is assumed in the I-O tables for the United States).

As we explained in Section Two, "Approach to Measuring the Two Types of Biases," the bias caused by the assumption that an industry's imports of each input, relative to its total demand, are the same as the economy-wide imports, relative to total demand, will be large if changes in the relative prices of imports and domestic products are large and if imports of each input, relative to the total demand for that input, are quite different across sectors.

Figure 7.1 shows how the ratio of the average price index of imported inputs over the average price index of domestically produced inputs has changed over time. As can be seen, the ratio declined by 40 percent in the period 1995–2008. This decline was not caused by yen appreciation, since, as Figure 7.1 also shows, the value of the yen as measured by the real effective exchange rate fell by more than 50 percent during the same period. Rather, a likely reason for the decline in relative import prices is the increase in Japan's imports of low-priced products from Asian countries and the decline of output price in countries of origin.[7]

Figure 7.2 shows the regional composition of Japan's imports of manufactured products for 2000, 2005, and 2008. Similarly, Figure 7.3 shows the regional composition of Japan's imports of machinery for

Figure 7.1 Average Price of Imported Inputs over Average Price of Domestically Produced Inputs (1995 = 1) and Japan's Real Effective Exchange Rate (yen/foreign currency): 1995–2008

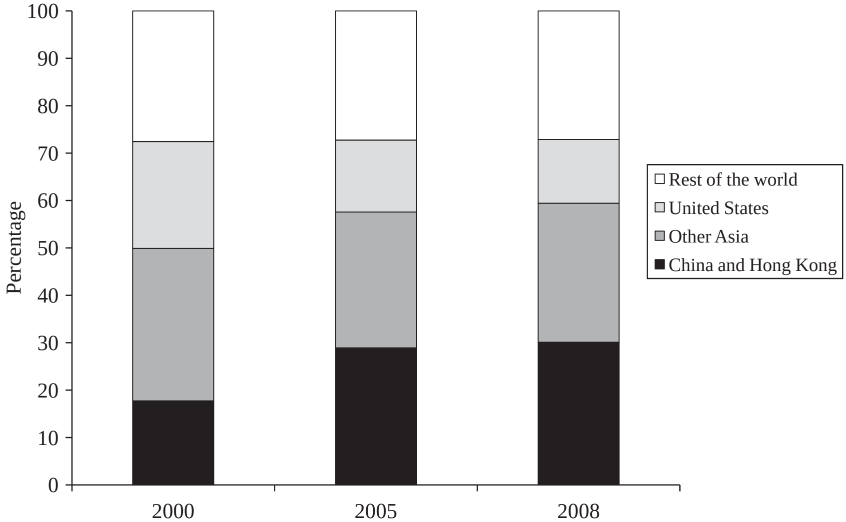


NOTE: "BIS" stands for Bank for International Settlements.
SOURCE: 1995-2000-2005 Linked Input-Output Tables, published by the Statistics Bureau of the Ministry of Internal Affairs and Communications (MIAC); 2008 Updated Input-Output Tables, published by the Ministry of Economy, Trade, and Industry (METI); and effective exchange rate, Bank of Japan.

2000, 2005, and 2008. The figures show that the share of imports from China and other Asian countries in Japan's total manufacturing and machinery imports increased rapidly in the 2000s.

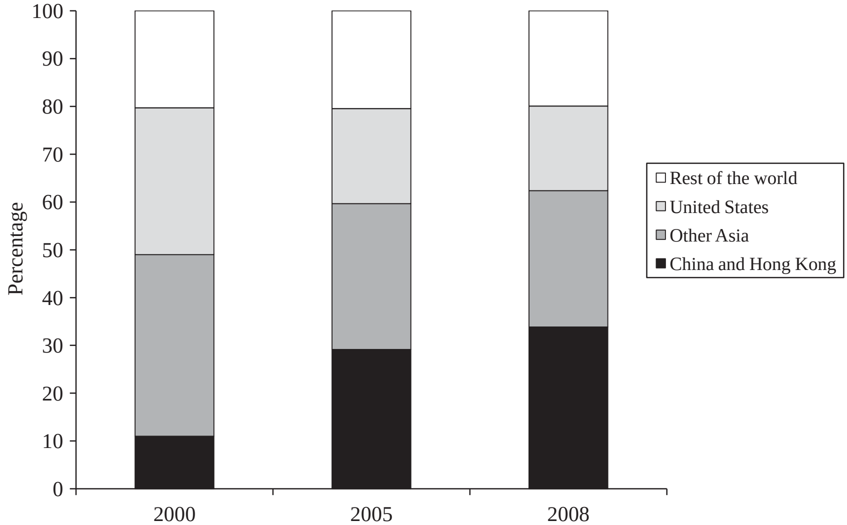
Next, Online Appendix Table 7A.2 provides a list of commodities for which the ratio of the price of imports over the price of domestic

Figure 7.2 Regional Composition of Japan's Imports of Manufactured Products: 2000, 2005, and 2008



SOURCE: Trade Statistics of Japan, published by the Ministry of Finance.

Figure 7.3 Regional Composition of Japan's Imports of Machinery: 2000, 2005, and 2008



SOURCE: Trade Statistics of Japan, published by the Ministry of Finance.

products declined by more than 25 percent from 1995 to 2008. The table confirms that the import price–domestic price ratio of many commodities, including important parts and components, sharply declined during the period. For instance, in the case of integrated circuits and semiconductor devices, the relative price declined by 33 percent and 28 percent, respectively.

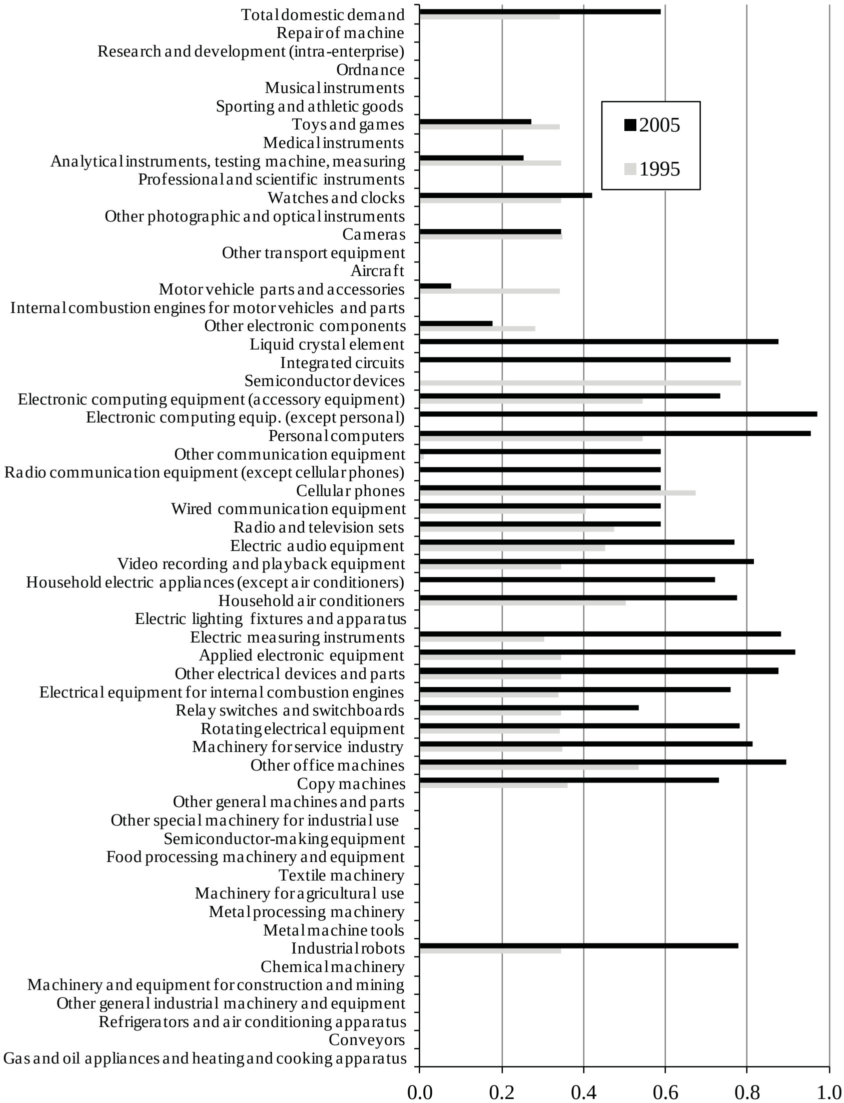
The next issue we examine is how much the share of imported inputs in total inputs differs across sectors, and how this share has changed over time. We do so by two illustrations, Figures 7.4 and 7.5, that use the examples of integrated circuits and semiconductor devices, which are important inputs in manufactured products.

Starting with integrated circuits, the nominal value of total intermediate inputs increased from 3.0 trillion yen in 1995 to 3.6 trillion yen in 2005.[8] While this increase in the nominal value is not particularly large, intermediate input in real terms in fact increased threefold. The share of the total nominal input of imports in total nominal input increased from 34 percent to 58 percent. The increase in the share of the total nominal input of imports was even more pronounced in the case of semiconductor devices, where it jumped from 18 percent to 61 percent.

However, as can be seen in Figures 7.4 and 7.5, the share of imports in total demand differs considerably across sectors. In the case of both figures, the import ratio tends to be high in electrical machinery sectors but relatively low in other sectors such as automobiles and precision machinery. This means that we will underestimate the growth of these electronics parts inputs in electrical machinery sectors and overestimate it in other machinery sectors if we assume that an industry's imports of each input, relative to its total demand, are the same as the economy-wide imports relative to total demand.

We calculate the extent of underestimation, $\ln(x_j^U(2008) / x_j^I(2008)) - \ln(x_j^U(1995) / x_j^I(1995))$, for all of the 202 manufacturing sectors, other than processing food, and all of the six mining sectors, using our data. Table 7.1 shows the 25 sectors in which the underestimation of intermediate input growth is largest among these 208 mining and manufacturing sectors.[9] By multiplying this value with two values—that is, with −1 and with the average of the nominal intermediate input–nominal gross output ratio of a particular sector for 1995 and 2008, we also calculate the extent of the overestimation of TFP growth for the period 1995–2008.

Figure 7.4 Share of Imported Inputs in Total Inputs: Integrated Circuits, 1995–2005



SOURCE: 1995 and 2005 Input-Output Tables, published by the Statistics Bureau of MIAC.

Figure 7.5 Share of Imported Inputs in Total Inputs: Semiconductor Devices, 1995–2005

SOURCE: 1995 and 2005 Input-Output Tables, published by the Statistics Bureau of MIAC.

Table 7.1 Underestimation of Intermediate Input Growth as a Result of the Import Proportionality Assumption: Top 25 Sectors, 1995–2008

Sector	Underestimation of intermediate input growth, $\ln(x^U/x^J)$ (%, 1995–2008) A	Intermediate input/gross output (average value of 1995 and 2008) B	Overestimation of TFP growth on a gross output basis (%, 1995–2008) A × B
Animal oils and fats	−14.04	0.715	10.04
Ordnance	−12.62	0.619	7.81
Aircrafts	−9.85	0.538	5.29
Liquid crystal elements	−8.13	0.727	5.91
Methane derivatives	−6.90	0.742	5.12
Organic fertilizers, n.e.c.	−4.49	0.657	2.95
Video recording and playback equipment	−4.25	0.722	3.07
Thermo-setting resins	−4.13	0.733	3.03
Salt	−4.13	0.546	2.25
Bicycles	−3.73	0.720	2.68
Turbines	−3.38	0.643	2.17
Glass fiber and glass fiber products, n.e.c.	−3.20	0.604	1.93
Integrated circuits	−2.62	0.650	1.70
Processed meat products	−2.62	0.710	1.86
"Tatami" (straw matting) and straw products	−2.47	0.703	1.74
Wooden chips	−2.39	0.733	1.75
Other resins	−2.34	0.749	1.75
Other glass products	−1.94	0.537	1.04
Nonferrous metal castings and forgings	−1.85	0.703	1.30
Dextrose, syrup, and isomerized sugar	−1.72	0.820	1.41
High function resins	−1.49	0.778	1.16
Electronic computing equipment (except personal computers)	−1.45	0.716	1.04
Optical fiber cables	−1.28	0.740	0.95
Applied electronic equipment	−1.22	0.716	0.88
Watches and clocks	−1.21	0.630	0.76

SOURCE: Authors' calculations.

In the top 14 sectors in which the underestimation of intermediate input growth caused by the import proportionality assumption is largest (namely, animal oils and fats, ordnance, aircraft, liquid crystal elements, methane derivatives, organic fertilizers not elsewhere classified, video recording and playback equipment, thermo-setting resins, salt, bicycles, turbines, glass fiber and glass fiber products not elsewhere classified, integrated circuits, and processed meat products), the negative bias of intermediate input growth caused by the import proportionality assumption is more than 2.6 percent, and the positive bias of TFP growth is more than 1.7 percent. These sectors include important high-tech machinery sectors, such as aircraft and integrated circuits.

Next, Table 7.2 shows the 27 sectors in which the overestimation of intermediate input growth is largest among all the manufacturing sectors. These include six sectors—cellular phones, radio and television sets, coal products, other nonferrous metal products, repair of aircraft, and other photographic and optical instruments—where the positive bias of intermediate input growth is at least 3.25 percent, and the negative bias of TFP growth is more than 1.9 percent.

ESTIMATION OF OFFSHORING BIAS

Using our data, we estimate offshoring bias by comparing the real input index based on information on the price gaps between domestically produced and imported intermediate inputs. That is, we estimate Equation (7.13) in Section Three ("Data Used"), which is a modified version of Equation (7.4) in Section Two ("Approach to Measuring the Two Types of Biases"). We also estimate the real input index, based on the assumption that an industry's imports of each input, relative to the total demand for that input, are the same as the economy-wide imports relative to total demand (as is assumed in the I-O tables for the United States)—i.e., Equation (7.3) in Section Two. For the estimation, we use the year 2000 as our base year and calculate how the two types of intermediate input indexes for each sector changed from 2000 to 2008. In addition, we analyze how much of a price gap there exists between domestically produced intermediate inputs, inputs imported from devel-

Table 7.2 Overestimation of Intermediate Input Growth as a Result of the Import Proportionality Assumption: Top 27 Sectors, 1995–2008

Sector	Overestimation of intermediate input growth, $\ln(x^U/x^J)$ (%, 1995–2008) A	Intermediate input/gross output (average value of 1995 and 2008) B	Underestimation of TFP growth on a gross output basis (%, 1995–2008) A × B
Cellular phones	5.49	0.782	−4.30
Radio and television sets	5.47	0.780	−4.27
Coal products	4.04	0.825	−3.33
Other nonferrous metal products	3.70	0.715	−2.64
Repair of aircraft	3.49	0.656	−2.29
Other photographic and optical instruments	3.25	0.592	−1.92
Confectionery	3.04	0.580	−1.76
Electric audio equipment	2.96	0.742	−2.20
Leather and fur skins	2.87	0.692	−1.98
Bottled or canned vegetables and fruits	2.69	0.770	−2.07
Chemical fertilizer	2.54	0.685	−1.74
Other electrical devices and parts	2.41	0.630	−1.52
Retort foods	2.40	0.704	−1.69
Dishes, sushi, and lunch boxes	2.16	0.697	−1.50
Synthetic dyes	2.12	0.649	−1.38
Other metal products	1.88	0.463	−0.87
Batteries	1.80	0.733	−1.32
Other electronic components	1.78	0.690	−1.23
Medicaments	1.67	0.608	−1.01
Dairy farm products	1.49	0.779	−1.16
Steel pipes and tubes	1.42	0.759	−1.08
Other industrial organic chemicals	1.26	0.672	−0.84
Soap, synthetic detergents, and surface active agents	1.21	0.715	−0.86
Synthetic fibers	1.21	0.633	−0.77
Preserved agricultural foodstuffs (other than bottled or canned)	1.21	0.631	−0.76
Nuclear fuels	1.21	0.541	−0.65
Inorganic pigment	1.18	0.687	−0.81

SOURCE: Authors’ calculations.

oped economies, and inputs imported from developing economies, as well as how these price gaps changed from 2000 to 2008.

As Diewert and Nakamura (2011) and Houseman et al. (2011) explain, offshoring bias tends to be greater when there are large price gaps between domestically produced intermediate inputs and imported inputs and when firms substitute imports for domestically produced inputs to a substantial extent.

Online Appendix Figures 7A.1 and 7A.2 show our results for estimating the price gaps between domestically produced intermediate inputs, inputs imported from developed economies, and inputs imported from developing economies for 2000 and 2008, respectively. For the calculation, we use Equations (7.5), (7.6), (7.9), (7.11), and (7.12). In the two figures, the price levels of domestically produced products are set to 1 for both 2000 and 2008. Moreover, for the figures, we aggregate the estimated price gaps for the 285 sectors into 53 sectors. As explained in Section Three, titled “Data Used,” our estimation of the price gaps between developed economies and Japan is based on U.S.-Japan price differentials, and our estimation of the price gaps between developing economies and Japan is based on China-Japan price differentials.

The two figures show that in the case of price gaps between domestically produced inputs and inputs imported from developed economies, domestically produced inputs are not always more expensive than imported inputs. On the contrary, in many sectors, including most of the machinery sectors, the price level of domestically produced inputs was lower than the price level of inputs imported from developed economies, both in 2000 and in 2008.

In the case of price gaps between domestically produced inputs and inputs imported from developing economies, imported inputs are cheaper than domestically produced inputs in most of the sectors. Moreover, in both 2000 and 2008, the price gap is considerable, not only in the case of most of the light-industry products (such as apparel and other textile products, timber and wooden products, and fur skins and miscellaneous leather products), but also in the case of most machinery products.

In comparing the price gaps between domestically produced inputs and inputs imported from developing economies in 2000 and 2008, the gaps do not seem to have widened in most sectors, although there are some exceptions such as electronic computing equipment and accessories as well as semiconductor devices and integrated circuits. In fact, price gaps narrowed slightly in some sectors, probably because of rapid increases in wages in China (as well as appreciation of the Chinese exchange rates).

These results suggest that during this period there was no large offshoring bias caused by a sharp decline in the prices of inputs imported from developing economies, except in the case of the electrical machinery industry. However, even though prices of imported inputs generally may not have fallen, it is still possible that there was substantial offshoring bias as a result of the rapid increase of imported inputs at prevailing price gaps. As seen in Figures 7.2 and 7.3, the share of imports of manufactured products from China, Hong Kong, and other Asian economies in Japan's total imports increased considerably between 2000 and 2008. Moreover, Figure 7.6 shows that Japan's imports of machinery increased not only in the case of final goods but also in the case of many types of parts and components.

To examine whether the rapid rise in imported inputs from developing countries gave rise to offshoring bias, we calculate the extent of underestimation of intermediate input growth, $\ln(x_j^U(2008) / x_j^O(2008)) - \ln(x_j^U(2000) / x_j^O(2000))$, using our data. By multiplying this value with −1 and with the average value of the nominal intermediate input–nominal gross output ratio of a particular sector for 2000 and 2008, we also calculate the extent of the overestimation of TFP growth for the period 2000–2008.

Table 7.3 shows the 27 sectors in which the underestimation of intermediate input growth is largest among all of the 208 mining and manufacturing sectors other than food processing. Probably reflecting the fact that Japan's imports of cheap electrical parts and components from developing economies have increased substantially, the 27 sectors include many electrical machinery sectors such as liquid crystal elements, personal computers, electronic computing equipment (except personal computers), and electric measuring instruments. Among the 27 sectors, about half produce machinery.

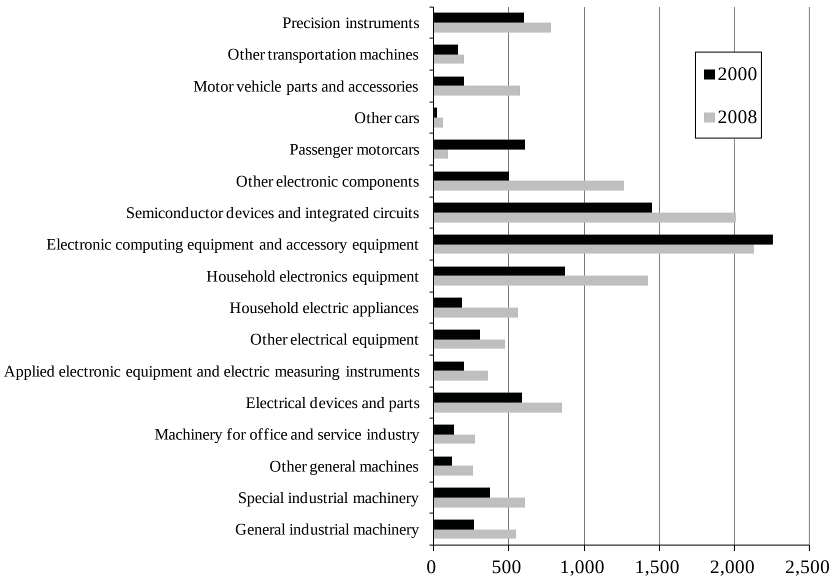
In many sectors, especially in machinery sectors, offshoring bias is of a substantial size that cannot be ignored. For example, Table 7.3 shows that the TFP growth rate in liquid crystal elements and in personal computers is overestimated by 5.92 percent and 5.34 percent,

Table 7.3 Underestimation of Intermediate Input Growth and Total Factor Productivity Growth from Offshoring Bias: Top 27 Sectors, 2000–2008

	Underestimation of intermediate input growth, $\ln(x^U/x^O)$ (%, 2000–2008)	Intermediate input/gross output (average value of 2000 and 2008)	Overestimation of TFP growth on a gross output basis (%, 2000–2008)
Sector	A	B	A×B
Tatami (straw matting) and straw products	−15.47	0.738	11.41
Nuclear fuels	−13.14	0.551	7.24
Toys and games	−9.92	0.700	6.95
Pumps and compressors	−8.90	0.644	5.73
Rayon and acetate	−8.84	0.678	6.00
Other nonmetallic ores	−8.55	0.578	4.94
Liquid crystal element	−8.21	0.721	5.92
Metallic ores	−7.78	0.465	3.62
Salt	−7.10	0.535	3.80
Repair of aircraft	−6.87	0.674	4.63
Pulp	−6.87	0.858	5.90
Food processing machinery and equipment	−6.85	0.582	3.98
Sheet glass and safety glass	−6.72	0.582	3.91
Personal computers	−6.56	0.814	5.34
Paperboard	−6.36	0.722	4.59
Other nonferrous metal products	−6.29	0.706	4.44
Electronic computing equipment (except personal computers)	−6.25	0.748	4.68
Electric measuring instruments	−6.24	0.660	4.12
Other office machines	−6.13	0.737	4.52
Coal mining, crude petroleum, and natural gas	−5.84	0.428	2.50
Boilers	−5.66	0.575	3.25
Textile machinery	−5.46	0.594	3.24
Machinists' precision tools	−5.44	0.540	2.93
Bearings	−5.40	0.596	3.22
Other structural clay products	−4.87	0.537	2.62
Chemical machinery	−4.77	0.574	2.74
Other wooden products	−4.75	0.547	2.60

SOURCE: Authors' calculations.

Figure 7.6 Japan's Imports of Machinery from Developing Economies: 2000 and 2008 (billions of yen)



SOURCE: Trade Statistics of Japan, published by the Ministry of Finance.

respectively (the annual rate in log value is 0.74 percent and 0.67 percent, respectively).

We should note that the biases shown in Table 7.3 contain both biases caused by the import proportionality assumption and biases caused by gaps in the absolute price levels between imported products and domestically produced products. It is probably for this reason that many electrical machinery sectors such as liquid crystal elements, personal computers, electronic computing equipment (except personal computers), and electric measuring instruments appear in both Tables 7.1 and 7.3.

Comparing Tables 7.1 and 7.3, we also find that the biases in Table 7.3 tend to be much larger than those in Table 7.1, although the period covered by Table 7.3 is five years shorter than the period covered by Table 7.1. The minimum value of the bias in TFP growth in Table 7.3 is 3.04 percent (for leather and fur skins), which is much larger than the minimum value of the bias in TFP growth in Table 7.1, 0.70 percent (for cameras). It seems that biases caused by gaps in the absolute price levels between imported products and domestically produced products are a more serious problem than biases caused by the import proportionality assumptions.

In the case of the overestimation of intermediate input growth, such overestimation occurred in only 29 out of the 208 mining and manufacturing sectors other than food processing. In other words, in 179 sectors, intermediate inputs were underestimated. Among the 29 overestimated sectors, only five sectors produce machinery. We also find that in many sectors the magnitude (absolute value) of the underestimation of TFP growth caused by offshoring bias is smaller than the magnitude (absolute value) of the overestimation of TFP growth caused by offshoring bias, which is reported in Online Appendix Table 7A.3.

As pointed out in Section Two, biases caused by the import proportionality assumption have zero-sum characteristics. In some sectors, the imports–total demand ratio is higher than the economy-wide average, while in others, the ratio is lower. Therefore, these biases will tend to cancel each other out when we calculate macro-level TFP growth.

However, offshoring biases do not have such zero-sum characteristics. If a majority of sectors shift their sourcing from high-cost domestic suppliers to low-cost foreign suppliers, then the TFP growth of all these sectors will be overestimated, and the TFP growth of the economy as a whole will also be overestimated. Table 7.3 and Online Appendix Table 7A.3 show that TFP growth was overestimated in 179 out of the 208 mining and manufacturing sectors during the period 2000–2008. It therefore seems likely that the TFP growth of Japan’s economy as a whole during this period may also have been overestimated.

CONCLUSION

Using import tables and other data from Japan’s input-output tables for 1995, 2000, 2005, and 2008, we estimated how much and in what direction the intermediate input index and TFP growth will be biased if we assume that an industry’s imports of each input, relative to the total demand for the input, are the same as the economy-wide imports relative to total demand. We also examined offshoring bias, which concerns the price gap between domestically produced inputs and imported inputs. For this analysis, we used the *Survey on Foreign and Domestic Price Differentials for Industrial Intermediate Input* (METI 1999) in addition to I-O tables.

Our main findings are listed in the following 10 points:

1) Our theoretical analysis shows that the bias caused by the import proportionality assumption will be large if imports of each input, relative to the total demand for it, are quite different across sectors and changes in the relative prices of imports and domestic products are large.

2) Japan experienced a 40 percent decline in the ratio of the average price of imported inputs over the average price of domestically produced inputs in the period 1995–2008. This decline was not caused by yen appreciation, since the value of the yen as measured by the real effective exchange rate in fact fell by more than 50 percent during the same period. Rather, a likely reason for the decline in relative import prices is the increase in Japan's imports of low-priced products from Asian countries.

3) The import price–domestic price ratio of many commodities, including important parts and components, declined sharply during the period 1995–2008.

4) We examined how the share of imported inputs in total inputs differs across sectors, focusing on the cases of integrated circuits and semiconductor devices. We found that for both types of input, the import ratio tends to be high in the electrical machinery sectors. Moreover, the ratio is relatively low in other sectors such as automobiles and precision machinery.

5) We found that the bias caused by the import proportionality assumption is quite large in some sectors. For example, in animal oils and fats, ordnance, aircraft, liquid crystal elements, methane derivatives, organic fertilizers not elsewhere classified, video recording and playback equipment, thermo-setting resins, salt, bicycles, turbines, glass fiber and glass fiber products not elsewhere classified, integrated circuits, and processed meat products, the negative bias of intermediate input growth

caused by the import proportionality assumption is more than 2.6 percent, and the positive offshoring bias of TFP growth is more than 1.7 percent.

6) On the other hand, in cellular phones, radio and television sets, coal products, other nonferrous metal products, repair of aircraft, and photographic and optical instruments, the positive offshoring bias of intermediate input growth is more than 3.2 percent, and the negative offshoring bias of TFP growth is more than 1.9 percent.

7) Next, we estimated offshoring biases caused by the price gap between domestically produced inputs and imported inputs and the substitution of intermediate inputs from expensive domestic products to cheap foreign products. In the case of price gaps between domestically produced inputs and inputs imported from developing economies, imported inputs are cheaper than domestically produced inputs in most sectors. Moreover, in both 2000 and 2008, the price gap was relatively large not only in the case of most light industry products, such as apparel and other textile products, timber and wooden products, and fur skins and miscellaneous leather products, but also in the case of most machinery products.

8) In the 2000s, Japan's imports of machinery from developing economies increased not only in the case of final goods but also in the case of many types of parts and components. As a result of the rapid increase of imported inputs at prevailing price gaps, in many sectors, especially in machinery sectors, a substantial offshoring bias arose that cannot be ignored. For example, the TFP growth rates for the liquid crystal elements and personal computers sectors are overestimated by 5.92 percent and 5.34 percent, respectively. (The annual rates in log value were 0.74 percent and 0.67 percent.)

9) Reflecting the fact that Japan's imports of cheap electrical parts and components from developing economies increased substantially, the 50 sectors in which the underestimation of intermediate input growth is largest include many electrical machinery sectors such as liquid crystal elements, personal computers,

electronic computing equipment (except personal computers), and electric measuring instruments.

10) Biases caused by the import proportionality assumption have zero-sum characteristics. In some sectors, the imports-total demand ratio is higher than the economy-wide average, while in others, the ratio is lower. Therefore, these biases will tend to cancel each other out when we calculate macro-level TFP growth. In contrast, offshoring biases do not have such zero-sum characteristics. If most sectors shifted their sourcing from high-cost domestic suppliers to low-cost foreign suppliers, then the TFP growth of these sectors would be overestimated. In this case, the TFP growth of the economy as a whole would also be overestimated. We found that during the period 2000–2008 TFP growth was overestimated as a result of offshoring bias in 179 out of the 208 mining and manufacturing sectors we examined. Consequently, Japan's TFP growth at macro-level during this period may also be overestimated.

One of the key findings is that there are relatively large biases due to offshoring in a substantial number of manufacturing sectors, including important machinery sectors. This means that the issue of biases from offshoring should be taken into account in future productivity analyses at the sectoral and firm levels. Moreover, since offshoring activities are likely to continue increasing, data collection by statistical offices to grapple with such offshoring biases will be of growing importance.

Notes

This research was conducted as part of the Research Institute of Economy, Trade, and Industry's (RIETI's) East Asian Industrial Productivity Project. We would also like to express our thanks for financial support from the Global Centers of Excellence program Research Unit for Statistical and Empirical Analysis in Social Sciences (G-COE Hi-Stat), Hitotsubashi University.

1. A good discussion of these types of biases is provided in the next chapter, Chapter 8.
2. For ease of presentation, it is assumed here that each sector produces one product, so subscript i is used to refer to both sectors and products.
3. Our quantity indexes are based on the Laspeyres formula for years after the base year T and on the Paasche formula for years before T.

4. In 2013, this survey became one of Japan's General Statistics and is now called the Survey on Input-Output Structure (Survey on Sale Destination of Import Goods).
5. The online appendix, containing Appendix Tables 7A.1, 7A.2, and 7A.3 and Appendix Figures 7A.1 and 7A.2, can be found at http://www.upjohn.org/MEG/Ch7appendix.pdf.
6. In the case of the 2000 survey, the survey investigates absolute price levels in each country's currency during the period September–November 2000 and converts these prices into prices in Japanese yen using average market exchange rates during the survey period. The exchange rates were 108.00 yen to the U.S. dollar and 13.05 yen to the Chinese yuan. In the case of the 2008 survey, the survey period was July–September 2008, and the exchange rates were 107.60 yen to the U.S. dollar and 15.74 yen to the Chinese yuan.
7. As already explained, we obtain deflators for imports and domestic output separately for each sector *i* from the 1995-2000-2005 Linked Input-Output Tables published by the Statistics Bureau, MIAC, and the 2008 Updated Input-Output Tables. In these I-O tables, the major original sources for deflators for commodities are the Domestic Corporate Goods Price Index (DCGPI) and the Import Price Index (IPI), both taken from the Corporate Goods Price Index, published by the Bank of Japan. When the Bank of Japan compiles the IPI, it specifies each commodity in great detail and tracks price changes of the same commodity from the same country of origin. Therefore, a shift of imports from high-price countries to low-price countries will not affect the IPI and the deflators of the I-O tables. However, in the case of some imported raw materials and manufactured products, for which IPI data are not available, the I-O tables use the unit price of imports as deflators. In the case of these products, a shift of imports from high-price countries to low-price countries will reduce the deflators in the I-O tables. Therefore, the decline in relative import prices in Figure 7.1 reflects not only the decline of output prices in countries of origin but also the increase in Japan's imports of low-priced products from Asian countries. We should also note that in the case of these products, for which unit prices from the trade statistics are used as import deflators, Equation (7.10) does not strictly hold. When the unit prices of imports decline because of a shift from high-cost exporters to low-cost exporters, there is a risk that Equations (7.11) and (7.12) will overestimate the price decline in exporting countries.
8. The reason that we focus on the period up to 2005 and not up to 2008 here is that we had to estimate the table on imports for 2008; we therefore think that the table on imports for 2005 is more reliable.
9. The reason that we are focusing only on 208 and not 285 industries is as follows: As explained in Section Three, titled "Data Used," the endogenous table we use is not symmetric. The table for each year has 514 rows and 401 columns. Out of the 514 rows, 285 are for mining and manufacturing sectors other than food processing. We prepared our special data on prices and imported intermediate inputs by country of origin and other categories for these 285 row sectors. Out of the 401 columns, 208 are for mining and the manufacturing sectors other than food processing. We calculated biases of intermediate inputs and TFP growth for these 208 column sectors.

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8
Import Allocation across Industries, Import Prices across Countries, and Estimates of Industry Growth and Productivity

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The increased role of international trade in U.S. economic activity is evident in the headline gross domestic product (GDP) statistics. Between 1948 and 1965, the value of imports of goods and services relative to gross domestic product held steady at about 4 percent. By the end of the 1970s this ratio had grown to close to 10 percent, and it remained at about 10 percent through the end of the 1980s. Between 1990 and 2000, imports relative to GDP increased to nearly 15 percent, and they peaked at 17.9 percent of GDP in 2008. During the events surrounding the financial crisis in 2009 and 2010, imports fell relative to GDP, but the value of imported goods and services relative to GDP bounced back to 17.6 percent of GDP in 2011.

While the trend of increased reliance on imports within the U.S. economy is clear, the uses of these imports within the economy are subsumed in the aggregate data. Given the published level of detail in the National Income and Product Accounts (NIPAs), which measure GDP from the expenditure side, it is difficult to analyze major questions about the economic impact of increased imports on the economy. More importantly, it is not possible to quantify how imports are used by industries in their production processes, and how these substitutions affect the economy as a whole. The most-often-studied economic impacts are the effects of increased globalization on U.S. labor markets and industry competitiveness.

The economic impact of imports depends on how the imports are used. For example, a particular import could be made for any of three purposes: 1) for direct consumption by households, 2) for a select group of industries as an intermediate input, or 3) for a broad set of industries as a substitute for goods that are already produced domestically. While each of these scenarios has ramifications for the production and labor-market decisions of U.S. producers, as well as for U.S. industry competitiveness, the implications across the economy may be significantly different. In one case, an import may be a close substitute for a good that is *used* by only one industry. In this case, not only are the U.S.-based suppliers of the competitive good affected, but the suppliers to the original domestic producers are affected as well, through reduced demand for their production of intermediate goods. In another case, an import may be a substitute for a good that is *produced* by only one industry. In this case, the production of the industry itself is affected, as are all of the suppliers that sell to the producing industry, and all of the industries that produce similar products and face new competition. Thus, analyzing the overall impact of imports on the U.S. economy requires a set of transaction data that accounts for interindustry linkages.

Empirical research on the effects of increasing imports on the U.S. economy has focused both on the broad economic impact of increased trade and on the industry-specific effects. A large body of research has examined the impact of increased trade on wages in the United States. For example, Feenstra and Hanson (1999) argue that, depending on the specification, outsourcing accounted for between 15 and 40 percent of the increase in the nonproduction-to-production relative wage rate between 1979 and 1990. Lawrence and Slaughter (1993) argue that international trade did not play a major role in the slow growth of real hourly compensation in the United States between 1973 and 1991, but Haskel et al. (2012) conclude that the effects of globalization on the labor market became more important in the early 1990s. Eldridge and Harper (2012) econometrically estimate the impact of imports on production processes in the manufacturing sector, while Kurz and Lengermann (2008) and Yuskavage, Strassner, and Medeiros (2008) analyze the contribution of offshoring to economic growth in the United States.

Analyzing the effects of imports across industries on the economy requires data on the use of imports by industry and by type of import. Houseman et al. (2011) argue that measurement issues related to imports result in an overstatement of growth in the official statistics on value-added and productivity growth in the manufacturing sector, a conclusion that may also have implications for economic research that relies on this type of data.

Two major issues related to assembling the data necessary to analyze the effects of increasing imports on the U.S. economy are that 1) imports used by industry and categorized by detailed type of import are not available at the necessary level of detail in the source data, and 2) shifts to lower-cost suppliers of imports are not captured in the price data, according to Houseman et al. (2011).

These two data issues are directly related to a primary objective of the Industry Directorate at the Bureau of Economic Analysis (BEA). Two major functions of the directorate are the production of estimates of 1) value-added growth by industry and 2) industry value-added contributions to aggregate growth; the directorate also estimates price and quantity inputs used by industry. When an import, at the level of detail in which the accounts are constructed, cannot be treated as a perfect substitute for the domestically produced good, either because of a lower price for the same good or because of quality or compositional differences, the estimation of real value-added at the industry level requires estimates of the value of imports used by industry by type of import, as well as estimates of each import's respective price.

As the body of research on the economic impact of globalization grows, these measurement issues have come to the forefront. Feenstra and Romalis (2012) construct a trade model that incorporates product quality and produces a quality-adjusted set of import and export prices to be used in the new generation of the Penn World Table. In Chapter 4 of this volume, Bridgman analyzes how to adjust import prices for quality differences in the presence of fixed market entry costs. Motivated by Houseman et al. (2011), Inklaar, in Chapter 6 of this volume, estimates the impact of import sourcing bias on 38 major economies over the 1995–2008 period.

In this chapter, we provide an overview of the role of imports in current measurement practices at the BEA in constructing estimates of value-added growth by industry. We compare these baseline accounts to alternative estimates that differ in their approach to estimating imported goods purchased as intermediate inputs. In particular, using broad economic categories (BEC), we employ a two-step approach to produce an alternative industry import-use matrix that underlies the estimates of the quantity index of intermediate inputs used across industries in the U.S. economy between 1998 and 2011. We also examine the import price data and, based on Inklaar (see Chapter 6), analyze an alternative price covering 2002–2011 that treats switches in sourcing between exporting countries as switches to goods with different prices, as opposed to switches to a heterogeneous good. In contrast to Inklaar, we present results at the industry level.

Overall, we frame the analysis in the context of an industry-level production account that provides the sources of U.S. economic growth across industries, factors of production, and multifactor productivity. Our approach focuses on the measurement of imported goods, but it also analyzes the impact on all industries within the economy that purchase these goods. We use the industry production account and growth accounting techniques to compare the baseline case of current practice to three alternatives: 1) an alternative import-use matrix for 1998–2011, 2) an alternative set of import prices for 2002–2011, and 3) both the alternative import-use matrix and the alternative set of import prices for 2002–2011.

Our major findings are as follows:

- Compared to the standard import proportionality assumption, the use of broad economic categories to allocate imports to intermediate inputs produces noticeably different distributions for many commodities, but this does not translate to significantly different import shares of intermediate inputs across most industries.
- The alternative assumptions we consider on import use and import prices have only a small impact on measures of aggregate real value-added and multifactor productivity growth. Over the 1998–2011 period, value-added grew by 1.87 percent a year in the baseline and by 1.87 percent a year based on the alternative import allocation. For the 2002–2011 period, aggregate value-added increased by 1.38 percent a year in the base-

line compared with a range of between 1.34 and 1.37 percent under the alternatives. Over the same period, multifactor productivity (MFP) increased by 0.42 percent a year in the baseline compared with a range of between 0.38 and 0.41 percent a year under the alternatives.

- The impact on real value-added and MFP for the manufacturing sector is also small: over the 2002–2011 period, manufacturing contributed 0.22 percentage points a year to aggregate value-added growth in the baseline, compared with a range of between 0.20 and 0.21 percentage points a year under the alternatives.
- For manufacturing excluding "Computer and electronic products," value-added growth was −0.13 percent a year between 2002 and 2011 in the baseline and ranged from −0.21 to −0.16 percent a year under the alternatives.

The chapter proceeds along the following outline: In Section Two, "The BEA Industry Accounts and the Role of Imports," we provide an overview of the current measurement practices in the BEA industry accounts, including the approach to accounting for imports across industries and their prices. In Section Three, "Alternative Import Allocation Using Broad Economic Catagories," we discuss our alternative import-use matrix, while in Section Four, "Import Prices and Country-Pooled Import Prices," we discuss the alternative set of import prices. Section Five, "Value-Added and Productivity under Alternative Import Assumptions," gives our results for the sources of U.S. economic growth under the baseline and alternative assumptions, and Section Six presents the conclusion.

THE BEA INDUSTRY ACCOUNTS AND THE ROLE OF IMPORTS

A major objective of the Industry Directorate at the Bureau of Economic Analysis is the production both of estimates of gross domestic product by industry and of estimates of contributions of industry GDP to aggregate GDP growth.[1] These measures of value-added by industry, which are published at the 65-sector level, require nominal values, prices, and quantities of industry output and intermediate input over time that are consistent with GDP measured from the expenditure side as part of the NIPAs. Real value-added is calculated using the double deflation method, so that real value-added growth is the difference between the growth rate of industry output, deflated by the appropriate output deflator, and the growth rate of industry input, deflated by an industry input deflator that reflects the heterogeneity of the input use of the industry. Mayerhauser and Strassner (2010) provide a complete description of the methodology used to construct the time series of industry accounts.

The starting point for the published time series of industry accounts is the benchmark input-output account produced approximately every five years. The most recent published version covers the year 2002 and is described by Stewart, Stone, and Streitwieser (2007). This account, while published at about the 550-industry level, is constructed at about the 900-industry level and the 5,000 "item," or product, level, and relies heavily on data tabulated by the Census Bureau from the quinquennial Economic Census.

As imports to the U.S. economy continue to grow, the treatment of import measurement in the GDP by industry accounts has garnered attention. For example, Houseman et al. (2011) argue that the current treatment of import prices may lead to an offshoring bias in estimates of industry value-added, especially for industries concentrated in the manufacturing sector.

Conceptually, imports are treated as heterogeneous items and distinct from domestically produced items in order to allow for price differences between foreign and domestically produced goods that are purchased as intermediate inputs. That is, at the item level, the import and the domestic commodity are treated as differentiated goods, whether because of the cost of the item, the quality of the item, or the composition of goods within the item category; thus, imports are allowed to have prices that differ from the domestically produced item. An important measurement difficulty is that the value of imports by item by industry is not measured directly.

The BEA uses the import proportionality, or comparability, assumption to allocate the value of imports by item by industry. This approach is discussed in Mayerhauser and Strassner (2010); Moyer, Reinsdorf, and Yuskavage (2006); Strassner, Yuskavage, and Lee (2010); and Yuskavage, Strassner, and Medeiros (2008, 2009). The proportionality method assumes that each industry that purchases an item for intermediate use purchases an amount from a foreign supplier that is in the same proportion as the ratio of imports to domestic supply for that item. In other words, the imported portion of intermediate inputs by industry is homogenous at the item level for each industry that purchases that particular item. This homogeneity is imposed only at the 900-industry-by-5,000-item level, not at higher levels of aggregation.

It is worth noting a couple of aspects of the treatment of imports in calculating GDP by industry. First, the import proportionality assumption does not affect the estimates of nominal value-added by industry. This is because the import proportionality assumption does not determine the level of use of an item by an industry; it only determines the share of an item used by an industry that belongs to imported intermediate use, for the purpose of deflating intermediate use by the appropriate price index in constructing real value-added. Second, if at the item level domestically produced and imported goods are assumed to be homogeneous, or perfect substitutes, import and domestic prices change at the same rate, and there is no need for a separate treatment of imports in calculating real value-added growth.

The allocation of intermediate inputs to domestic versus foreign sources allows the BEA to incorporate the full suite of price statistics available within the U.S. economic statistical system. The Bureau of Labor Statistics' (BLS) producer price indexes are the primary source used to deflate the domestic portion of intermediate inputs. These prices are the same as those used to deflate the commodity composition of gross output by industry. In other words, each industry that purchases a domestic item pays the same price for that item. Table F in Washington et al. (2012) provides the principal sources of data used to deflate gross output by industry and the domestic portion of intermediate inputs by item. BLS import price indexes (MPI) are used to deflate the imported portion of intermediate inputs by item, also with the assumption that each industry that purchases imported inputs pays the same price for the imported intermediate input. Both the Producer Price Indexes (PPIs) and the MPIs are used at their most detailed levels available: PPIs range mostly from four- to seven-digit detail; NAICS MPIs are more aggregated—typically these indexes are available only for two- to four-digit detail. To deflate a small subset of items, the BEA uses prices from the National Income and Wealth Division at the BEA.

ALTERNATIVE IMPORT ALLOCATION USING BROAD ECONOMIC CATEGORIES

Our alternative approach to allocating commodity imports across industries is motivated by the World Input-Output Database (WIOD) method of Timmer (2012). The WIOD approach deviates from the import proportionality assumption by first assigning imports to one of three BECs: 1) intermediates, 2) final consumption, or 3) investment. The second step is to proportionally allocate imported intermediate inputs across industries after this initial split has been applied. It is worth noting that this approach is purely an alternative allocation, and no new data are used to give additional detail on actual use of different types of imports by industry.[2]

For the first step in this exercise, our objective is to construct a share for each imported item in the BEA industry accounts that reflects its broad economic classification. Specifically, for each imported item in the BEA industry accounts and each year, we estimate the share of the item that is sold to intermediates, consumption, and investment based on a concordance between harmonization codes and BEC categories. Our objective is not to construct new estimates of trade flows but to reallocate current estimates of trade flows. This preserves consistency with the NIPA trade data. Once we have item-level BEC shares, we apply these shares to estimate the value of each item sold to intermediate input. The second step is to allocate this total value of imported intermediate input across industries.

We use the concordance between the harmonized trade data and broad economic categories that is published by the United Nations to do the initial allocation of imports to the three broad groups.[3] The harmonized trade data are at the 10-digit level, while the harmonization code for BEC concordance is at the six-digit level. Because of the different levels of detail, we first assume that for each of the six-digit commodities in the harmonization code to BEC mapping, the 10-digit components have the same broad economic category.[4] This gives us the value of imported goods by broad economic classification at the 10-digit level for all of the components of the harmonized trade data.[5] To go from the 10-digit harmonized data by broad economic classification to the BEA's item-level detail, we apply the Industry Directorate's mapping between harmonization codes and items to get the value of items by broad economic classification, based on the harmonized trade data.[6] We use these import values by item and broad economic category to construct the share, by BEA item, that was sold to intermediate input. We apply this value share to the current estimates of imports by item in the BEA industry accounts to derive an alternative value of imports that were sold to intermediate use. Finally, we allocate this total imported intermediate proportionally by item across industries to yield the import-use matrix. Because the harmonized trade data cover mostly goods, we exclude any adjustments to nongoods items. We apply the above methodology for years 1998–2011 so that the results are consistent with the GDP-by-industry estimates published in November 2012. For the sake of clarity, the following nine steps enumerate how we construct our alternative import-use table:

1) Compile concordances between the six-digit harmonization code trade data and the United Nations–based broad economic categories covering 1998–2011.
2) Construct a map from 10-digit harmonization data to six-digit harmonization codes.
3) Aggregate the 10-digit harmonization trade data on imports to the six-digit level.
4) Apply the six-digit harmonization code to the BEC concordance to get estimates at the six-digit level of the values sold in the intermediate, final consumption, investment, or undetermined categories.[7]
5) Assume that the allocation for the 10-digit components of the harmonization code data is the same as for the 6-digit allocation to obtain values sold in the intermediate, final consumption, investment, or undetermined categories at the 10-digit harmonization level.
6) Allocate the 10-digit values to BEA item codes using the existing internal BEA mapping. Note that a 10-digit code may apply

to multiple items, and a single item may be made up of multiple 10-digit coded values.

7) Based on the results from Step 6, construct the share of each BEA item that was sold to intermediate input.

8) Use the baseline item-level import data as a control and distribute the value that was sold to intermediate input using the shares of values calculated in Step 7.

9) Allocate imports across industries.
   - For items that have a portion that goes to intermediate input according to UN Comtrade, allocate items across industries using the proportionality assumption. This is the two-step approach of Timmer (2012).
   - For items that have an undetermined allocation, revert to the standard proportionality assumption.
   - For items that have a BEC coding of "capital good," revert to the standard proportionality assumption.[8]

The impact of the BEC allocation of imports on estimates of GDP by industry depends on three basic elements. The first is that the value of trade by item that belongs to intermediate input based on the BEC allocation must be different from that based on the baseline import proportionality assumption. A different allocation of imports translates to a different nominal value of imported goods used by industries that buy a particular item. Second, the price of imported items must differ from prices paid for domestic goods. And third, the value share of imports used in production within an industry must be significantly different under the BEC allocation. The third condition is important, because while the BEC allocation may produce a different allocation of inputs for a particular item, if the value share of total imports in a particular industry's production is relatively unchanged as a result of the new allocation across all commodities used by the industry, the BEC-based allocation will have very little impact on estimates of value-added growth by industry.

Table 8.1 compares the share of imports allocated to intermediate input by commodity based on the alternative import allocation to the baseline approach of applying the import proportionality assumption. The level of aggregation corresponds to that published in the annual input-output accounts, although, as described above, the import allocations are estimated at the item level. Differences in estimated allocations have the potential to affect estimates of value-added growth for any industry that purchases that particular commodity. The difference in allocations between the baseline and BEC-based allocation reflects the binary assignment of an import to either an intermediate or final demand in the BEC mapping; it also reflects the item-level component allocations from the import proportionality assumption. For example,

Table 8.1 Share of Imports Allocated to Intermediate Inputs by Commodity, 2007

	Baseline	BEC-based allocation	Difference (absolute value)
Forestry, fishing, and related activities	0.85	0.24	0.61
Utilities	0.45	1.00	0.55
Food and beverage and tobacco products	0.48	0.13	0.35
Textile mills and textile product mills	0.53	0.37	0.16
Publishing industries (includes software)	0.15	0.02	0.14
Chemical products	0.51	0.64	0.14
Miscellaneous manufacturing	0.16	0.28	0.12
Plastics and rubber products	0.72	0.83	0.11
Printing and related support activities	0.82	0.72	0.11
Farms	0.56	0.48	0.08
Apparel and leather and allied products	0.10	0.02	0.08
Electrical equipment, appliances, and components	0.55	0.61	0.06
Machinery	0.42	0.48	0.06
Furniture and related products	0.15	0.10	0.04
Computer and electronic products	0.36	0.39	0.03
Fabricated metal products	0.82	0.84	0.03
Motor vehicles, bodies and trailers, and parts	0.31	0.33	0.02
Other transportation equipment	0.51	0.52	0.01
Paper products	0.93	0.92	0.01
Mining, except oil and gas	0.99	1.00	0.01
Wood products	0.92	0.93	0.01

SOURCE: Bureau of Economic Analysis (BEA) and authors' calculations.

within the "Forestry, fishing, and related activities" commodity, the BEC-based approach allocated 98 percent of commercial fishing to final demand, while the baseline allocated 20 percent.

The largest differences in import allocation are for the "Forestry, fishing, and related activities" commodity and the "Utilities" commodity, for each of which the share of imports allocated to intermediate inputs differs by more than 50 percentage points. The next largest difference is for "Food and beverage products," where the item-level import proportionality assumption allocated 48 percent to intermediate purchases, while the BEC approach allocated only 13 percent, a difference of 35 percentage points. Next, there are differences in allocations of between 10 and 16 percentage points for the following categories: "Textile mills and textile product mills," "Publishing industries (includes software)," "Chemical products," "Petroleum and coal products," "Miscellaneous manufacturing," "Plastics and rubber products," and "Printing and related support activities." Allocation differences of between 5 and 10 percentage points exist for "Farms," "Apparel and leather and allied products," "Electrical equipment appliances and components," and "Machinery." The remainder of the commodities show minor differences or none at all in import allocation. Recall that we restrict our alternative import data to only goods.

While there are some large differences in import allocations across intermediate and final use, the impact of the alternative allocations depends on the particular imports by an industry and on the value of imported goods relative to the use of goods produced domestically. For example, if an industry relies heavily on chemical products relative to all other inputs, a change in the estimated share of imported goods used in production has the potential to have a significant impact on estimates of the growth of that industry's intermediate input, and thus on that industry's value-added growth. Table 8.2 gives the share of imported intermediate inputs relative to total intermediate inputs based on the baseline and the BEC allocations. Based on the baseline allocation, 15 percent of the inputs in "Miscellaneous manufacturing" are imported, while according to the BEC mapping, 26 percent are imported. The "Food services and drinking places" category differs by 5 percentage points across allocations, and "Ambulatory health care services," "Food and beverage and tobacco products," and "Nonmetallic mineral products" all differ by 4 percentage points. The alternative allocation

Table 8.2 Share of Imports in Total Industry Intermediate Use, 2007

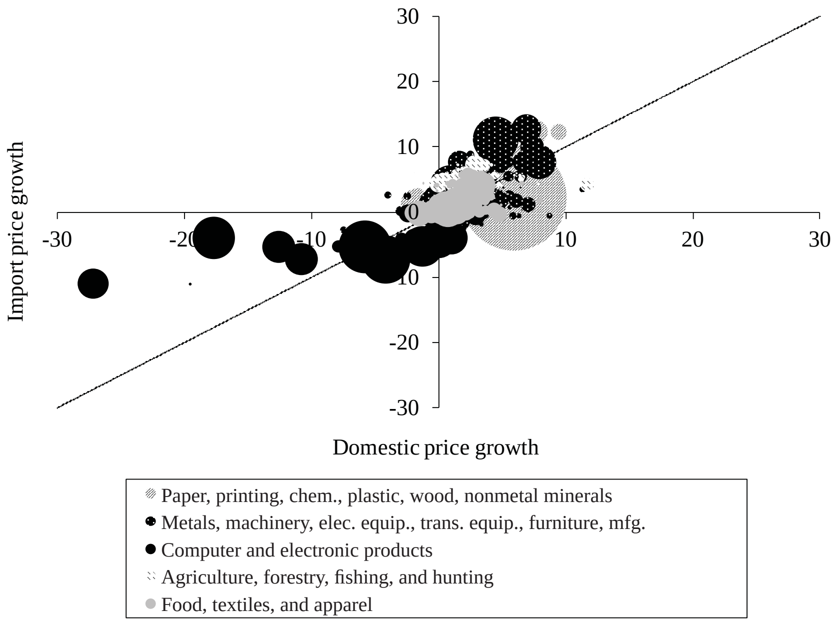
	Baseline	BEC-based allocation	Difference (absolute value)
Miscellaneous manufacturing	0.15	0.26	0.11
Food services and drinking places	0.09	0.04	0.05
Ambulatory health care services	0.08	0.12	0.04
Food and beverage and tobacco products	0.10	0.06	0.04
Nonmetallic mineral products	0.10	0.14	0.04
Computer and electronic products	0.23	0.26	0.03
Furniture and related products	0.19	0.17	0.03
Social assistance	0.06	0.04	0.02
Printing and related support activities	0.12	0.10	0.02
Other transportation equipment	0.19	0.21	0.02
Motor vehicles, bodies and trailers, and parts	0.23	0.25	0.02
Mining, except oil and gas	0.09	0.11	0.02
Federal general government	0.14	0.15	0.01
Amusements, gambling, and recreation industries	0.06	0.05	0.01
Wholesale trade	0.08	0.09	0.01
Accommodation	0.06	0.05	0.01
Textile mills and textile product mills	0.17	0.16	0.01
Machinery	0.19	0.19	0.01
State and local general government	0.08	0.08	0.01
Educational services	0.05	0.04	0.01
Electrical equipment, appliances, and components	0.20	0.21	0.01
Forestry, fishing, and related activities	0.12	0.13	0.01
State and local government enterprises	0.07	0.08	0.01
Chemical products	0.15	0.16	0.01
Hospitals and nursing and residential care facilities	0.06	0.07	0.01

SOURCE: Bureau of Economic Analysis (BEA) and authors' calculations.

made very little or no difference for the remainder of the industries at the published level.

As mentioned above, for the allocation of imports based on BECs to produce different estimates of value-added growth by industry, the price of imported goods must be different from the price used to deflate purchases from U.S suppliers. Figure 8.1 plots the item-level price growth of imported versus domestically produced goods, excluding "Mining except oil and gas" and "Petroleum and coal products,"

Figure 8.1 Item-Level Price Growth (%), 1998–2011



NOTE: This figure plots import price growth by item between 1998 and 2011 versus domestic price growth for prices used in the industry accounts. Area of marker determined by value of imports in 2007.
SOURCE: BEA GDP by Industry accounts.

weighted by the import values of the individual items relative to other items in the same aggregated commodity. The figure indicates that, in general, there are item-level price differences between imported and domestic goods. Thus, the allocation of intermediate input between domestic and foreign is a potentially important element in estimating value-added growth by industry.

Comparing import and domestic prices at the detailed level limits compositional effects at higher levels of aggregation. For example, the price indexes for total imported intermediate materials and total domestic intermediate materials reflect the compositional differences in types of materials that are imported versus purchased from domestic sources. At the item level, skewness above the 45-degree line would indicate a disproportionate number of cases where import prices increased relative to domestic prices. The data indicate that, at the item level, about 62 percent of the items are assigned import prices that fell relative to their domestic counterparts over the 1998–2011 period.

Tables 8.1 and 8.2 indicate that the allocation of imports between final demand and intermediate input is noticeably different based on the BEC coding, but that the import share of inputs is not significantly different for most industries under the BEC coding. To estimate the effect of the BEC allocation on measured value-added growth at the industry level requires taking into account these effects, in addition to the price differences between domestic and foreign goods. We do this analysis below in the context of an industry-level production account covering 1998–2011.

IMPORT PRICES AND COUNTRY-POOLED IMPORT PRICES

Recent literature has argued that the prices used in estimating GDP by industry may be biased. Specifically, Houseman et al. (2011) contend that switches to low-cost providers are excluded from the index number estimate of the intermediate input price at the time of the switch, leading to an overstatement of the growth in value-added quantity indexes in manufacturing industries. Inklaar, in Chapter 6 of this volume, argues that a portion of the bias can be analyzed by assuming that imports across countries are perfect substitutes. It is worth noting that in our exercise below, we do not consider the index number problems that occur when product sourcing is switched between domestic and foreign sources, which is a major focus of Houseman et al. We focus on switches between foreign suppliers.

We follow the basic approach used in Inklaar (see Chapter 6) to construct alternative import prices that we refer to as country-pooled import prices. The rationale for this adjustment is that import source switches between high-priced and low-priced exporting countries may not be captured in the official import price data because the same good from different countries has the potential to be treated as a different good. Thus, the import price index for an item needs to “link in” the switch to the new provider, instead of treating the new lower price paid in the initial year of the switch as a lower price paid for the same good.

For example, if a low-cost Chinese semiconductor producer enters the market and an importer switches from Japan to China, treating the semiconductors as homogenous would result in a price index that declines to reflect the price discount. On the other hand, if the semiconductor from China was treated as heterogeneous, there would be no period $t-1$ price to use to calculate the price decline in the semiconductor from China, so this observation would, effectively, be dropped from the estimation of the import price.

We use data from UN Comtrade that include the value (V_{ic}) and quantity (Q_{ic}) of imports of type by six-digit harmonization codes from 2002 to 2011 into the United States from Country c.[9] Unfortunately, while data exist for earlier years, the relationship between the Comtrade-based and official prices deteriorates in years prior to 2002.[10] We map imports by country by year to the level of detail for which the BEA has import price information from the BLS and construct two alternative price indexes for item i.[11] The first is

$$\Delta \ln pf_i = \sum_c \overline{w_{ic}} \Delta \ln pf_{ic} \ ,$$

where pf_i is the item-specific import price, c indexes country, and $\overline{w_{ic}}$ is the average value share of imports of type i from Country c in periods t and $t-1$, so that pf_i is a Törnqvist price index. Assuming that items are perfect substitutes across countries yields an alternative price for item i:

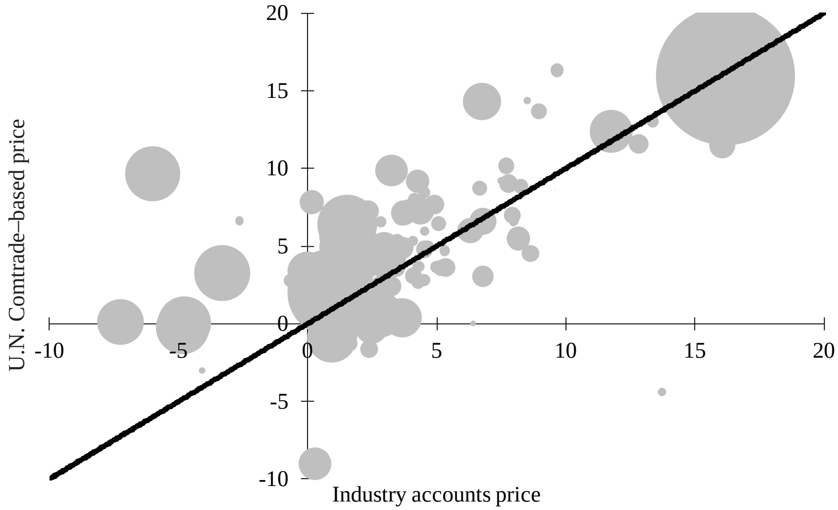
$$\Delta \ln pf_{alt,i} = \Delta \ln \left(\frac{\sum_c V_{ic}}{\sum_c Q_{ic}} \right) .$$

The annual adjustment, which we refer to as country-pool adjustment, is defined as $\Delta \ln B_i = \Delta \ln pf_i - \Delta \ln pf_{alt,i}$ for each imported item and captures the difference in item-level prices under the two alternative assumptions. We apply this bias adjustment to the baseline import prices used in the construction of GDP by industry at the item level. The approach of adding the bias to the baseline prices used in the construction of GDP by industry allows the import prices to maintain the existing adjustments to hold quality fixed. This is particularly important for information technology goods, which exhibit rapidly changing product characteristics. The relationship between the UN Comtrade–based prices and the import prices used in the industry accounts is given in Figure 8.2.

VALUE-ADDED AND PRODUCTIVITY UNDER ALTERNATIVE IMPORT ASSUMPTIONS

In this section, we analyze how the alternative approaches to imports affect measured value-added and productivity growth at the industry and aggregate level. We use an industry-level production account that includes nominal values, along with prices and quantities for industry output and inputs. The account used here covers 1998–2011 and is an updated version of Fleck et al. (2012), which covers the 63 industries

Figure 8.2 Item-Level Price Comparison: Price Growth (%), 2002–2011



NOTE: This figure plots growth of the Törnqvist index of UN Comtrade–based prices by item versus import prices used in the industry accounts. Area of marker determined by value of imports between 2002 and 2011.

SOURCE: Author calculations, based on BLS import prices and Comtrade data, as described in text.

that are published in the BEA's GDP-by-industry data.[12] This section discusses the pertinent accounting details, but we refer the reader to Fleck et al. (2012) for detail on the data sources and methods.

Industry-Level Production Account

The fundamental equation for analyzing the industry sources of growth is the equation defining multifactor productivity (MFP) as the residual after subtracting from industry output growth ($\Delta \ln Q_j$) the weighted growth rates of industry capital ($\Delta \ln Q_{Kj}$), labor ($\Delta \ln Q_{Lj}$), and intermediate inputs ($\Delta \ln Q_{Xj}$):

$$(8.1) \quad \Delta \ln MFP_j \equiv \Delta \ln Q_j - \overline{w_{Kj}} \Delta \ln Q_{Kj} - \overline{w_{Lj}} \Delta \ln Q_{Lj} - \overline{w_{Xj}} \Delta \ln Q_{Xj}$$

where the weights are the average of period t and $t - 1$ value shares of each of the inputs in the value of output, which is the typically used Törnqvist index of MFP.

To analyze the industry contributions to aggregate value-added growth, we appeal to the translog production possibility frontier analyzed in Jorgenson et al. (2007):

$$(8.2) \quad \Delta \ln V = \sum_j \overline{w_j} \Delta \ln V_j \ ,$$

so that aggregate value-added growth $\Delta \ln V$ is a translog index over industry value-added growth rates $\Delta \ln V_j$. Because the quantity index of industry value-added $\Delta \ln V_j$ is not directly observable, we appeal to the nominal accounting identity that says the value of gross output equals nominal value-added plus nominal intermediate input. Differentiating this accounting identity with respect to time and taking a discrete time approximation yields a Törnqvist index for the growth rate of industry gross output:

$$(8.3) \quad \Delta \ln Q_j = \overline{w_{Vj}} \Delta \ln V_j + \overline{w_{Xj}} \Delta \ln Q_{Xj} \ ,$$

which, solving for $\Delta \ln V_j$, yields an estimate of industry value-added growth. This approach to estimating value-added growth is typically referred to as the double deflation method because it allows for separate price deflators for output and intermediate input.

To analyze the industry sources of growth at the aggregate level, we combine Equations (8.1), (8.2), and (8.3) to yield a decomposition of aggregate value-added growth:

(8.4)

$$\Delta \ln V = \sum_j \overline{w_j} \frac{\overline{w}_{K,j}}{\overline{w}_{V,j}} \Delta \ln Q_{Kj} + \overline{w_j} \frac{\overline{w}_{L,j}}{\overline{w}_{V,j}} \Delta \ln Q_{Lj} + \overline{w_j} \frac{1}{\overline{w}_{V,j}} \Delta \ln MFP_j$$

which gives aggregate economy value-added growth as the weighted industry contributions of capital, labor, and MFP to industry output growth. We define

(8.5) $$\Delta \ln MFP_{Agg} \equiv \sum_j \overline{w_j} \frac{1}{\overline{w}_{V,j}} \Delta \ln MFP_j$$

and refer to this as aggregate MFP growth.[13] We call $\overline{w_j} \frac{1}{\overline{w}_{V,j}} \Delta \ln MFP_j$ the industry contribution to aggregate MFP, or Domar-weighted MFP growth.[14] The industry production account framework allows us to analyze contributions of industries and sectors to aggregate growth and productivity. The aggregate sector classification scheme that we use is based on the classification scheme in Jorgenson and Schreyer (2013).

Import Measurement and Growth Accounting

Our analysis of the treatment of imports in the industry accounts reduces to alternative estimates of Q_{Xj}, which is the quantity index of intermediate inputs used by industry. Intuitively, the three reasons why Q_{Xj} differs under the alternatives are as follows:

1) With an alternative allocation of imports by broad economic category, the share of intermediate use by industry by item that is imported now reflects the information available in the BEC mapping; this division of use by industry by item across domestically produced and imported items then is deflated by either the domestic or the import price. In other words, under the alternative, the share of imports is different, and this new share is deflated by the import price index.

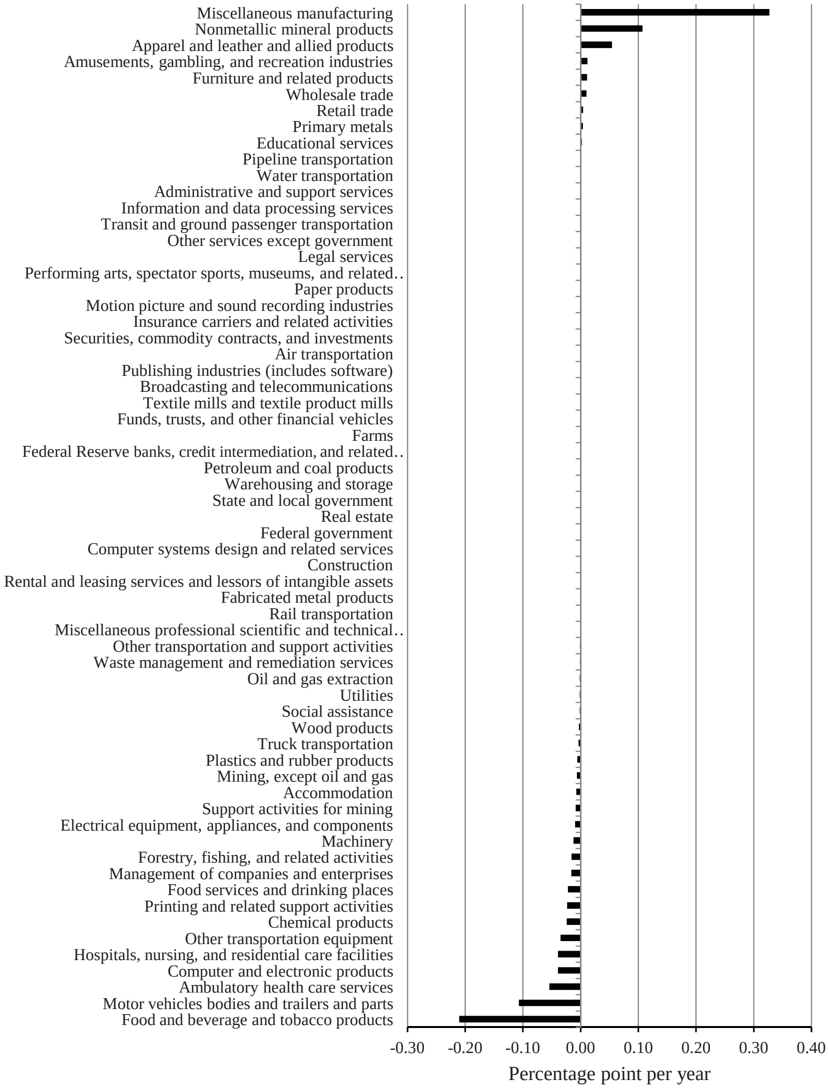
2) The value of imports is deflated by an alternative price index, thus yielding a different quantity.
3) Both an alternative estimate of the value of imports by item by industry (Reason 1) and an alternative price index (Reason 2) contribute to yielding a different quantity.

The three treatments of imports lead us to define alternative estimates of Q_{Xj} that feed through our exercise by means of Equation (8.1); the first uses the BEC-based allocation, the second uses the country-pooled import prices, and the third uses both the BEC allocation and the country-pooled price. Based on Equations (8.1) through (8.5), we define the alternative estimates of value-added growth and its sources. Equation (8.3) yields three alternative estimates of value-added growth by industry: $\Delta \ln V_{j,Alt1} \ldots \Delta \ln V_{j,Alt3}$. Equation (8.1) gives alternative estimates of MFP growth by industry: $\Delta \ln MFP_{j,Alt1} \ldots \Delta \ln MFP_{j,Alt3}$. Based on Equation (8.2), there are three alternative estimates of aggregate value-added growth: $\Delta \ln V_{Alt1} \ldots \Delta \ln V_{Alt3}$, while based on Equation (8.5) each alternative estimate of aggregate MFP is due to alternative estimates at the industry level.

Import Treatment and Value-Added Growth Estimates

In this section, we compare the baseline estimates of industry value-added growth in the United States to estimates based on the alternative treatments of imports.[15] Figure 8.3 shows that the BEC allocation of imports produces minor differences in the estimates of value-added growth by industry over the 1998–2011 period. The effects are detailed across industries in Table 8.3. As discussed above, the differences between the baseline estimate of value-added growth and the alternatives are due to alternative estimates of the growth of intermediate inputs by industry. This difference takes into account the alternative value of imported commodities within an industry and the price difference between domestic and foreign purchases. Between 1998 and 2011, value-added in “Miscellaneous manufacturing” would have grown 0.3 percentage points a year faster (3.22 percent a year versus 2.89 percent a year) if estimated with the BEC allocation, while “Food and beverages” would have grown about 0.2 percentage points a year slower (0.85 percent a year versus 1.06 percent). “Nonmetallic minerals” would be esti-

Figure 8.3 Measured Value-Added Growth, 1998–2011: Alt1 Less Baseline



NOTE: Difference in value-added growth under Alt1. See text.
SOURCE: Authors' calculations, based on BEA and BLS data.

Table 8.3 Growth in Industry Value-Added and MFP under Alternatives (%)

	Value-added growth						MFP Growth					
	1998−2011		2002–2011				1998–2011		2002–2011			
	Baseline	Alt1	Baseline	Alt1	Alt2	Alt3	Baseline	Alt1	Baseline	Alt1	Alt2	Alt3
Farms	2.12	2.12	1.34	1.34	1.34	1.34	0.95	0.95	0.57	0.57	0.57	0.57
Forestry, fishing, and related activities	3.34	3.33	2.84	2.81	2.83	2.83	2.05	2.03	1.43	1.40	1.42	1.42
Oil and gas extraction	−3.74	−3.75	−2.45	−2.45	−2.46	−2.46	−2.84	−2.84	−3.02	−3.02	−3.03	−3.03
Mining, except oil and gas	−2.92	−2.93	−4.29	−4.30	−4.36	−4.38	−1.38	−1.38	−2.85	−2.85	−2.88	−2.89
Support activities for mining	6.31	6.30	4.75	4.74	4.67	4.65	1.81	1.81	−0.15	−0.16	−0.19	−0.19
Utilities	1.36	1.36	1.57	1.57	1.57	1.56	0.28	0.28	0.15	0.15	0.14	0.14
Construction	−2.24	−2.24	−3.54	−3.54	−3.58	−3.58	−1.15	−1.15	−1.28	−1.28	−1.30	−1.30
Wood products	0.22	0.22	0.28	0.28	0.27	0.26	1.21	1.20	1.36	1.36	1.36	1.36
Nonmetallic mineral products	−3.15	−3.04	−4.11	−3.97	−4.09	−4.01	−0.73	−0.69	−0.76	−0.71	−0.74	−0.72
Primary metals	−3.13	−3.13	−4.53	−4.52	−4.65	−4.64	−0.12	−0.12	−0.80	−0.79	−0.82	−0.82
Fabricated metal products	−1.18	−1.18	−0.49	−0.49	−0.50	−0.51	−0.06	−0.06	0.11	0.11	0.10	0.10
Machinery	0.22	0.21	2.84	2.82	2.53	2.51	0.64	0.64	1.30	1.30	1.19	1.18
Computer and electronic products	17.51	17.47	15.41	15.36	15.08	15.02	8.15	8.13	8.07	8.04	7.92	7.88
Electrical equipment appliances and components	0.80	0.79	−0.13	−0.14	−0.20	−0.23	0.96	0.95	0.43	0.42	0.40	0.39
Motor vehicles, bodies and trailers, and parts	0.28	0.17	−1.02	−1.15	−1.55	−1.70	0.70	0.68	0.64	0.62	0.55	0.52
Other transportation equipment	0.95	0.92	1.55	1.53	0.93	0.95	0.57	0.56	0.35	0.34	0.12	0.13
Furniture and related products	−2.76	−2.74	−3.37	−3.37	−3.38	−3.38	0.08	0.09	0.37	0.37	0.36	0.36
Miscellaneous manufacturing	2.89	3.22	2.48	3.00	2.48	2.91	1.46	1.63	1.22	1.47	1.21	1.43

Food and beverage and tobacco products	1.06	0.85	1.26	0.90	1.33	0.98	0.19	0.14	0.29	0.20	0.33	0.23
Textile mills and textile product mills	−4.26	−4.26	−4.40	−4.41	−4.62	−4.63	1.33	1.33	1.78	1.78	1.70	1.70
Apparel and leather and allied products	−4.83	−4.77	−4.30	−4.29	−4.39	−4.37	3.37	3.39	4.35	4.35	4.30	4.31
Paper products	−2.87	−2.87	−2.58	−2.58	−2.58	−2.58	−0.09	−0.09	0.05	0.05	0.05	0.05
Printing and related support activities	−0.96	-0.98	−1.35	−1.39	−1.39	−1.45	1.11	1.11	0.98	0.97	0.97	0.95
Petroleum and coal products	1.44	1.44	2.24	2.24	2.35	2.34	0.20	0.20	0.37	0.37	0.38	0.38
Chemical products	1.03	1.00	0.36	0.33	0.51	0.43	0.42	0.41	0.28	0.27	0.33	0.31
Plastics and rubber products	−0.68	−0.69	−1.00	−1.01	−0.84	−0.84	0.24	0.23	0.26	0.26	0.32	0.32
Wholesale trade	2.19	2.20	1.21	1.23	1.20	1.21	0.67	0.68	0.13	0.14	0.13	0.13
Retail trade	1.41	1.42	0.60	0.61	0.59	0.60	0.15	0.15	0.03	0.03	0.02	0.02
Air transportation	3.03	3.03	3.42	3.42	3.42	3.42	2.18	2.18	2.57	2.57	2.57	2.58
Rail transportation	0.10	0.10	0.27	0.27	0.23	0.23	0.54	0.54	0.07	0.07	0.05	0.05
Water transportation	9.00	9.00	17.17	17.17	17.17	17.17	2.73	2.73	5.21	5.21	5.21	5.21
Truck transportation	1.74	1.74	2.20	2.20	2.18	2.18	0.68	0.68	1.03	1.02	1.02	1.01
Transit and ground passenger transportation	1.25	1.25	0.62	0.63	0.62	0.62	−0.71	−0.71	−0.89	−0.89	−0.90	−0.90
Pipeline transportation	6.62	6.63	5.03	5.03	5.05	5.05	2.20	2.20	1.68	1.68	1.69	1.69
Other transportation and support activities	1.77	1.77	1.92	1.91	1.91	1.91	1.39	1.39	1.67	1.67	1.67	1.67
Warehousing and storage	3.69	3.69	4.95	4.95	4.94	4.94	0.76	0.76	1.64	1.64	1.64	1.64
Publishing industries (includes software)	2.62	2.62	2.30	2.30	2.29	2.29	0.28	0.28	0.91	0.91	0.90	0.90

(continued)

Table 8.3 (continued)

	Value-added growth						MFP Growth					
	1998–2011		2002–2011				1998–2011		2002–2011			
	Baseline	Alt1	Baseline	Alt1	Alt2	Alt3	Baseline	Alt1	Baseline	Alt1	Alt2	Alt3
Motion picture and sound recording industries	1.18	1.18	0.14	0.14	0.15	0.14	0.59	0.59	0.37	0.37	0.37	0.37
Broadcasting and telecommunications	5.79	5.79	5.04	5.04	5.01	5.00	1.85	1.85	2.73	2.72	2.70	2.70
Information and data processing services	7.16	7.16	4.69	4.69	4.67	4.67	−0.17	−0.17	−0.40	−0.40	−0.41	−0.41
Federal Reserve banks, credit intermediation, and related activities	2.99	2.99	0.68	0.68	0.67	0.67	0.45	0.45	−0.23	−0.23	−0.24	−0.24
Securities, commodity contracts, and investments	5.59	5.59	−0.83	−0.83	−0.83	−0.83	1.02	1.02	−1.47	−1.47	−1.47	−1.47
Insurance carriers and related activities	1.41	1.41	2.57	2.57	2.57	2.57	−0.51	−0.51	0.50	0.51	0.51	0.51
Funds, trusts, and other financial vehicles	4.48	4.48	3.24	3.24	3.24	3.24	0.04	0.04	−0.29	−0.29	−0.29	−0.29
Real estate	2.28	2.28	2.05	2.05	2.05	2.05	0.25	0.25	0.28	0.28	0.28	0.28
Rental and leasing services and lessors of intangible assets	1.89	1.89	0.89	0.89	0.89	0.89	−1.08	−1.08	0.41	0.41	0.41	0.41
Legal services	−0.35	−0.35	−1.51	−1.51	−1.51	−1.51	−2.28	−2.28	−2.69	−2.69	−2.70	−2.70
Computer systems design and related services	6.91	6.91	8.08	8.08	8.05	8.05	2.02	2.02	3.09	3.09	3.07	3.07
Miscellaneous professional scientific and technical services	3.11	3.11	2.96	2.96	2.95	2.95	0.13	0.13	0.22	0.22	0.22	0.21

Management of companies and enterprises	0.27	0.26	−0.75	−0.77	−0.78	−0.79	−2.28	−2.29	−3.58	−3.59	−3.60	−3.61
Administrative and support services	3.06	3.06	3.23	3.23	3.23	3.23	1.23	1.23	1.83	1.83	1.83	1.83
Waste management and remediation services	2.56	2.56	2.34	2.33	2.32	2.32	0.90	0.90	0.80	0.80	0.79	0.79
Educational services	1.15	1.15	0.82	0.81	0.80	0.80	−1.26	−1.25	−1.11	−1.11	−1.12	−1.12
Ambulatory health care services	3.52	3.47	3.35	3.28	3.30	3.14	0.36	0.32	0.03	-0.02	-0.01	-0.11
Hospitals, nursing and residential care facilities	1.89	1.85	2.00	1.94	1.96	1.85	−0.17	−0.19	0.00	−0.04	−0.02	−0.09
Social assistance	2.99	2.99	2.58	2.57	2.58	2.57	0.62	0.61	0.90	0.89	0.90	0.89
Performing arts, spectator sports, museums, and related activities	2.28	2.28	1.53	1.52	1.53	1.53	0.27	0.27	−0.24	−0.24	−0.24	−0.24
Amusements, gambling, and recreation industries	1.25	1.26	2.16	2.17	2.14	2.17	0.10	0.11	1.39	1.40	1.38	1.40
Accommodations	1.77	1.76	1.53	1.52	1.53	1.52	0.19	0.19	0.06	0.05	0.06	0.05
Food services and drinking places	2.04	2.02	1.57	1.52	1.56	1.51	0.64	0.63	0.53	0.50	0.53	0.50
Other services, except government	−1.00	−0.99	−0.82	−0.82	−0.82	−0.82	−1.15	−1.14	−0.73	−0.73	−0.73	−0.73
Federal government	1.03	1.03	1.34	1.34	1.34	1.34	0.20	0.20	0.22	0.22	0.22	0.22
State and local government	0.85	0.85	0.35	0.35	0.35	0.35	−0.38	−0.38	−0.35	−0.35	−0.35	−0.35

NOTE: Alt.1 uses the alternative import allocation based on the BEC. Alt. 2 uses the alternative set of import prices. Alt. 3 uses both the alternative allocation and the alternative import prices.

SOURCE: Authors’ calculations, based on BEA and BLS data.

mated to decline by 3.04 percent a year instead of 3.15 percent a year, while “Motor vehicles” would have grown at 0.17 percent a year versus 0.28 percent. The other of the 63 industries all exhibited percentage-point differences of less than 0.1 percentage points a year.

To understand the impact of the BEC allocations (summarized in Table 8.1) on the value-added growth estimates, we trace the effect of the BEC-based distribution of “Forestry, fishing, and related activities.” Table 8.1 indicates that a significantly smaller share of imported “Forestry, fishing, and related activities” was purchased as an intermediate input under the BEC mapping. The implication of this alternative allocation for value-added growth depends on which industries purchase “Forestry, fishing, and related activities” items, and the value of the imported items relative to the value of other intermediate inputs used by the industries. Furthermore, the impact depends on the item-level allocations within each commodity. For example, as discussed above, the major difference between the BEC-based and the baseline treatment of “Forestry, fishing, and related activities” is the treatment of commercial fishing. Because the commercial fishing item is sold mainly to a subset of the industries that purchases forestry and fishing items, the BEC-based allocation affects only this set of industries. In particular, the largest purchaser of “Forestry, fishing, and related activities” is the “Wood products” industry, yet the BEC-based and baseline estimates of imports of “Forestry, fishing, and related activities” purchased by the “Wood products” industry are equivalent because the wood industry does not purchase commercial fishing.[16]

On the other hand, the treatment of commercial fishing has a large impact on the estimates of imports purchased by the “Food services and drinking places” industry. In this “Food services and drinking places” industry, however, purchases of forestry and fishing items were about 2 percent of total intermediate purchases, while the difference in price growth between domestic and imported items was about 8 percentage points. This implies a value-added growth rate for the “Food services and drinking places” industry that differs by about 0.1 percentage points in 2007, and no difference in value-added growth in the “Wood products” industry. Over the 1998–2011 period, value-added estimates for the “Food services and drinking places” industry differed by 0.02 percentage points when the baseline was compared to the BEC-based import allocation. This difference reflects the treatment of commercial fishing, other items in the "Forestry, fishing, and related activities" commodity, and the effects on value-added growth for the other years in the sample.

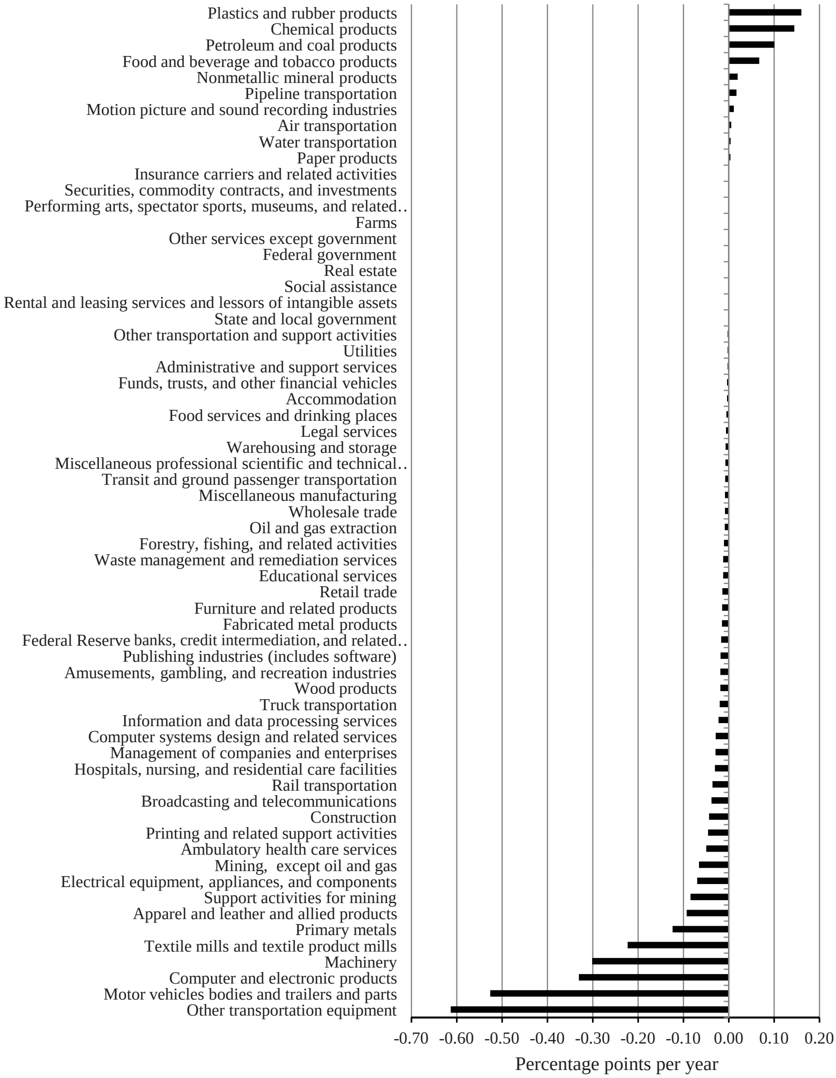
The differences in value-added by industry estimates that incorporate the country-pooled adjusted import prices are given in Figure 8.4. In 49 out of the 63 industries, estimated value-added growth was slower during the 2002–2011 period (the details are given in Table 8.3). The largest difference (in absolute value) was for "Other transportation equipment"; it is estimated that that category would have grown about 0.6 percentage points a year more slowly using the country-pool-adjusted import price. "Motor vehicle bodies and trailers and parts," "Computer and electronic products," "Machinery," "Textile mills and textile product mills," "Primary metals," "Plastics and rubber products," and "Chemical products" were the industries where estimated value-added growth differed by more than 0.1 percentage points a year, with the differences for plastics and chemicals being of opposite sign.

Table 8.3 and Figure 8.5 show the combined effects for the 2002–2011 period of the BEC-based allocation and alternative import prices. "Motor vehicle bodies and trailers and parts" would have been estimated to grow more slowly, by about 0.7 percentage points a year; "Other transportation equipment" also more slowly, by 0.6 percentage points a year; "Computer and electronic products" more slowly by 0.4 percentage points a year; and "Machinery" and "Food and beverage and tobacco products" more slowly by about 0.3 percentage points a year. "Miscellaneous manufacturing" would have been estimated to grow about 0.4 percentage points a year faster. Table 8.3 indicates that, in general, differences in growth estimates due to the alternative treatments were small in comparison to the baseline estimates of value-added growth.

Import Treatment and MFP Growth Estimates by Industry

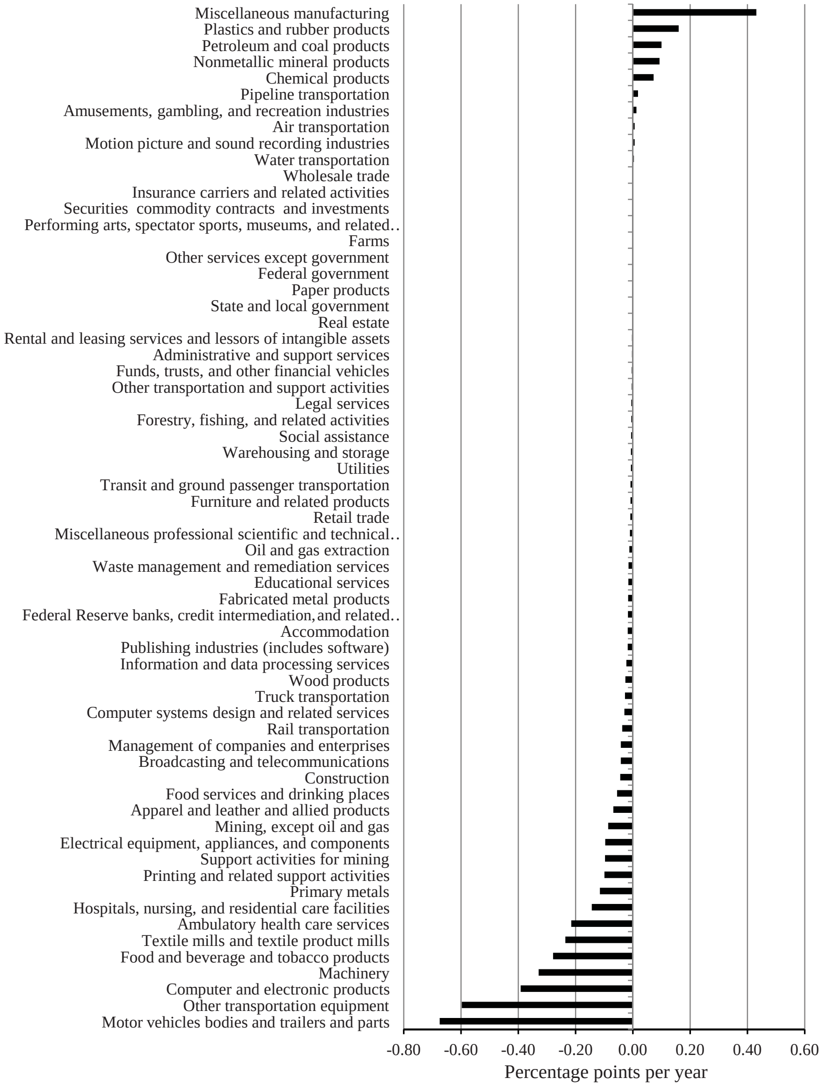
Because MFP growth accounts for about 30 percent of growth in aggregate value-added between 1998 and 2010, according to Fleck et al. (2012), small changes in estimates of MFP growth at the industry level may have important ramifications for the sources of aggregate MFP growth.

Figure 8.4 Measured Value-Added Growth, 2002–2011: Alt2 Less Baseline



NOTE: Difference in value-added growth under Alt2. See text.
SOURCE: Authors' calculations, based on BEA and BLS data.

Figure 8.5 Measured Value-Added Growth, 2002–2011: Alt3 Less Baseline



NOTE: Difference in value-added growth under Alt3. See text.
SOURCE: Authors' calculations, based on BEA and BLS data.

Table 8.3 compares MFP growth rates across the baseline and alternative treatments for imports. The table shows that the BEC-based import allocation produces both marginally faster and slower MFP growth rates across industries. The largest difference was for "Miscellaneous manufacturing," where MFP would have grown about 0.17 percentage points a year faster under the BEC mapping (1.63 percent versus 1.46 percent). "Food and beverages and tobacco products" MFP grew 0.05 percentage points a year slower based on the BEC, while all of the other industries' MFP growth differed by less than 0.05 percentage points a year.

Table 8.3 shows the effect of the alternative import prices (Alt2) and the combination of the alternative import prices and BEC allocation (Alt3) on MFP estimates. With the alternative import prices, measured MFP growth in "Other transportation equipment" would have been 0.22 percentage points a year slower compared to the baseline, while that for "Computer and electronic products" would have been about 0.1 percentage points a year slower. Both "Machinery" and "Motor vehicle bodies and trailers and parts" would have exhibited slower MFP growth by about 0.1 percentage points a year. "Plastics and rubber products" would have been estimated to have higher MFP growth for the period by about 0.05 percentage points a year. Table 8.3 shows that the differences in MFP under the alternatives are, in general, small compared to the baseline estimates. Finally, Table 8.3 indicates that combining the alternative import allocation and alternative import prices leads to relatively minor differences in MFP estimates across industries. The industries with the largest differences are "Other transportation equipment," "Computer and electronic products," "Ambulatory health care services," and "Miscellaneous manufacturing."

Houseman et al. (2011) argue that the measurement bias from offshoring as a percentage of growth in real value-added and MFP is particularly high for manufacturing excluding computers. Table 8.4 presents the effects of the alternative import assumptions on estimated value-added and MFP in this sector of the economy. For the 1998–2011 period, under the BEC allocation of imports, value-added would have decreased by 0.15 percent a year compared to 0.13 percent a year, while MFP growth would have been unchanged under the alternative. In comparison, under the alternative import prices between 2002 and 2011, valued-added fell by 0.16 percent a year compared to a decrease of

Table 8.4 Value-Added and MFP: Manufacturing Excluding Computers and Electronic Products (%)

	1998–2011		2002–2011			
	Baseline	Alt1	Baseline	Alt1	Alt2	Alt3
Value-added growth	−0.13	−0.15	−0.13	−0.16	−0.16	−0.21
Contribution to aggregate VA growth	0.00	−0.01	0.00	0.00	0.00	−0.01
MFP growth	0.37	0.36	0.33	0.32	0.32	0.31
Contribution to aggregate MFP growth	0.11	0.11	0.10	0.09	0.09	0.09

NOTE: All figures are average annual percentages. Sector aggregation is discussed in the text. Alt. 1 uses the alternative import allocation based on the BEC. Alt. 2 uses the alternative set of import prices. Alt. 3 uses both the alternative allocation and the alternative import prices.

SOURCE: Authors' calculations, based on BEA and BLS data.

0.13 percent a year in the baseline. Again, MFP growth was basically unchanged. Combining the alternative import allocation and prices yields a value-added decline of 0.21 percent a year compared to a 0.13 percent decline in the baseline, and MFP growth of 0.09 percent a year compared to 0.10 percent a year without the adjustments.

The Sources of Growth under the Alternatives

In this section, we compare the sources of aggregate value-added and MFP growth by industry across the alternative treatments. Table 8.5, which presents the sector contributions to aggregate value-added growth, indicates that there are very few significant differences based on the alternative import measurement approaches. For the BEC-based allocation over the 1998–2011 period, the contributions by major sector were observationally equivalent at 1.87 percent a year. Over the 2002–2011 period, for which we consider both the BEC-based import allocation and the alternative import prices, there were some minor differences in sector contributions to growth. Specifically, in the baseline aggregate, value-added grew by 1.38 percent a year, while it grew by 1.34 percent a year under the alternative using the BEC allocation and alternative import price. This difference was due to minor differences in "Construction," "Manufacturing," "Information," and "Other services."

Across each of the cases that we consider, MFP growth accounts for between 25 and 30 percent of aggregate value-added growth. Table 8.6 shows that for the broad economic sectors, the sources of aggregate MFP growth exhibit a similar pattern across the treatments of imports that we analyze. For the 1998–2011 period, the BEC-based allocation produces a sectoral decomposition of aggregate MFP that is almost identical to the baseline. For the 2002–2011 period, there are minor differences in "Transportation, warehousing, and utilities," "Durable goods," and "Other services." Overall, the fundamental sources of aggregate MFP are very similar across the different treatments of imports for this sector classification.

Table 8.5 Sector Contributions to Aggregate Value-Added Growth (%)

	1998–2011		2002–2011			
	Baseline	Alt1	Baseline	Alt1	Alt2	Alt3
Value-added	1.87	1.87	1.38	1.37	1.36	1.34
Agriculture, forestry, fishing, hunting, and mining	0.02	0.02	0.01	0.01	0.01	0.01
Transportation, warehousing, utilities	0.10	0.10	0.11	0.11	0.11	0.11
Construction	−0.10	−0.10	−0.15	−0.15	−0.16	−0.16
Manufacturing	0.25	0.25	0.22	0.21	0.21	0.20
Durable goods	0.25	0.25	0.22	0.22	0.21	0.21
Nondurable goods	0.00	0.00	0.00	−0.01	0.00	0.00
Trade	0.23	0.23	0.11	0.11	0.11	0.11
Information	0.21	0.21	0.18	0.18	0.17	0.17
Finance, insurance, real estate, rental and leasing	0.51	0.51	0.33	0.33	0.33	0.33
Other services	0.54	0.54	0.52	0.51	0.51	0.50
Government	0.11	0.11	0.06	0.06	0.06	0.06

NOTE: All figures are average annual percentages. Sector aggregation is discussed in the text. Alt. 1 uses the alternative import allocation based on the BEC. Alt. 2 uses the alternative set of import prices. Alt. 3 uses both the alternative allocation and the alternative import prices.

SOURCE: Authors' calculations, based on BEA and BLS data.

Table 8.6 Sector Contributions to Aggregate MFP Growth (%)

	1998–2011		2002–2011			
	Baseline	Alt1	Baseline	Alt1	Alt2	Alt3
Aggregate MFP	0.49	0.48	0.42	0.41	0.40	0.38
Agriculture, forestry, fishing, hunting, and mining	−0.01	−0.01	−0.04	−0.04	−0.04	−0.04
Transportation, warehousing, utilities	0.07	0.07	0.09	0.09	0.08	0.08
Construction	−0.11	−0.11	−0.13	−0.13	−0.13	−0.13
Manufacturing	0.39	0.39	0.33	0.33	0.32	0.31
Durable goods	0.35	0.35	0.30	0.30	0.28	0.28
Nondurable goods	0.04	0.04	0.03	0.03	0.04	0.03
Trade	0.07	0.07	0.01	0.01	0.01	0.01
Information	0.09	0.09	0.14	0.14	0.14	0.14
Finance, insurance, real estate, rental and leasing	0.06	0.06	0.01	0.01	0.01	0.01
Other services	−0.03	−0.04	−0.01	−0.02	−0.02	−0.03
Government	−0.04	−0.04	0.02	0.02	0.02	0.02

NOTE: All figures are average annual percentages. Sector aggregation is discussed in the text. Alt. 1 uses the alternative import allocation based on the BEC. Alt. 2 uses the alternative set of import prices. Alt. 3 uses both the alternative allocation and the alternative import prices.

SOURCE: Authors' calculations based on BEA and BLS data.

CONCLUSION

Estimated GDP from the expenditure side demonstrates the increasing role of imports in U.S. economic activity. In this chapter, we have examined a narrow set of issues related to import measurement and the effects on estimates of the sources of GDP growth from an industry perspective. Between 1998 and 2011, the value of imports relative to GDP increased from 12.7 percent to 17.7 percent. Over the same period, based on the value-added approach to measuring GDP, the share of imported intermediates used in domestic production increased from about 9 percent in 1998 to 13 percent in 2011 for the economy as a whole, and from 16 percent in 1998 to 25 percent in 2011 in manufacturing. Because of interest in how these imports are treated in the measurement of GDP by industry, we have documented the current approach to capturing the role of imports on measures of growth and productivity at the industry level and have shown how import measurement at the industry level is related to aggregate measures of growth and productivity. The industry production account that we analyze in this chapter is an important element of quantifying the impact of imports on the U.S. economy.

Because a basic requirement in assembling industry estimates of real value-added and MFP growth is knowing the values of imports by type that are used by all industries in the economy, we have discussed the application of the import proportionality assumption in the BEA industry accounts and compared this to an approach that relies on the broad economic classifications published by the United Nations. We find that estimates of GDP and MFP growth by industry show no major differences based on the BEC allocation. We attribute this to the level of detail at which the BEA applies the import comparability assumption, which is much finer than the 63-sector level at which the annual accounts are published.

Another component of the accounts that affects measures of GDP and MFP by industry is made up of the prices that serve to deflate imports used across industries. We compare the current practice, which relies heavily on published BLS import price indexes, to an import price that pools goods across countries. This approach allows us to capture import switches from a new, lower-priced entrant into the export market, which Houseman et al. (2011) have argued may be missing from the official import prices. Again, we do not find significant impacts on the industry growth rates, or on the sectoral growth decomposition at the aggregate level.

The industry production account approach that we make use of in our analysis reinforces the notion that the economy-wide impact of increasing imports depends on industry measures of import use. While there is some evidence that the alternative methodologies that we consider have some minor industry-specific measurement effects, across industries these effects often cancel each other out. Thus, at higher levels of aggregation there are very few observable differences across the methodologies that we analyze. It is worth recalling that our analysis focuses solely on different treatments of imported goods in the accounts.

Surely, measurement issues related to the growth in globalization will not dissipate. This study was based on the 2002 benchmark input-output table, which forms the basis of the annual industry accounts. The 2007 benchmark input-output table, which became available in December 2013, incorporates updated information on the structure of inter-industry purchases, and the annual industry accounts will be revised to reflect this new information. Looking further ahead, the treatment of factoryless goods production is a measurement area that is gaining attention. Methodologists for the GDP-by-industry account are actively involved in discussing methods to treat factoryless goods and how to incorporate these concepts into their estimates.

Notes

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1. The vintage of data used in this project is consistent with the GDP by industry and annual Input-Output accounts, released in December 2012. The latest data are updated here: http://www.bea.gov/industry/index.htm.

2. Strassner, Yuskavage, and Lee (2010) use data from multinational companies (MNC) and compare reported use of imports by broad type to the import proportionality assumption. They find broadly consistent results between current practice and the MNC data and attribute some of the differences to the difference between establishment and company concepts.
3. Because our analysis covers 1998–2011, we use the 1996 concordance for 1998–2001, the 2002 concordance for 2002–2006, and the 2007 concordance for 2007–2011. Concordances are available here: http://unstats.un.org/unsd/trade/conversions/HS%20Correlation%20and%20Conversion%20tables.htm.
4. There are limited cases where the BEC code for a given six-digit commodity is ambiguous in the published concordance. For example, the six-digit harmonization code can be listed multiple times and assigned to BEC codes that do not give a unique map to intermediate input, consumption, or investment. In these cases, we default to the import proportionality assumption for the proportion of this item included in this six-digit harmonization code.
5. In constructing the "GDP by Industry" accounts, typically reexports are netted out from the value of imports, but in constructing the value to be used to allocate imports across broad economic categories, we do not net out reexports.
6. The foundation for this mapping is made up of the census guidelines on appropriate NAICS codes for each harmonization code (when this information is available).
7. An import is assigned to "undetermined" if the six-digit harmonization code to the BEC map is ambiguous.
8. An alternative is to assume that capital goods get sold only to final demand, but this leads to all of the capital goods that typically get embedded in other goods being allocated to final demand.
9. UN Comtrade provides quantity data in units recommended by the World Customs Organization. We construct prices for each of the 13 quantity types and construct value-share-weighted growth rates for each item (across quantity type). We use the value and quantity to define the implicit price. A previous version of this research used only data that was reported in kilograms.
10. In a regression with observations weighted by import values of UN Comtrade Törnqvist prices on BEA prices, the coefficient on the BEA prices is about 0.7 for the 2002–2011 period but declines to −0.1 over the 1997–2002 period.
11. The BEA has details on about 150 import prices from the BLS.
12. Industry output and intermediate input for the baseline case is taken from the 1998–2011 annual revision of the GDP-by-industry data (http://www.bea.gov/industry/gdpbyind_data.htm). Capital and labor services are extrapolated through 2011 using internal estimates and include a labor and capital composition adjustment based on the approach of Jorgenson, Ho, and Samuels (2011).
13. This decomposition is the direct-aggregation-across-industries approach of Jorgenson et al. (2007).
14. Note that this differs from the concept of aggregate TFP used in Jorgenson et al. (2007) by their reallocation terms.
15. Because of differences in index number methodology, there are small differences between published estimates and estimates given here.

16. This excludes the purchases by the “Forestry, fishing, and related activities” industry itself. It is based on the 2007 annual input-output table.

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Part 3

Eliminating Biases: Proposals to Improve Price Statistics

9
The Impact of Globalization on Prices

A Test of Hedonic Price Indexes for Imports

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Sourcing patterns for many types of imported products have changed dramatically over the past two decades as emerging economies have become major producers of the manufactured products consumed in the United States. In addition, goods with regular quality improvements due to new or improved technology have also increased their representation in U.S. imports. The U.S. export and import price indexes are constructed using a "matched-model" approach that is likely to miss price reductions for imports that occur when sourcing shifts from high-cost countries to low-cost countries of origin. The matched-model approach is also likely to miss changes in quality-adjusted prices that occur when new models that embody improved technology enter the market. Hedonic methods for quality adjustment could help to resolve these problems. This chapter demonstrates the feasibility of applying these methods to import price index data by estimating hedonic indexes for two products that have experienced changes in sourcing and technological progress: televisions and consumer cameras. The hedonic indexes imply that significant upward bias in matched-model import indexes for these products arises both from changes in sourcing and from new technologies.

WHY STUDY HEDONIC INDEXES FOR IMPORTS?

An important element of globalization is the growth of export-oriented manufacturing industries in emerging economies, bringing with it expanded opportunities to source imports from new locations where costs are lower. Since the mid-1990s, shifts in sourcing to emerging economies have become more common for a wide variety of consumer products and intermediate inputs, including electronic goods, textiles, and apparel. Such shifts in sourcing create measurement challenges for price statisticians since direct price comparisons of the items from the new and previous source countries are usually not possible.

Another element of globalization has been the rapid growth in imports by countries like the United States of products for which technological improvements are an important phenomenon, such as electronic goods. For products with evolving technologies, comparisons of new models to previous models may again be impossible without a way to do a quality adjustment, but omitting new and existing models will cause bias if the new models tend to enter with lower- (or higher-) quality-adjusted prices.

Changes in source country and changes in technological characteristics both present a risk of bias for the U.S. import price index (MPI) because the Bureau of Labor Statistics' (BLS) International Price Program (IPP) constructs its indexes as matched-model indexes. In a matched-model index, only continuing items (models that match) are used in the index calculation. Changes in sample composition resulting from item replacements or sample rotations are handled by linking the incoming items into the index. Linking means that any item that is not present in both the initial and the comparison period is excluded from the calculation of the change in the index. Linking therefore prevents the MPI from capturing any cost savings that an importer enjoys by switching suppliers. Any remaining gap that exists between the inflation-adjusted price of the old supplier and the price of the new supplier is, in effect, attributed to quality change. The bias in the MPI from failing to capture price reductions caused by shifts in sourcing resembles the phenomenon of outlet substitution bias in the consumer price index from consumers switching to low-priced outlets like Walmart (Reinsdorf 1993).[1]

A matched-model index avoids making possibly specious comparisons of items that may be of differing quality. Rather than omitting price changes that occur during item replacements, as the matched-model method does, hedonic price indexes adjust for quality differences in a way that allows these price changes to be taken into account. Hedonic methods therefore offer a potential solution to the biases created by globalization. Indeed, by using other kinds of data as a proxy for U.S. import data, hedonic techniques have already been applied to these or related problems. In particular, Grimm (1998) uses proprietary data on worldwide markets for semiconductors to construct hedonically adjusted deflators for exports and imports of semiconductors in the U.S. National Income and Product Accounts (NIPAs) for the years 1981 to 1997. To our knowledge, however, no one has yet applied hedonic regression techniques to trade data directly.

LITERATURE ON BIAS IN IMPORT PRICE INDEXES

Changes in sample composition can also occur in the import index for reasons other than sourcing changes and technological progress. Recent research finds that an important part of overall price change for exports and imports occurs at times of product entry and exit. Nakamura and Steinsson (2012) analyze a sample of the microdata that the BLS used to compile the import and export price indexes. They find that items in the sample tend to be subject to frequent replacement and tend to have rigid prices during their lifespan in the sample (44.3 percent of the items in import price samples never have a price change). They conclude that a high proportion of price changes must therefore occur at the time of item replacements.

In Nakamura and Steinsson (2012), the sign of the bias in the matched-model index depends on whether the index has an upward or downward trend: If the price index is trending downward, excessive flatness of the matched-model index means that it has an upward bias. With the matched-model index, there is an assumption that changes in quality-adjusted prices at times of item replacements are, on average, the same as the observed price changes for continuing items. This assumption implies corrections to estimated changes in the index for nonoil imports that raise the standard deviation of quarterly log changes from 1.1 percent to 1.6 percent. This in turn would imply that the matched-model index for imports is significantly flatter than it should be.[2]

The assumption that quality-adjusted price changes associated with item replacements have the same mean as price changes for continuing items may, however, be unrealistic for products undergoing rapid technological progress or for entry by new producers in low-wage countries that have cost advantages. For these kinds of goods, even a matched-model index that is trending downward might have an upward bias because the changes in quality-adjusted prices at times of item replacements are smaller than the average price change of continuing items. Erickson and Pakes (2011) provide evidence that unmeasured price changes associated with item replacements tend to be systematically lower than the measured price changes when a product is undergoing improvement as a result of technological progress.[3]

The lower prices that import buyers obtain by sourcing from China and other emerging economies have also been topics of several papers. Thomas, Marquez, and Fahle (2008) infer the size of the price reductions that U.S. importers realize by switching to sources from emerging economies on the basis of purchasing-power parity data from the Penn World Tables. More recently, Byrne, Kovak, and Michaels (2013) have directly looked at prices from traditional sources of semiconductors and from new sources in China and find that the China price is 17 percent lower for an identical semiconductor. Finally, Reinsdorf and Yuskavage (2013, Table 1) show that changes in import sourcing to countries like China could plausibly have resulted in an upward bias in the MPIs for consumer durable goods, including computers but excluding motor vehicles, of up to almost 1 percent per year.[4]

An indirect method for estimating the bias in a matched-model import price index from new and disappearing varieties was introduced by Feenstra (1994). In applying the method, varieties are usually distinguished on the basis of source countries. The model underlying this method implies that a variety may be bought in limited quantities just because it is different, but that because market shares are inversely proportional to quality-adjusted prices, for a variety to sell well it must have a low quality-adjusted price. If the post-entry share of the entering varieties is greater than the pre-exit share of the exiting varieties, the estimated bias in the matched-model index will be positive. Feenstra et al. (2013) use this method to estimate the bias associated with variety entry and exit in the deflator for nonpetroleum imports in the U.S. national accounts, with new countries of origin treated as new varieties. They find an average bias of about 0.6 percent per year, indicating substantial net gains in market share by new supplying countries. This estimate reflects a combination of several factors, including entry of low-priced producers in emerging low-cost locations, lower quality-adjusted prices made possible by technological progress, and a general broadening of the available range of varieties as markets thicken.

Finally, Houseman et al. (2011) and Mandel (2007, 2009) focus on price effects that are due to the offshoring of production from the United States to lower-cost locations. Offshoring substantially reduces the price paid by buyers of intermediate inputs, yet this price reduction cannot be captured either in the MPI or in the producer price index. Alterman (2009 and Chapter 10 of this volume) proposes a buyer's price index for intermediate inputs as a way of capturing the effects of substitution from local to offshore production. Note, however, that if the buyer's price index relies exclusively on the matched-model approach to handle quality change, it may miss some of the price changes associated with changes in where the intermediate inputs are produced because the offshored version of the product may not be matched with the previous local version of the product. Hedonic methods are likely to be needed to enable the buyer's price to fully measure the effects of changes in source countries.

HEDONIC PRICE INDEXES FOR IMPORTS

Hedonic price indexes do not exclude from the index calculation observations that are only present in one time period. They are based on hedonic regressions that model the effects of items' characteristics on the price.

The history of hedonic price index research extends back for more than 80 years, and in the years since the Stigler Commission report included Griliches's (1961) chapter applying this method to autos, there have been innumerable empirical applications of this technique to the consumer or producer price indexes. Aizcorbe, Corrado, and

Doms (2003) explore conditions under which matched-model and time-dummy hedonic quality-adjustment techniques lead to comparable measures of prices. They find that the two approaches give numerically similar estimates when rates of entry and exit are low, or when observations are at high frequency and changes in characteristics occur gradually over time.

One traditional specification of a hedonic regression model includes dummy variables for time periods along with a set of characteristics variables. If the dependent variable is log price, the coefficient on a time period's dummy variable is the logarithm of its price index. Another common approach employs fitted coefficients from a regression using data from time period *s* to predict the price that an observation from the other time period, say time period *t*, would have had, had it been present in period *s*. An analogous regression run for period *t* is then used to predict the prices of items that only existed in period *s*. The predicted prices can then be included in the calculation of the index.

Recently, Erickson and Pakes (2011) have developed a modification of this hedonic technique that accounts for the selection bias caused by exiting goods being supplanted by more technologically advanced goods. Their technique accounts for unobserved price-determining characteristics by making use of the information in the residuals from the standard hedonic regression. In principle, the method should work well for handling the data limitations faced by the IPP, as it does not require that a large number of characteristics be observed. Unfortunately, a key assumption is not met: Erickson and Pakes assume that for a given set of characteristics, the marginal cost is the same across sellers. This assumption does not hold true in our data.

Despite the high degree of interest in the questions that hedonic methods might help to answer, to our knowledge this chapter is the first to estimate a hedonic import price index using data collected from importers by a statistical agency. Data limitations are probably the main reason for the lack of research on hedonic indexes for import prices. Many countries construct most of their export and import indexes as unit value indexes from customs data values and volumes for detailed classes of items, such as the 10-digit categories of the Harmonized System (which is an internationally agreed-upon classification scheme for traded commodities). A unit value in these indexes will typically cover a variety of items whose characteristics vary, so no particular set of characteristics can be ascribed to an observation.

The United States no longer uses unit values for its export and import indexes except in special cases: The BLS began to produce complete sets of specification-based price indexes for goods imports in 1982 (Alterman 1991, p. 113). This means that the observations in the U.S. import index sample have well-defined characteristics. Nevertheless, detailed characteristics information can be difficult to collect from respondents in IPP surveys, so the import price index database often lacks full information.

We found that for items that have a make and model number, the problem of missing characteristics information could be largely overcome by performing Internet searches on the make and model number of the sampled items. Except for the items that exited before the Internet became pervasive, we were generally able to find good product description information using this method from owner's manuals or other product literature.

DATA DESCRIPTION

To construct experimental hedonic indexes and benchmark matched-model indexes for imports, we use three subsets of the import price data from the International Price Program (IPP) Research Database (Blackburn, Kim, and Ulics 2012). In particular, we use the description field in the IPP database to assemble data sets on imports of consumer televisions, consumer cameras, and bananas.[5] Bananas are intended as a kind of control group. Unlike televisions and cameras, they are relatively homogeneous (though besides the main Cavendish variety, the sample also contains some specialty varieties).

The description field in the IPP database is also the basis for the quality variables that we construct for each product type. The variables used in the hedonic models cover the characteristics that are well documented in the description portion of the IPP database, although even for these variables blanks sometimes have to be filled in through Internet searches on make and model number. (See Appendix Table 9A.1 for the list and description of quality characteristics that we are able to pull from the database.)

The data set for televisions and bananas covers the months between January 2000 and December 2010. Unfortunately, for cameras the data on quality and monthly prices become too sparse after March 2006, so our camera indexes end at that point.

The IPP database contains two types of prices: reported prices and net prices. To derive the net price, the BLS adjusts the reported price as needed for discounts, duties, freight charges, and the exchange rate. The net prices are estimates of actual transaction prices in dollars and are used for the official import and export price indexes. Thus, we also use the net prices. In addition, for certain commodities, the BLS allows reporters to give "index" prices.[6] These types of prices, which were reported for some of our banana items, are excluded from our analysis.

We include intrafirm "transfer" prices in our study to keep sample sizes from becoming too small. We do, however, include a dummy variable for intrafirm prices in our hedonic regressions because these prices behave differently from arm's length prices; they are characterized by less stickiness, less synchronization, and greater exchange rate pass-through, as found in Neiman (2010). For tractability, we assume that the intrafirm pricing strategy is the same across firms and time throughout this study. As shown in Table 9.1, the share of intrafirm prices is high for cameras and bananas.

Table 9.1 Share of Prices That Are Intrafirm in Each Month

	Televisions	Cameras	Bananas
Mean	0.41	0.89	0.85
Min.	0.15	0.72	0.62
Max.	0.64	1.00	1.00

SOURCE: Authors' calculations.

In the IPP database, many items are repriced less often than every month, so monthly prices are often temporarily missing. Temporarily missing prices can also occur because the respondent fails to report a price one month.[7] We experimented with two ways of imputing temporarily missing prices. The simple method of carrying forward the last observation to fill in the missing prices is a standard practice in research using IPP data. (See, for instance, Nakamura and Steinsson [2012] and

Gagnon, Mandel, and Vigfusson [2012].) Given that for many products in the IPP long periods of price rigidity are common, this method is a reasonable approximation.

On the other hand, for official price indexes, the BLS generally imputes missing values by adjusting the last observation to reflect an estimate of the subsequent price change using either "cell-relative" imputation or "class-mean" imputation.[8] We found that our results were insensitive to whether we used cell-relative imputation or the simple carry-forward method favored by researchers, so below we will focus on indexes that include carry-forward imputations. Table 9.2 reports the share of missing values that are imputed for each subset considered.

Table 9.2 Share of Prices That Are Imputed in Each Month

	Televisions	Cameras	Bananas
Mean	0.03	0.04	0.00
Min.	0.00	0.00	0.00
Max.	0.32	0.50	0.12

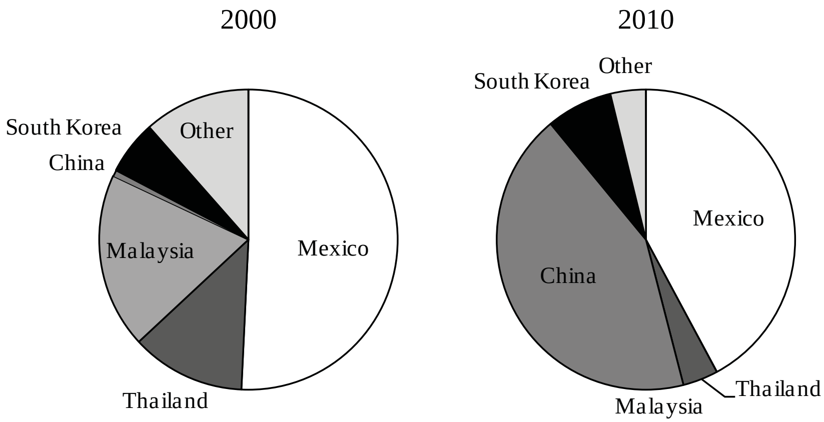
SOURCE: Authors' calculations.

Both televisions and cameras exhibit a great deal of cross-sectional variation in price levels. Television prices vary 300-fold, while camera prices vary 500-fold. Television prices are much less sticky than camera prices. In the television sample, items change price an average of 6.4 times during their time in the sample, while in our camera sample items on average have only 1.6 price changes between entering and exiting.[9]

Source countries shifted for both televisions and cameras over our sample periods; televisions shifted from Mexican imports to Chinese imports (see Figure 9.1), while cameras moved away from Japanese imports to imports from China and Thailand (Figure 9.2). The growth in television screen sizes over our sample period is also noteworthy (Figure 9.3).

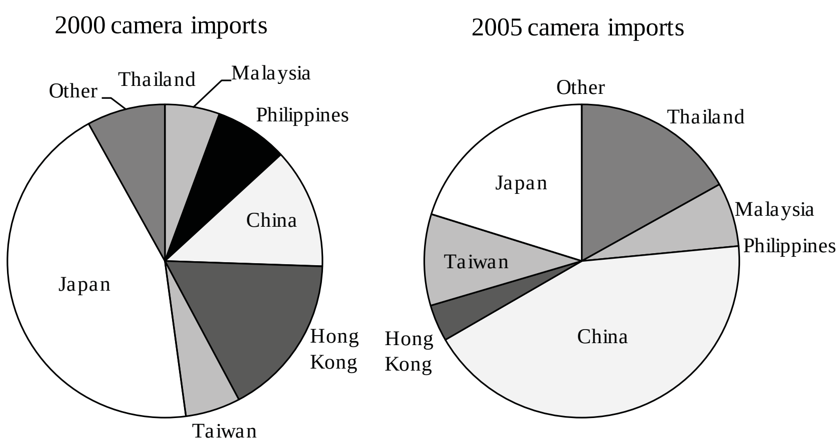
Televisions experience slightly more sample entry than sample exit throughout the period that we study. Cameras, on the other hand, experience almost one and a half times more exits than entries of items into the sample. On average about 4.7 percent of televisions in a given month are no longer present in the next month, while for cameras the hazard rate for sample attrition is 5.6 percent per month (see Table 9.3 for a summary of exit reasons). The mean duration of a television in the

Figure 9.1 Change in Share for the Source Country for Television Imports, 2000–2010



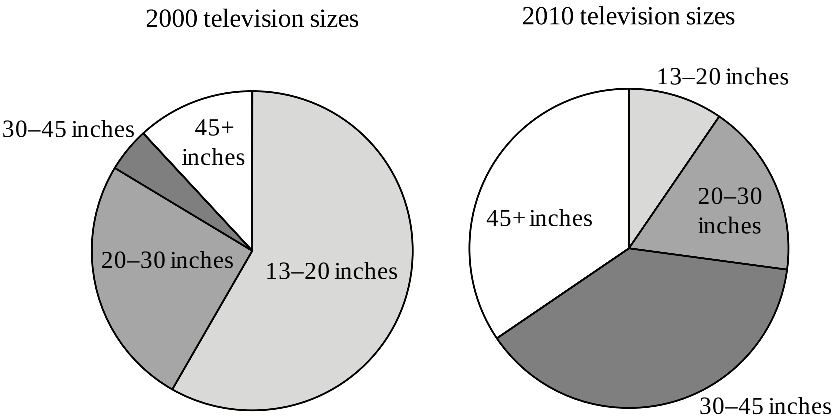
SOURCE: Authors' calculations.

Figure 9.2 Change in Share for the Source Country for Camera Imports, 2000–2005



SOURCE: Authors' calculations.

Figure 9.3 Change in Share for Imported Television Sizes, 2000–2010



SOURCE: Authors' calculations.

sample is 18.1 months (with a standard deviation of 12.9 months). This is slightly shorter than the 21 months that would occur if the hazard rate for exit were constant. On the other hand, mean duration of an item in the camera sample, at 17.8 months (with a standard deviation of 11.6 months), is consistent with a constant hazard rate for sample exit.

Bananas behave very differently from televisions and cameras. Prices for bananas only vary sixfold, reflecting their greater homogeneity. Moreover, bananas change prices very frequently compared to

Table 9.3 Mean Share of Items Experiencing Permanent Exit in Each Month, by Reason (mean)

	Televisions	Cameras	Bananas
Refusal	0.01	0.00	0.01
Out of business	0.00	0.00	0.00
Out of scope	0.02	0.04	0.00
Out of scope, replaced	0.01	0.01	0.01

NOTE: "Out of scope" items are items that are no longer traded. Reporters sometimes are able to give a quote for a replacement item. At other times, there is no replacement.

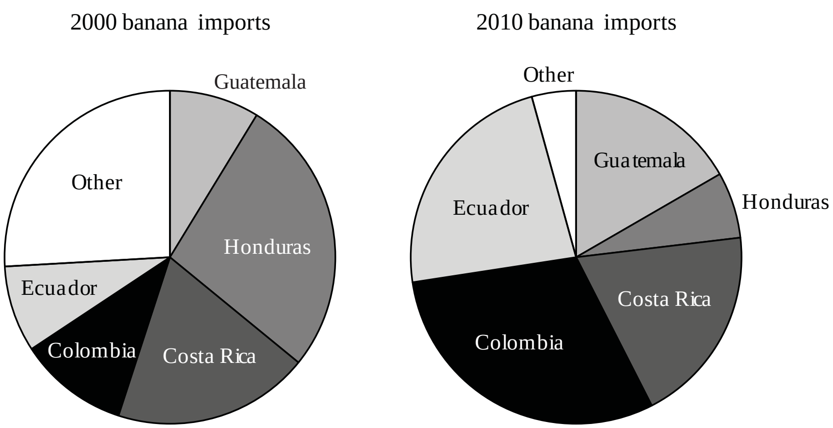
SOURCE: Authors' calculations.

televisions and cameras; on average, a banana quote changes price 19.3 times during the time that it is in our sample. Bananas in our data set primarily are imported from Guatemala, Honduras, Costa Rica, Colombia, and Ecuador. Colombia, Ecuador, and Guatemala have increased their representation in the import price index sample, while the share of the sample from Honduras has fallen and the one from Costa Rica has remained about the same (Figure 9.4). On average, about 1.9 percent of bananas in each period are no longer present in the next period. The mean duration of an item in the banana sample is substantially longer than those of televisions or cameras, at 32.2 months (with a standard deviation of 23.9 months).

BASELINE NONHEDONIC MEASURES OF PRICE CHANGE

Before calculating sets of hedonic price indexes, we calculate two baseline measures of price change. The first of these simply tracks the change in the geometric average price of the sample. The average price index should exhibit similar behavior to a unit value index: Like a unit

Figure 9.4 Change in Share for Source Country for Bananas, 2000–2010



SOURCE: Authors' calculations.

value index, it does not hold the sample composition constant when comparing time periods. (We cannot calculate true unit-value indexes because we do not have the necessary data on quantities.) Changes in sample composition are likely to alter the average quality level represented in the sample, so the behavior over time of the average price reflects both price and quality developments. Deflating the average price index by a price index that holds quality constant yields an index of quality change.

Second, we construct matched-model indexes to use as benchmarks to compare to our hedonic price indexes. The matched-model indexes of the MPI include item weights in a Laspeyres-like index formula.[10] We do not have the item weight information needed to replicate these Laspeyres matched-model indexes, so our matched-model indexes are calculated as modified Jevons indexes of the prices of the continuing items, for which less detailed weights based on customs data are used.[11] A matched-model Laspeyres index is calculated as a share-weighted arithmetic average of price relatives of continuing items, while the logarithm of our weighted, matched-model Jevons index is a share-weighted average of logarithms of these same price relatives. We also include our calculated weights for observations in all of the indexes that we calculate so that the overall weight for each source country is proportional to its importance in the trade data for the product in question.

BLS policies on disclosure of nonpublic data allow us to report only publication-level indexes. We are unable to report indexes at the level of the individual products that make up a publication-level index, nor can we report coefficient estimates that would allow someone to reproduce one of these unpublished indexes. Therefore, besides calculating matched-model indexes for the three products of interest, we calculate matched-model Jevons indexes for the other products contained in the published index and then aggregate up to the level of the published index. For example, for bananas, we simulate the relevant published index for “edible fruits and nuts” (Harmonized System Code 08, or HS 08) by combining our index for bananas with an index for other edible fruits and nuts with weights based on the number of items in each category.

Despite these limitations, we can use the difference between the aggregated matched-model indexes and the aggregated hedonically adjusted indexes to infer the effects of the quality adjustment on the products of interest. In particular, we divide the change in the logarithm of the more aggregate index by the weight of televisions or cameras in that index to find the implied change in the logarithm of the index for televisions or cameras.

HEDONIC INDEXES

Sample size limitations affect what kinds of hedonic models we can investigate. The simplest specification we try is the pooled time dummy hedonic regression, which assumes that the effect of quality characteristics on the log price is constant over the whole span of time covered by the sample. The general form of the pooled time dummy regression equation is

$$(9.1) \quad p_{it} = \alpha_t + X_{it}\beta + \varepsilon_{it} ,$$

where p_{it} is the log price of item i at time t, and X_{it} is a vector of quality characteristics such as the television's screen size and screen type. The price index comparing time t to $t-1$ is then just the exponential difference between α_t and α_{t-1}.

As a more flexible alternative to the pooled hedonic regression, we also estimate a set of overlapping hedonic regressions that use a moving window of just 24 months for their sample. The time periods covered by these regressions have 12-month overlaps so that a cumulative price index from the beginning of the overall sample can be constructed from a sequence of transitive comparisons. Ideally, we would have run these regressions on monthly data, but, in practice, to get around sample size problems, we had to pool the observations for each quarter. The moving-window approach has the advantage of allowing the coefficients on characteristics to change over time if evolving technologies and market conditions alter the hedonic relationships.[12]

We fit these models by both including and excluding country dummies from the set of variables in X_{it} in Equation (9.1). The specification that includes country dummies assumes that price differences between countries of origin are due to quality differences between these countries, while the specification that omits the country dummies assumes that price-level differences between countries of origin are real. The truth probably lies between these alternatives—ease of doing business and quality assurance may vary by country, but on the other hand, the large gains made by countries offering lower prices suggest that the value of the quality differences is small in comparison with the price differentials.

Rather than leaving the country dummies out of the hedonic regression, a hedonic index that includes price changes due to changes in source country can instead be calculated by adding back the part of the hedonic index's quality adjustment coming from changes in source countries. Using the pooled hedonic index as an example, let $\hat{a}_t$ be the fitted coefficient on the time dummy for period t (with the time dummy omitted in the base period), $\Delta\overline{p}$ be the change in the average log price, and ΔX be the change in the average characteristics including the country dummies. The log hedonic index with country dummies included equals the raw price change minus a quality adjustment equal to the predicted effect of the average characteristics change:

$$(9.2) \qquad \hat{a}_t = \Delta\overline{p} - (\Delta X)\hat{\beta}.$$

Now break X into a physical attributes part and a country mix part:

$$(9.3) \qquad \hat{a}_t = \Delta\overline{p} - (\Delta X_{PA})\hat{\beta}_{PA} - (\Delta X_{CM})\hat{\beta}_{CM}.$$

The index that includes the effect of source country changes in the measure of price change is

$$(9.4) \qquad \tilde{a}_t = \hat{a}_t + (\Delta X_{CM})\hat{\beta}_{CM}.$$

EMPIRICAL RESULTS

HS 8528 and Televisions

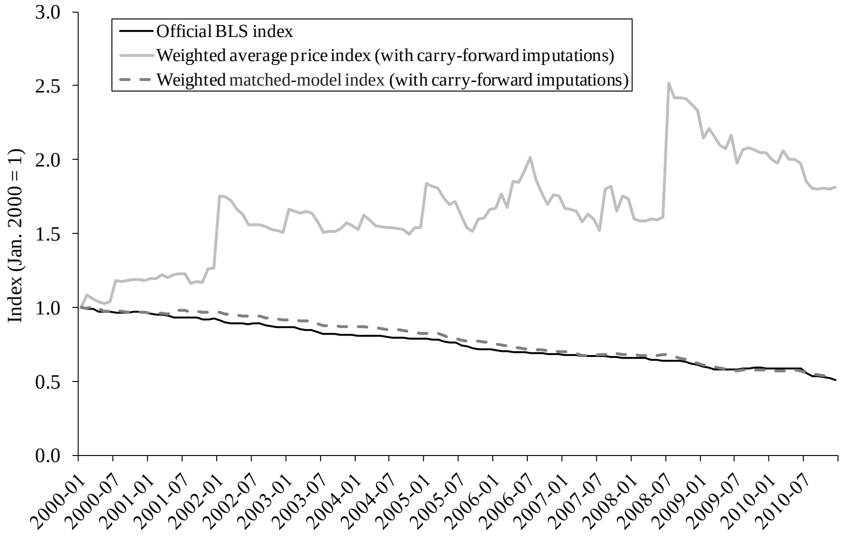
The first set of hedonic indexes that we estimate are for imported televisions. As explained above, BLS disclosure policies prevent us from showing research indexes that would correspond to an unpublished level of detail, so we show indexes at the lowest published level that includes televisions, HS code 8528. HS 8528 covers televisions and other video devices.[13]

Comparisons of the official index with our hedonic indexes would be affected by more than just the differences in compilation methods that we want to investigate, so we construct a matched-model import index of our own for use in these comparisons. The key feature of the official import index is its use of the matched-model index. Our matched-model index replicates that feature, but it differs in the choice of aggregation formula. Whereas the official index has a modified Laspeyres formula, we use a Jevons (geometric means) index formula to combine the matched-model indexes for televisions with that for other video devices. Also, whereas the usual Jevons index is an *unweighted* geometric mean of price relatives, our Jevons indexes include country weights that reflect the relative importance of different source countries in the trade data. Note, however, that our weights do not precisely match the weights used for the official index.

Our matched-model Jevons index with country weights closely tracks the official matched-model index for HS 8528 most of the time (Figure 9.5). It also has a similar long-run trend. Over the whole period of January 2000 to December 2010, our matched-model index falls at an average rate of 5.7 percent per year, close to the official index's 6 percent per year rate of decline. On a few occasions the indexes diverge, however. In May of 2001, August–September of 2005, and April of 2008, our index has a higher rate of change than the official index, while in August–September of 2008 and April–May of 2009 our index measures lower inflation.

Televisions and video devices experienced rapid increases in quality over the period covered by the sample, including the displacement of CRT screens by superior flat-screen technologies (plasma, LCD, and, finally, LED) and an increase in the average screen size. These quality improvements substantially affected the average price of a television. The difference between the growth rate of the average price and the growth rate of the matched-model index reflects the value of the quality improvements. In contrast to the rapidly falling matched-model indexes, the weighted average price rises at an average rate of 5.6 percent per year. Assuming, for the sake of argument, that the matched-model Jevons index correctly measures the pure price change, we can

Figure 9.5 Matched-Model and Average Import Price Indexes for HS 8528: Televisions and Other Video Devices



SOURCE: Bureau of Labor Statistics and authors' calculations.

infer that quality improvements added more than 11 percent per year to the annual growth rate of the average price of televisions and other video devices over the period that we study.

Next, we check the accuracy of the matched-model index by comparing it to hedonic indexes. To estimate the effects of the entry of new source countries whose prices may be lower, one alternative is to control for physical characteristics of televisions, but not source countries, in the hedonic model. Including dummy variables for country of origin in the hedonic regression would cause the hedonic index to include country effects in its quality adjustments.

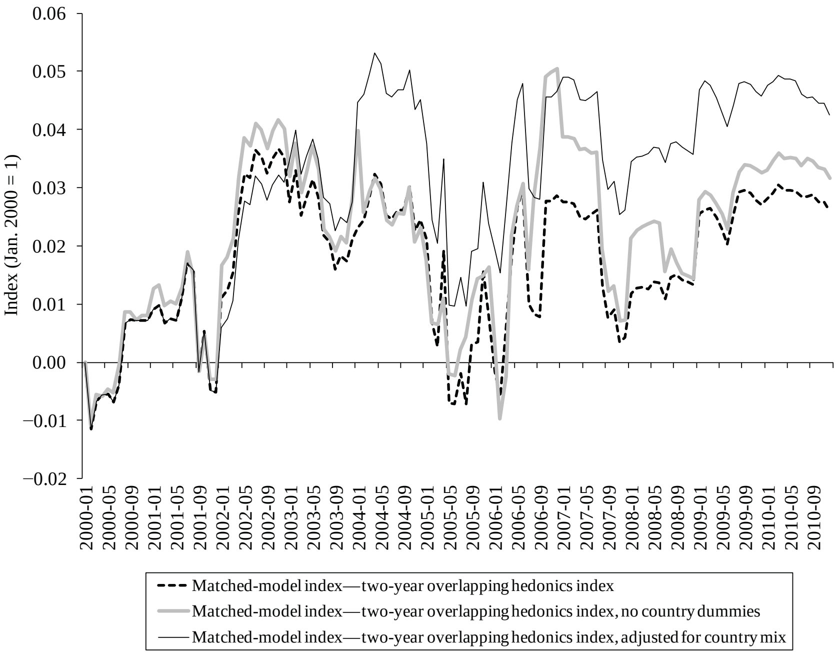
A weakness of this approach is, however, that it is vulnerable to omitted variable bias. If characteristics and countries are correlated, some of the effects of the omitted country variables could be reflected in the coefficients on the physical characteristics. This may then cause effects of changes in country mix to be embedded in the coefficients on the physical characteristics.

Including country dummies in the hedonic regression makes the coefficients on the physical characteristics less likely to include effects of changes in source countries that are correlated with changes in physical characteristics. The coefficients on the country dummies can be used to adjust the hedonic index so that it includes the price effects of changes in country mix, as shown in Equation (9.4). (Note, however, that a problem of collinearity between countries and characteristics may not be completely solved by this technique, because if the sample size is not large enough, such collinearity would likely lead to high variances for the coefficient estimates.) The difference between the adjusted hedonic index and the matched-model index will then include the price effects of changing source countries that are missed by the matched-model index. If the adjustment is not made, the difference between the raw hedonic index that includes country dummies and the matched-model index will estimate the amount of quality change from improvements in physical attributes due to technological advances that is missed by the matched-model index.

Of the two types of hedonic indexes that we estimate for televisions, the moving-window hedonic index is likely to be more reliable than the pooled hedonic index. In the pooled hedonic regression, a single set of coefficients on the quality characteristics and country dummies (if included) is estimated for the entire time interval covered by the sample, so a characteristic's effect on the logarithm of a TV price is constrained to be constant over a long interval. On the other hand, the moving-window approach allows the slope coefficients to evolve over time by estimating separate sets of hedonic coefficients for overlapping pairs of years. Over longer time intervals, technological progress significantly alters the shadow value of at least some television characteristics, and changes in prices and income could change the demand for characteristics in ways that affect their shadow values. Suppose, for example, that the price differential for large screens declines over the course of the period covered by the sample, and that near the end of the sample period imports from China start to grow rapidly, with a specialization in smaller screen sizes. The pooled hedonic regression would then tend to underestimate the relative quality of the Chinese televisions in the period when they are growing, and hence tend to overestimate the quality-adjusted price level of televisions from China.

Another advantage of the moving-window regression approach is that one can see what the estimate of the bias would have been if the analysis had stopped earlier than December 2010. Differences between the matched-model index for HS 8528 and indexes for HS 8528 that incorporate moving-window hedonic price indexes for televisions are shown in Figure 9.6. The growth-rate gap between the matched-model index and the adjusted moving-window hedonic index is not uniform over time; some earlier stopping points would have implied larger estimates of the bias in the matched-model index. Adjusting the hedonic index for the changes in source countries lowers its growth rate by 0.016 index points and brings the estimate of the bias in December 2010 of the matched-model index up to 0.042 index points. The unadjusted moving-window hedonic index for HS 8528 is about 0.026 index points

Figure 9.6 Differences between Weighted Matched-Model and Weighted Overlapping Hedonic Indexes for HS 8528: Televisions and Other Video Devices



SOURCE: Authors' calculations.

lower than the matched-model index in December of 2010, suggesting that incomplete measurement of the gains from improved technology adds about 0.026 to the matched-model index.

Omitting the country dummies implies a slightly smaller estimate of the bias in the matched-model index of 0.032 index points in December 2010. This implies that the bias in the matched-model index due to the failure to capture price declines from changing source countries is only about 0.006 index points in December 2010. The difference between the hedonic index that includes country dummies and the hedonic index from the regression with no country dummies may underestimate the country mix effect because of omitted variable bias. The differences between the weighted matched-model index and the various hedonic indexes, stated in terms of differences in average annual growth rates, are shown in Table 9.4.

Table 9.4 Amounts by Which Matched-Model Index Growth Rate Exceeds Moving-Window Hedonic Growth Rates for HS 8528 (% per year, 2000–2010)

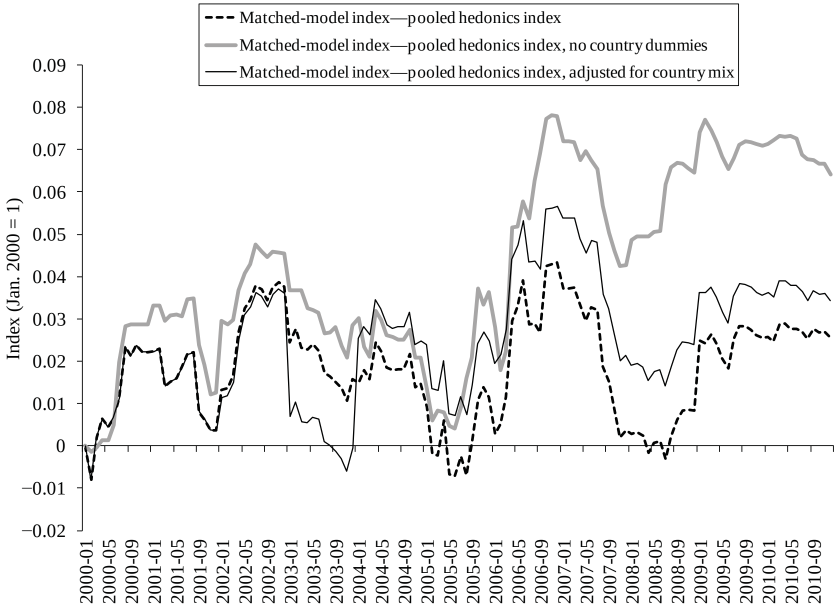
Country dummies included	0.44
Country dummies excluded	0.53
Adjusted for changing country mix	0.72

SOURCE: Authors' calculations.

We also estimate pooled hedonic indexes as a kind of robustness check on the moving-window hedonic results. Figure 9.7 shows the differences between the pure matched-model index for HS 8528 and the indexes that incorporate pooled hedonic price indexes for televisions. Like the moving-window hedonic indexes, the pooled hedonic indexes all imply positive estimates for the ending bias in the matched-model index. Indeed, the pooled version of the unadjusted hedonic index that includes country dummies implies the same estimate of bias owing to underestimation of gains from improvements in technology as the moving-window version, 0.026 index points.

On the other hand, the pooled specification produces a lower hedonic index than the moving-window specification in the case where country dummies are omitted from the model, and a slightly higher hedonic index in the case where country dummies are included and an adjustment is made for the effects of changing country mix. Under the pooled

Figure 9.7 Differences between Weighted Matched-Model and Weighted Hedonic Indexes for HS 8528: Televisions and Other Video Devices



SOURCE: Authors' calculations.

specification, the no-country-dummies index is 0.064 index points below the matched-model index in December 2010, while the adjusted hedonic index is just 0.034 index points lower than the matched-model index. Under the pooled specification, the adjusted hedonic index implies a bias in the matched-model index from changing sourcing of 0.008 index points, while the no-country-dummies hedonic index implies that this bias is 0.038 index points. These differences in average annual growth rates between the pooled hedonic indexes and the matched-model index are shown in Table 9.5.

Table 9.5 Amounts by Which Matched-Model Index Growth Rate Exceeds Pooled Hedonic Growth Rates for HS 8528 (% per year, 2000–2010)

Country dummies included	0.43
Country dummies excluded	1.11
Adjusted for changing country mix	0.58

SOURCE: Authors' calculations.

Television Component of HS 8528

Even though we cannot show the television component of HS 8528 as a separate index, we can calculate how sensitive the television index is to the choice of method. To find the difference between a matched-model index and a hedonic index for televisions, we divide the difference between the logarithmic matched-model and hedonic indexes for HS 8528 by the weight of the television component of HS 8528, which is 0.343. The implied difference for televisions in the final period can then be converted into an average annual growth rate over the 11 years covered by the sample.

The growth rate of the matched-model index for televisions is 2.2 percent per year above that of the adjusted moving-window hedonic index (Table 9.6). Subtracting the 1.3 percentage points coming from unmeasured technological improvements (measured by the unadjusted hedonic index) leaves 0.9 percentage points of the bias in the matched-model index growth rate to be attributed to changing source countries.

To gauge the robustness of the results to the estimation method, we show in Table 9.6 some alternative estimates of the bias in the matched-model index. Omitting the country dummies rather than adjusting for the predicted effect of changing country mix reduces the estimate of the total bias implied by a moving-window hedonic index to 1.6 percent per year. Pooling all the years rather than running overlapping regressions on pairs of years reduces the estimate of the total bias based on the model with country dummies to 1.8 percent per year but increases the estimate based on the model with no country dummies to 3.4 percent per year. Subtracting the estimate of the bias from technology-related quality change from each of the alternative estimates of the total gives a range of estimates of 0.5 to 2.1 percent per year for the effect of changing source countries.

Table 9.6 Estimates of Bias in a Matched-Model Index for Televisions Implied by Different Specifications of the Weighted Hedonic Regression

Type of hedonic regression	From hedonic regression excluding country dummies (% per year)	From using country's coefficients to adjust for change in country mix (% per year)	From hedonic regression with country dummies, undermeasurement of technology-related quality change (% per year)
Moving window	1.6	2.2	1.3
All years pooled	3.4	1.8	1.3

SOURCE: Authors' calculations.

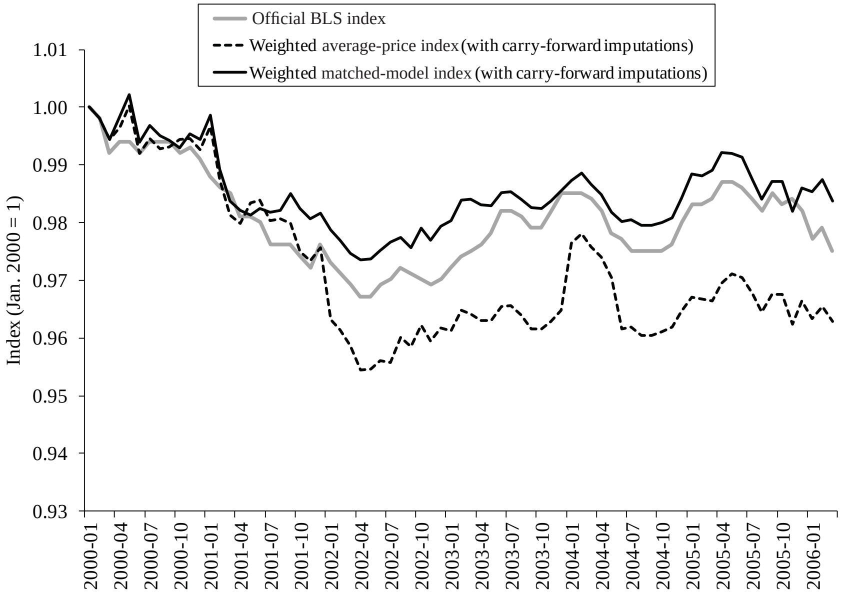
HS 90 and Cameras

Besides televisions, we investigate differences between hedonic and matched-model indexes for cameras. Cameras are a component of the published import index for HS 90, "Optical, photographic, measuring, and medical instruments," so we show indexes for HS 90 that incorporate matched-model and hedonic indexes for cameras. Even though fewer than 4 percent of the observations classified in HS 90 are for cameras during the period we examine (January 2000–March 2006), the HS 90 index is sufficiently sensitive to the choice of method for its cameras component to produce interesting results.

The baseline for the comparisons with hedonic indexes is again a matched-model index meant to simulate the official methodology. Most of the time our weighted matched-model Jevons index has virtually the same rate of change as the official index for HS 90, and it exhibits similar turning points (Figure 9.8). However, there are two episodes where our matched-model index is flat or slowly rising at the same time that the official indexes are falling. The first episode occurs in June–September of 2001, and the second occurs in January–March of 2006.

An index of the weighted average price is also shown in Figure 9.8. A notable decline in the average price relative to the matched-model index occurs between June 2001 and April 2002. The growing gap between the matched-model and average-price indexes implies that the average quality of imported cameras was declining over that time interval. An alternative explanation could, of course, be that the matched-

Figure 9.8 Matched-Model and Average Import Price Indexes for HS 90: Cameras and Other Photographic, Measuring, and Medical Instruments



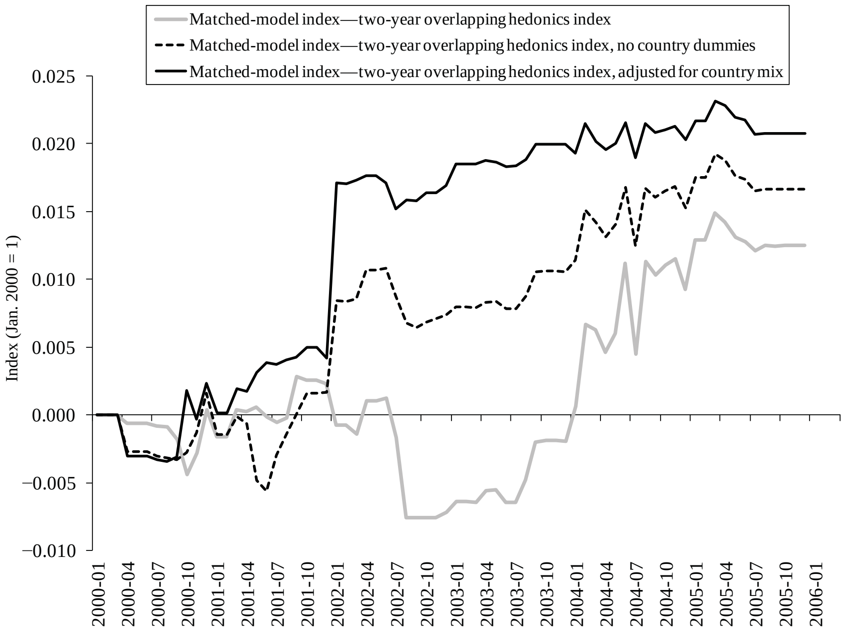
SOURCE: Bureau of Labor Statistics and authors' calculations.

model index is upwardly biased. Part of the relative decline in average price comes from the emergence of inexpensive digital cameras as a popular camera type, and another part of the decline seems to be due to changes in source countries. Such collinearity between physical changes in characteristics and changes in source countries tends to reduce the precision with which independent slope coefficients for these two kinds of effects can be identified in a hedonic regression.

The moving-window hedonic index with country dummies assumes that price differentials between countries reflect quality differences. According to this index, the matched-model index has a cumulative bias of zero up to January 2004 (Figure 9.9). In other words, the adjustments for declining quality that are implicit in the matched-model procedure are deemed to be correct, on average, up to 2004. Over the subsequent two years, however, changes in physical characteristics embodied in new camera models do appear to cause declines in quality-adjusted prices that are missed by the matched-model index.

Adjusting the moving-window hedonic index so it includes effects of country-sourcing changes gives a different picture. In fact, this adjusted hedonic index behaves much like the index of the average price up to 2004. Figure 9.8 shows that in early 2002, the average price index dropped precipitously relative to the matched-model index; as a result, the matched-model index considerably overstates price change in early 2002, according to the adjusted moving-window hedonic index. Thereafter, the cumulative bias in the matched-model index implied by the adjusted hedonic index rises slowly but consistently until the end of the sample period.

Figure 9.9 Difference between Matched-Model Index and Hedonic Indexes for HS 90: Cameras and Other Photographic, Measuring, and Medical Instruments



SOURCE: Authors' calculations.

The implication that physical changes in cameras between 2000 and 2004 did not affect their average quality level seems questionable. The low slope coefficients on physical characteristics in the model with country dummies could reflect the imprecision caused by collinearity and small sample sizes. In fact, the hedonic index with no country dummies implies that roughly half of the large decline in the average price index relative to the matched-model index is caused by falling quality that is due to changes in physical characteristics. This quality adjustment results in a smaller estimate of the total bias in the matched-model index than is produced by the adjusted hedonic index.

The pooled approach to fitting the hedonic regression may also help with the problem of collinearity and small sample size. The magnitude of the adjustment for country mix is markedly smaller using the pooled regression model, and the behavior of all three hedonic indexes is plausible (Figure 9.10).

The growth rate differences between the matched-model index and the various moving-window approaches and the pooled hedonic indexes are summarized in Table 9.7. The two approaches agree on the total size of the bias in the matched-model indexes, but the moving-window hedonic implies that a larger portion of this bias comes from changing source countries.

Table 9.7 Differences in Average Growth Rate between the Matched-Model Index and Hedonic Indexes for HS 90

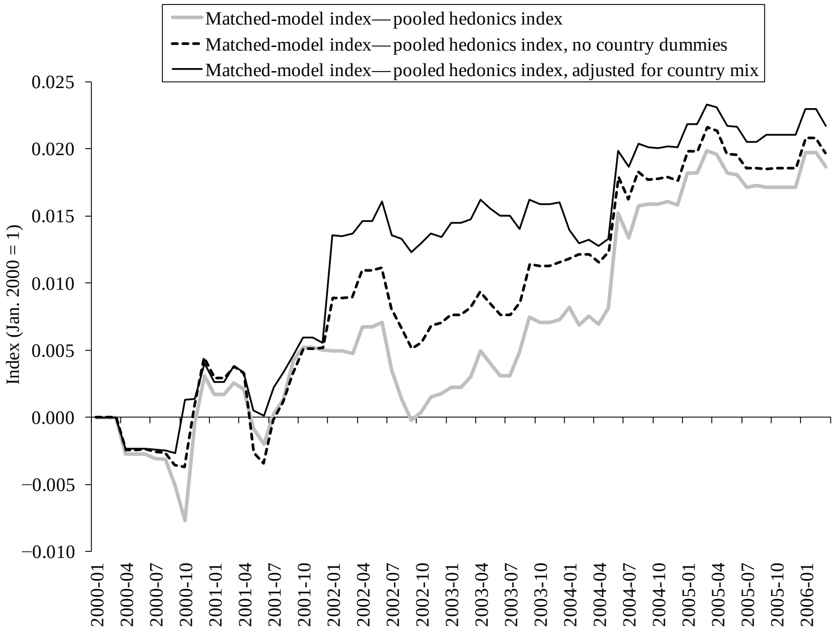
	Moving-window hedonic	Pooled hedonic
Country dummies included	0.21	0.31
Country dummies excluded	0.29	0.33
Adjusted for changing country mix	0.36	0.36

SOURCE: Authors' calculations.

Camera Component of HS 90

The weight of cameras within the HS 90 aggregate is about one-thirtieth, so we infer the effects of hedonic adjustment on the cameras index by scaling up the effects on the logarithmic HS90 index by a factor of 30. Table 9.8 shows the implied differences in average annual growth rates. The first two rows are based on the last date available for

Figure 9.10 Difference between Matched-Model Index and Hedonic Indexes for HS 90: Cameras and Other Photographic, Measuring, and Medical Instruments



SOURCE: Authors' calculations.

each individual time series, while the third row of Table 9.8 uses the ending date for the pooled hedonic indexes that is used for the moving-window hedonic indexes. (The pooled hedonic indexes in Figure 9.10 end three months later than the moving-window hedonic indexes in Figure 9.9.) If the same ending date is used, the moving-window and pooled approaches imply similar estimates of the total bias in the matched-model index of about 11.5 percent per year. On the other hand, if a longer period is used for the pooled hedonic regression, the pooled indexes are all 0.9 percentage points below the comparable moving-window hedonic index.

According to the moving-window indexes, the bias in the matched-model index caused by declines in quality-adjusted prices associated

Table 9.8 Estimates of Bias in the Matched-Model Index for Cameras Implied by Different Specifications of the Weighted Hedonic Regression

Type of hedonic regression	Estimate from hedonic regression excluding country dummies (% per year)	Estimate from adjusting for change in countries using country coefficients (% per year)	Estimated unmeasured technology-related quality change from hedonic regression with country dummies (% per year)
Moving window	9.0	11.4	6.7
All years pooled	8.1	10.5	5.8
All years pooled, same ending month as for moving window	10.1	11.6	9.3

SOURCE: Authors' calculations.

with new technology amounts to 6.7 percent per year, whereas based on the pooled hedonic indexes this bias amounts to just 5.8 percent per year. The latter figure is consistent with prior literature: moving-window estimates from an earlier study by Manninen (2005) also imply a bias of 5.8 percent per year in a matched-model index for digital cameras from Q4 of 1999 to Q4 of 2002. (Manninen used consumer prices, so the matched-model index in that study may have captured the price declines caused by changing source countries.)

The adjustment for the price effect of changing country mix is 4.7 percent per year both for the moving-window hedonic regressions and for the full-sample pooled hedonic regression. On the other hand, using the shorter time period, the pooled hedonic regression attributes just 2.3 percent per year of the total bias to changes in source country. The hedonic regressions with no country dummies (using either the moving window or the full sample for the pooled index) also imply a bias of 2.3 percent per year from changes in source country.

The sample period for the camera indexes is only about six years long, and the variances of the moving-window coefficient estimates tend to be high because of problems of small sample size and collinearity between changes in physical characteristics and changes in source country. Imposing additional restrictions can be a way of reducing the variances of regression coefficient estimates, and holding the coefficients constant over our relatively short panel data set on cameras does not seem highly restrictive. Thus, in this case, the pooled approach may produce more reliable estimates of the hedonic model than the more flexible moving-window approach.

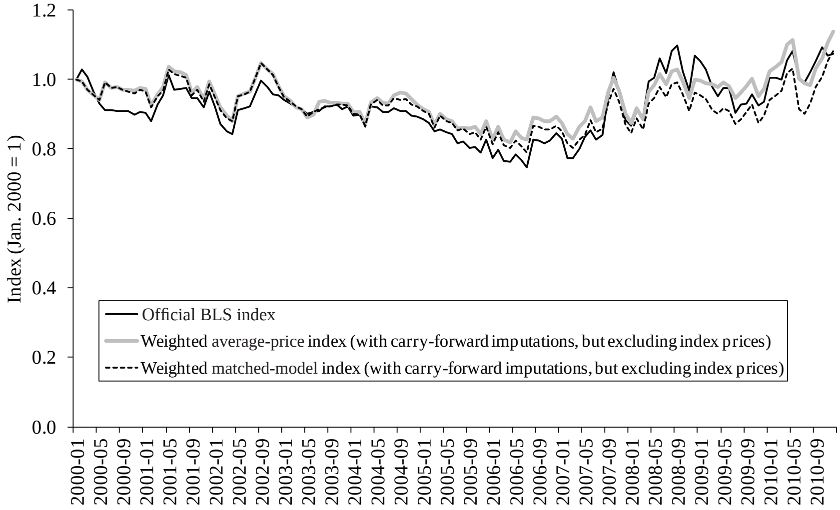
Bananas

As a check on whether our hedonic indexes for televisions and cameras could be producing spurious measures of the effects of evolving technology, we calculate the same sort of hedonic indexes for bananas. We would not expect to find evidence of unmeasured gains from technological progress for this product, nor is there a reason to expect that large cost savings have been realized by changing source countries for this product. However, as noted above, bananas have had changes in source country, so price effects from changes in source country may not equal zero.

Bananas have a weight of about one-fifth in the publication-level import index for HS 08, the category “edible fruits and nuts.” After excluding “index prices” (which are reference prices reported by respondents who prefer not to provide an actual transaction price), our matched-model index for HS 08, edible fruits and nuts, usually tracks the shorter-term movements of the official index for HS 08, and over the longer run it shows very similar growth to the official index (Figure 9.11). Its average growth rate over the whole sample period is 0.73 percent, compared with 0.65 percent per year for the official index. The average price index, on the other hand, has a long-run growth rate of 1.18 percent per year.

The hedonic indexes for bananas behave very differently from those for televisions and cameras. In contrast to the estimates of upward bias in matched-model import indexes for televisions and cameras, they imply that some price increases are missed by the matched-model index (Figure 9.12). Thus, in this case there is no evidence of unmeasured price declines from factors such as technological progress. However, this difference in the sign of the matched-model index’s bias is consistent with the hypothesis that matched-model indexes tend to be too flat, missing increases when prices are generally rising and decreases when prices are generally falling. The indexes for televisions and cameras have a downward trend, while banana prices have an upward trend.

Figure 9.11 Matched-Model and Average Import Price Indexes for HS 08: Edible Fruits and Nuts



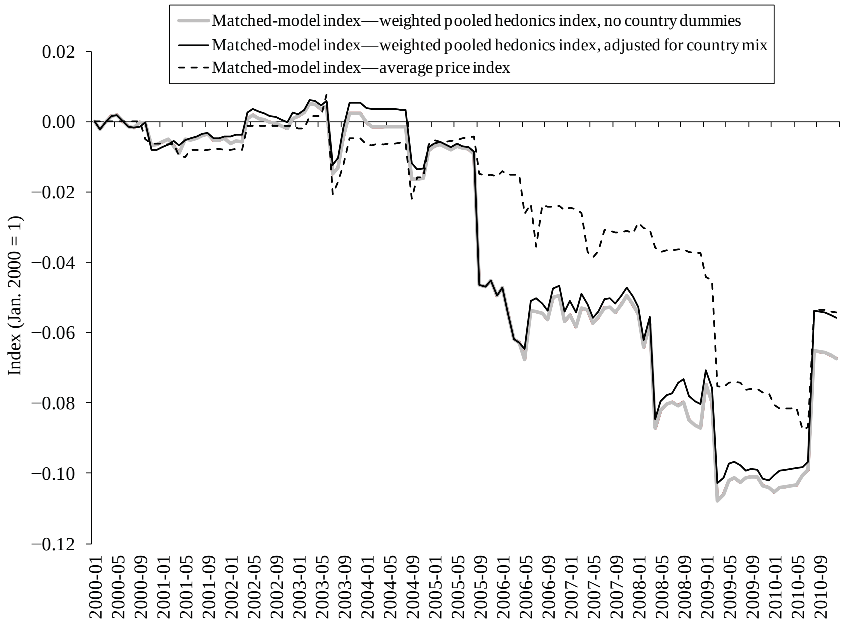
SOURCE: Bureau of Labor Statistics and authors' calculations.

Furthermore, comparing the unadjusted hedonic index that includes country dummies to either 1) the index with no country dummies or 2) the index that was adjusted to treat price differential between countries as true price differences rather than quality differences shows that sourcing for bananas has a slight tendency to migrate to more expensive countries. The unadjusted hedonic index that includes country dummies grows on average 1.28 percent per year, whereas the adjusted index grows 1.19 percent per year. In contrast, for televisions and cameras, sourcing had a strong tendency to migrate to less expensive countries.

CONCLUSION

The import and export price indexes are constructed as matched-model indexes. If new entrants have lower quality-adjusted prices than incumbents, and incumbents either exit or fail to adjust their prices to

Figure 9.12 Difference between Matched-Model Index and Hedonic Indexes for HS 08: Edible Fruits and Nuts



SOURCE: Authors' calculations.

match those of the entrants, the matched-model index will be upwardly biased, other things being equal. Thus, when technological progress leads to frequent entry of new models with lower quality-adjusted prices, matched-model indexes can easily suffer upward bias. Furthermore, the movement of production to lower-cost foreign locations can also lead to price reductions that would not be measured by a matched-model import index, because sourcing an item from a new country usually results in that item being treated as a new item. Hedonic index methods are a possible way to address these concerns. Yet they have not been viewed as feasible for import price indexes because of the limited collection of information on product characteristics and, in some cases, small sample sizes for purposes of estimating a hedonic regression model.

One goal of this chapter is to disprove the view that hedonic indexes are not feasible for imports. Our results show that hedonic methods indeed are a realistic alternative for at least some of the imported products that have experienced technological progress and changes in sourcing. Our results also provide evidence on the existence and size of the biases in a matched-model-type import index for two of these products, televisions and cameras. They support the hypothesis that technological progress and changes in source countries have led to reductions in quality-adjusted prices that are incompletely reflected in the matched-model import price index. In the case of televisions, our preferred adjusted moving-window hedonic regression implies a bias in the matched-model index of 2.2 percent per year, of which 1.3 percentage points come from undermeasured gains from new technology and 0.9 percentage points come from unmeasured price savings from country substitution. For cameras, our preferred pooled hedonic regression specification implies a total bias in the matched-model index of 10.5 percent per year, of which 5.8 percentage points come from undermeasured gains from new technology and 4.7 percentage points come from country sourcing changes.

Notes

The views expressed in this chapter are those of the authors and should not be attributed to the IMF, its management, or its executive directors; nor do they reflect the views of the Bureau of Labor Statistics.

1. For a recent study with estimates of outlet substitution bias, see Greenlees and McClelland (2011).
2. Gagnon, Mandel, and Vigfusson (2012) prefer different assumptions and find smaller effects of omitted price changes for exiting and entering items than those found by Nakamura and Steinsson (2012).
3. For example, Byrne, Kovak, and Michaels (2013) show that new producers in China supply identical-quality semiconductors at lower prices than established producers in other countries. Thomas, Marquez, and Fahle (2008) attempt to measure price reductions from substitution to low-cost countries for a wider range of products.
4. For motor vehicles, the upper-bound estimate for the bias from import sourcing changes is a bit smaller, at about 0.7 percent per year, while for apparel it is about 0.25 percent per year.
5. We focus on color televisions sized 13 inches or larger and exclude television/VCR combinations. We do not include plantains in the analysis of bananas.

6. When respondents are worried about disclosure of their transaction price, they can give an index price that approximates the behavior of the actual price instead of an actual transaction price.
7. Almost 12 percent of the televisions experience these temporary exits, as opposed to about 6 percent for bananas.
8. When using the cell-relative method, the missing value is determined by the change in the index value for the nonmissing values in a particular class. When using the class-mean method, the missing value is determined by the mean of the nonmissing values for a particular class. The International Price Program also sometimes uses linear interpolation to impute prices.
9. In calculating these average durations and price change frequencies, we included items for which the observable life span was truncated because they entered before January 2000 or exited after the end of our sample (December 2010 for televisions or March 2006 for cameras). Correcting for truncation bias will raise our estimates slightly.
10. The Laspeyres indexes used by the BLS are more precisely described as Lowe indexes because their weights are based on values from a previous year; these values have subsequently been updated for price change. From 1997 to 2001 the weights in the MPI came from 1995. After 2001 the weights began to be updated annually, with a lag of two years.
11. The standard definition of a Jevons index is an unweighted geometric mean of price relatives. Within any given classification group our Jevons indexes are, indeed, unweighted, but weights are applied when we aggregate over the classification groups that make up a Jevons index. These weights come from the same year used for the official index and reflect trade values in that year.
12. In future research we plan to test the method of full hedonic imputation. This method uses the estimated coefficients from the comparison period regression to predict prices of items that were present in the base period, and it uses the estimated coefficients from the base period to predict prices of items present in the comparison period.
13. For national accounts purposes it would be helpful to have separate data on values and prices of imported televisions and video monitors. Televisions are mostly used for final consumption, but video monitors have significant uses as investment goods. Because of the way investment is measured in the U.S. national accounts, an inaccurate split between imports of final consumption goods and imports of investment goods could affect the measurement of GDP.

Appendix 9A

Table 9A.1 Quality Characteristics Used in Hedonic Regressions

Product	Characteristics
Televisions	
Type	Plasma, CRT, LCD, projection, LED
Size	
Brand	Premium (Sony, Sharp, LG, Samsung, Panasonic) or other
Intrafirm	
Country of origin	
Cameras	
Type	Point-and-shoot, Polaroid, SLR
Format	Digital, film
Focus	Autofocus, fixed focus, manual focus
Brand	Canon, Nikon, or other
Intrafirm	
Country of origin	
Bananas	
Type	Cavendish or other
Grade	Grade 1 or 2
Crate size	
Intrafirm	
Country of origin	

SOURCE: Authors' compilation.

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10
Producing an Input Price Index

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This chapter is designed to address the need—and especially the feasibility—of producing what is referred to as an input price index (IPI) at the U.S. Bureau of Labor Statistics (BLS).[1] The current interest in this set of proposed price indexes grew out of concerns that the BLS does not directly measure price decreases associated with the dramatic rise in offshoring (or its corollary, onshoring) in its industrial price programs.[2] These new price indexes would help alleviate unease that current estimates of several key indicators of the U.S. economy—including gross domestic product (GDP), productivity, and inflation—may be inadequate.

Currently, the BLS has three price indexes that cover the production (or supply) of goods: 1) the U.S. Import Price Index (MPI), 2) the U.S. Export Price Index (XPI), and 3) the Producer Price Index (PPI). The MPI only covers goods that are being imported, the XPI only covers the export of goods, and the PPI only covers goods and services that are produced domestically. Thus, a good that is domestically produced and repriced by the PPI, and subsequently has its production sent overseas, will no longer be tracked in the PPI. Correspondingly, the MPI will not begin to price that particular item until after it has become an import. Therefore, neither program will directly show the price change that occurs when the item goes from domestic production to foreign (or vice versa).

In order to address this limitation, the BLS would need to develop an entirely new set of "input" price indexes, which would directly price goods and services that are inputs into the production function of a domestic company. Indeed, the BLS itself recognized the need for this type of series over 30 years ago when the old "wholesale price index" was transformed into the more comprehensive and systematic output-based producer price indexes. At that time, the BLS actually piloted a "buyers'" index, but, primarily because of budget limitations, this earlier effort at an input price index was never extended.

This chapter will detail the problem in the current methodology for price indexes that an import price index would be designed to overcome, as well as review some of the evidence on the need for these data. Finally, the chapter will discuss the practical aspects and limitations of attempting to produce such an index. These include surveying the data sources necessary for drawing a sample of establishments and items to reprice, evaluating possible sources for appropriate weights in an input price index, determining a proper index estimation formula, and verifying the publication structure necessary to support the different uses of these series.

THE PROBLEM

An example of how the BLS constructs an import price index and a producer price index will help to illuminate the problem described above. Let us look at how both indexes would reflect price changes in the manufacturing of furniture. Table 10.1 contains prices for four different chairs. All chairs that are being produced domestically sell for $10, while all imported chairs sell for $5. Chair A is only produced domestically, while Chair D is only imported. During the year, the remaining two chairs shift from domestic production to being imported—Chair B in March and Chair C in May.

The PPI tracks only Chair A for the entire period, and Chairs B and C for the months that they are domestically produced. The MPI tracks only chair D for the entire period, and chairs B and C only for the months they are imported. Thus, both the PPI and the MPI for chairs would reflect no change during the entire reference period.[3]

Is there a way to combine the two indexes to reflect the impact of a switch from domestic production to importing the same chairs? Since the indexes are always unchanged, no amount of recombining or reweighting will produce anything other than a series showing unchanged prices. The only way to construct a price index that would show the price decline resulting from the offshoring of chairs B and C would be to directly track the price changes of items as they move from

Table 10.1 Tracking Prices When Sourcing Shifts

		Jan. ’09	Feb. ’09	Mar. ’09	Apr. ’09	May ’09	June ’09
Chair A	Domestic ($)	10	10	10	10	10	10
Chair B	Domestic ($)	10	10				
Chair B	Imported ($)			5	5	5	5
Chair C	Domestic ($)	10	10	10	10		
Chair C	Imported ($)					5	5
Chair D	Imported ($)	5	5	5	5	5	5
PPI (%)		100.0	100.0	100.0	100.0	100.0	100.0
MPI (%)		100.0	100.0	100.0	100.0	100.0	100.0
Combined index (%)		100.0	100.0	100.0	100.0	100.0	100.0
Input index (%)		100.0	100.0	85.7	85.7	71.4	71.4

SOURCE: Author’s construction.

domestic to foreign and vice versa. This is not possible under the methodology (and concepts) currently in use in the bureau’s two industrial price programs.[4]

WHY AN INPUT PRICE INDEX IS IMPORTANT

Although the BLS was aware of the potential data gaps between XPI, MPI, and PPI, the shifts over time between domestic and foreign production may have been gradual enough that it was not evident that the limitation of the indexes could be introducing biases into the nation’s economic data. This potential gap in BLS data, however, became more serious as the proportion of the U.S. economy tied to the global economy expanded, and especially in conjunction with the growing perception that U.S. jobs were being lost to foreign competition and foreign workers.

The potential shortcomings in the BLS indexes were highlighted in an article in *BusinessWeek* (Mandel 2007) and subsequently in a study funded by the Sloan Foundation and the Bureau of Economic Analysis (BEA).[5] As the article and the study point out, an accurate estimate of the trend in prices paid by domestic U.S. establishments for inputs of both goods and services is crucial to a number of broad and critical measures of the economy, such as GDP and productivity. For example, in order to properly estimate GDP by industry (as constructed by the BEA) and by industry productivity estimates (as constructed by the BLS), the producers of these economic data must subtract input costs. Although these data are usually readily available on a current dollar basis, in order to convert these nominal values to a constant dollar basis—that is, to an inflation-adjusted basis, also referred to as a real (as opposed to a nominal) basis—they must be adjusted by changes in price levels. However, the appropriate price measures paralleling these input values are not currently being produced by the BLS. Consequently, the BEA and BLS must make use of whatever price data are available. Generally, this has required the agencies to make use of the PPI price indexes or the import price indexes.

The argument has been made that using these next-best sources may lead to significant mismeasurements in the economy. For example, the *BusinessWeek* story estimated that the increase in real GDP from 2003 to mid-2007 may have been overestimated by $66 billion.

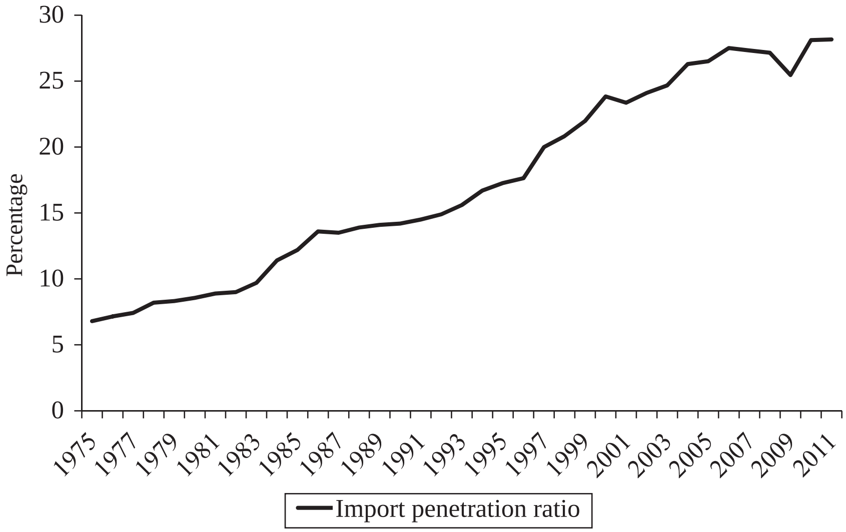
As evidence of this, the article's author, Mandel, points out the apparently contradictory behavior of consumer prices for furniture—which had been falling—at the same time that the indexes for domestic producer prices as well as import prices for this category had both been moving higher. Conversely, the article also infers that the lack of an input price index may lead to a significant overestimate of productivity in U.S. industry. A rise in a nation's productivity is considered the key factor in an economy's ability to improve that nation's standard of living, as it is presumed that increases in real hourly earnings should move in conjunction with gains in productivity. If, in fact, GDP and productivity are being overestimated, this implies that the gains from trade (i.e., the terms of trade) are being underestimated and that, in real terms, the value of imports is greater than currently measured.

A growing body of literature—much of it in conjunction with the original 2009 conference and a second conference in 2013—has looked into the increasing role of imports in intermediate inputs in the U.S. economy, the current price index methodology used in the BLS, and their implications in U.S. estimates of GDP and productivity. For example, Kurz and Lengermann (2008) note that foreign inputs accounted for one-third of growth in the manufacturing sector between 1997 and 2005. Houseman et al. (2011) further explore the subject and find that as a result of the mismeasurement of the shift from domestic to low-cost foreign suppliers, the growth in real value-added in manufacturing may have been overstated by between 0.2 and 0.5 percentage points from 1997 to 2007. Along similar lines, Feenstra et al. (2009) attribute a substantial portion of the apparent acceleration in productivity gains after 1995 to gains in the terms of trade and to tariff reductions. Additional work on this topic has been conducted by Houseman, Bartik, and Sturgeon (Chapter 5, this volume), who raise concerns over potential overestimates of productivity in the computer sector. In looking at Japanese data, Fukao and Arai (Chapter 7, this volume) conclude Japan also has “a relatively large offshoring bias.” Using data from 38 economies, Inklaar (Chapter 6, this volume) finds evidence of systematic bias as a result of offshoring for the advanced economies. In related work, Nakamura and Steinsson (2009) find limitations in the import and export price indexes associated with “product replacement bias.” Finally, Nakamura et al. (Chapter 2, this volume) see the need for a large increase in data collection by statistical agencies as well as changes in their price index methodology that would allow for more direct comparisons of closely related items from different sources.

In order to provide additional evidence of the growing need for a set of input price indexes that incorporate both domestic and foreign sourcing, I analyzed the most recent available data on the role of imports in domestic supply. In 1975, imports, as measured in current dollars, represented less than 7 percent of inputs into manufacturing. By 2007 the figure had climbed to almost 28 percent (see Figure 10.1). Equally important is that between 1997 and 2007 the percentage of imports in inputs increased by an average of more than 0.40 percent a year, whereas in the previous decade the percentage had increased by less than 0.25 percent a year. This point is interesting because it implies that there is an acceleration in companies’ shifting their products from domestic sourcing to foreign sourcing, making the need for additional data more critical.[6]

Indeed, globalization may be happening so quickly that the ability of traditional measures to capture these shifts has become increasingly problematic. For example, the household wood furniture manufacturing industry—the industry highlighted in the *BusinessWeek* article—recorded a dramatic increase during the past decade in the value of imports, which jumped from \$13.2 billion in 1999 to \$27.0 billion in

Figure 10.1 Imports as a Percentage of Domestic Supply Manufacturing Sector



NOTE: There is a break in the series in 1998. Data prior to 1998 are based on the Standard Industrial Classification (SIC) code for manufacturing. More recent data are based on the North American Industry Classification System (NAICS).
SOURCE: Bureau of Economic Analysis.

2007. The article also points out that, according to official statistics, productivity went up 23 percent and output rose 3 percent between 2000 and 2005 (Mandel 2007). Interestingly, in 2006 the preliminary estimate from the Annual Survey of Manufactures (ASM) for the household wood furniture sector recorded an increase in the value of domestic production, up from $13.0 billion in 1999 to $13.5 billion in 2006 (U.S. Census Bureau 2013). However, when the final figures were revised the following year, the number was adjusted substantially downward, to only $8.6 billion. This may be due in part to the difficulty of properly (and in a timely manner) coding companies to the correct North American Industry Classification System (NAICS) number when they shift from being a manufacturer to being essentially a wholesaler. The key point is that economic data tasked with reflecting current trends must be flexible enough to allow for continual changes in the composition of the economy.[7] Ideally, an input price index will facilitate this flexibility, as it allows for rapid capturing of changes in suppliers (and prices) of inputs.

EARLIER ATTEMPTS TO CONSTRUCT INPUT OR BUYERS' PRICE INDEXES

The seminal 1961 report of the NBER Price Statistics Review Committee, the so-called Stigler Report (Stigler 1961), made a number of recommendations surrounding the wholesale price indexes—the name given to the industrial price series then being produced by the BLS. One of the recommendations called for the creation of a set of conceptually rigorous input and output price indexes. A second recommendation was that the bureau should rely on buyers' prices and not on sellers' prices. The report included a study that suggested that buyers' prices were more likely than list prices to reflect the prices of actual transactions.

Using Buyers' Prices

In response to the Stigler Report and subsequent studies, the then-BLS commissioner as well as others expressed concerns that the cost of collecting buyers' prices would outweigh the potential benefits because of potential problems such as buyers' prices from an invoice sometimes not reflecting real transaction prices, difficulties capturing retroactive price adjustments based on cumulative volume, and financial assistance given by sellers to buyers for advertising and other expenses.[8] The BLS did, however, agree that the project had merit on a case-by-case basis in order to facilitate analysis of price trends in industries where transaction pricing was especially problematic.

A more detailed study looking into the advantages of buyers' prices was subsequently published in Stigler and Kindahl (1970), which pointed out the differences in price trends between buyers' and sellers' prices. Because much of the concern with the then-named BLS wholesale price index (WPI) focused on the use (or potential misuse) of so-called list prices, BLS economists began working with the sellers who were participating in the price survey to encourage the reporting of actual transaction prices. In doing so, they made substantial progress in some industries in improving the quality of the received prices. In addition, the bureau also began the process of evaluating specific products where buyers' prices should be collected because of the unavailability of transaction prices from sellers. As a result of this study, in January 1972 the newly renamed PPI began publishing a commodity index for aluminum ingots using buyers' prices from a selected sample of reporters.

Building on this work, in 1974 the bureau attempted a systematic sampling approach to obtaining buyers' prices. This project was undertaken with the goal of determining the feasibility and cost of collecting prices directly from buyers in order to either calculate price indexes or evaluate the quality of the transaction prices being reported by sellers. The project identified product areas where sellers refused to provide transaction data, or the quality of current transaction data was questionable, and where there were homogeneous products frequently purchased by buyers in consistent quantities. The project focused on titanium forgings instead of aluminum ingots because the PPI was able to create a sampling frame and document the typical transaction characteristics of buyers in this product area. Even after significant resources had been spent on this project, pricing issues remained, and an effective process had not been identified to refine and systematically sample from the frame. As a result, the project was dropped, and the program switched its focus back to obtaining good transaction prices from sellers even in these more difficult cases. No further work was done on buyers' prices, and in 1980, the BLS introduced indexes calculated using sellers' transaction prices from the systematic sample for the primary aluminum industry output index. When this occurred, the buyers' price commodity index for aluminum ingots was dropped.

Input/Output (and Other) Price Indexes

Also in response to the Stigler Report, the BLS began examining a more systematic approach to creating input and output price indexes (as well as other indexes) for industries. For example, in the early 1960s the PPI built output industry-sector price indexes (ISPI) for some industries by combining the judgmentally sampled data collected for the commodity indexes using different classification structures and weighting. Finally, in the mid-1970s, the PPI began a comprehensive revision in order to plan and implement many improvements that had been recommended over the years, including in the Stigler Report. The long-term goal of the revision was to expand the PPI's coverage to include every industry in the private economy and to publish a system of price indexes that included the following:

- Industry output indexes
- Industry input indexes
- Detailed commodity indexes
- Industry-based stage-of-processing indexes

In the late 1970s the Bureau began systematically sampling industries, and starting in 1980 it began introducing industry *output* indexes on a regular basis. Throughout the years, the PPI continued expanding the number of industry output indexes, and as of 2013 it covered 98 percent of domestic goods manufacturers and 72 percent of in-scope domestic service industries.

While the practical work focused on an output price index, work did proceed on the theory of an input price index, culminating in a BLS working paper by Archibald (1975). Furthermore, as an attempt to fulfill the recommendations of the Stigler report, and as a component of the stage of processing indexes, the bureau did publish a set of input price indexes from 1988 to 2003. These indexes were calculated by reweighting output prices using input weights. This allowed the use of output price indexes at a great level of detail. However, these indexes did not include imports, nor did they directly account for substitution from a buyer's perspective. Thus they assumed that sellers' prices are a good proxy for buyers' prices and that prices for imports and domestic production move similarly. The BLS discontinued these series in 2003, but the method is still used in the BEA and BLS for constructing input price indexes where necessary.[9]

CURRENT USES AND USERS OF THE DATA

The fundamental question facing the BLS, of course, is, "Can the Bureau produce an input price series that will meet the needs of its primary users?" In order to answer this question, one must first delve into the intricacies of the construction of the outputs of the two primary potential users of these data, the Office of Productivity and Technology (OPT) at the BLS, and the Industry Sector Division (ISD) of the BEA.

The Office of Productivity and Technology at the Bureau of Labor Statistics

We will start with the OPT, which produces three sets of estimates of multifactor productivity (MFP), or output per unit of combined inputs. First, OPT publishes multifactor productivity estimates for the broad private business and private nonfarm business sectors of the economy. These sectors represent 74 percent of U.S. GDP. In calculating these series, outputs are measured on a value-added basis, and consequently the multifactor productivity measure only shows the returns to labor and capital.[10] The value of material inputs does not enter into these calculations. However, staff does use detailed price indexes to deflate inputs of capital expenditures. Physical capital, as measured by the OPT, consists of 42 types of equipment and software, 21 types of nonresidential structures, nine types of residential capital, inventories (manufacturing available for three stages of fabrication), and land. Deflation of each capital expenditure category is actually done at the detailed five- or six-digit input-output (I-O) level.

Second, the OPT also publishes annual multifactor productivity measures for total manufacturing and 18 broad three-digit NAICS manufacturing industries, comparing sectoral output (total output excluding intraindustry or intrasector transactions) to a broad set of inputs, including capital, labor, energy, materials, and business services (KLEMS) inputs. Consequently, MFP measures in this set of manufacturing industries reflect the return on each of these inputs to production. (Note that on a value-added basis, manufacturing represented 12 percent of GDP in 2012.) In the manufacturing sector of the economy and in individual industries, intermediate purchases constitute the largest component of inputs. The nominal dollar and constant dollar values of energy, materials, and services used by the OPT are obtained from the BEA.

Finally, the OPT publishes more detailed annual multifactor productivity measures for 86 four-digit NAICS manufacturing industries, plus air transportation and line-haul railroads. These productivity measures also compare industry sectoral output to a broad set of combined inputs. The OPT publishes estimates of intermediate purchases, capital, and labor for each of the detailed manufacturing industries. The index of intermediate purchases for each industry is constructed by combining separate quantities (or constant dollar costs) of electricity, fuels, materials, and purchased services. In order to deflate nominal dollar cost inputs for each industry, weighted deflators for materials and for services are calculated by combining detailed price indexes using weights derived from the cost of commodities consumed by each industry, as shown in the detailed benchmark I-O tables produced by the BEA. I-O commodities from the benchmark I-O tables generally relate to the primary products of six-digit NAICS industries, or occasionally a combination of industries. For materials commodities that are heavily imported, the OPT's Division of Industry Productivity Studies (DIPS) combines PPIs and import price indexes using weights from the BEA's import matrix. DIPS also uses PPIs in creating weighted deflators for deflating the annual fuel purchases of each industry.

The OPT also uses PPIs to deflate capital expenditures. Price deflators for each equipment asset category are constructed by combining detailed PPIs with weights from the BEA capital flow tables at roughly the six-digit level. For the DIPS detailed manufacturing industry measures, physical capital consists of 25 categories of equipment, two categories of structures, three categories of inventories, and land.[11] Since industry MFP calculations are based on annual data, the nominal input values are adjusted by annual PPIs (representing the average of 12 monthly price indexes).

The Industry Sector Division at the Bureau of Economic Analysis

The Industry Sector Division at the BEA is responsible for producing the annual industry accounts and the benchmark input-output accounts. These accounts, which shed critical light on the relationships between U.S. industries, take a value-added approach to, and are consistent with, the BEA's flagship GDP estimates. Although the BEA does not publish detailed annual real I-O estimates, it does publish annual price and quantity indexes for 65 detailed industries, including 19 manufacturing industries, which do require data on the real value of inputs.

As the BLS does in its work, the BEA attempts to make its adjustments at the most detailed level possible. For example, at the BEA, the effort to construct updated values for intermediate inputs of goods and services entails making adjustments to approximately 3,500 different items, of which roughly 2,300 represent categories of goods. Ideally, like the BLS, the BEA would like to have a level of detail that lists input price indexes *by industry* for each of the 1,179 six-digit NAICS categories. In practice, however, since the cost of producing that many separate price indexes could prove prohibitive, like the BLS, the BEA would accept a set of product-based input price indexes. In addition, at a minimum, category definitions should be consistent with the 12 expense categories recently added to the Census Bureau's Annual Survey of Manufactures (ASM) forms (most of which are services inputs). While the BEA currently only produces annual estimates of GDP by industry, there has been growing interest in providing these estimates on a quarterly basis.

In sum, although superficially the level of publication required to produce the currently published set of economic data is comparatively high, in actuality the detail necessary to properly support these estimates may be considerably more disaggregated.

Limitations

It is important to point out that the construction of an input price index by itself may not directly alleviate the potential mismeasurement issues associated with the problem noted. This is worthy of note because GDP can be estimated using two different methods: It can be constructed by measuring final sales (Method 1) or it can be estimated using a value-added approach (Method 2).[12] The current methodology in the United States focuses on the former of these two approaches, illustrated in the following equations:

(10.1) $Y = C + I + G + (X - M)$ (Expenditures/Final Sales Approach)

(10.2) $Y = \Sigma (S_i - C_i)$ (Production, or Value-Added, Approach),

where S_i represents total sales for industry i, and C_i represents the input costs for the same industry.

As mentioned earlier, in order to calculate real—or constant dollar—GDP, all of these values must be adjusted for inflation using appropriate price indexes. Under Method 1, the adjustments for inflation do not take into account adjustment for inflation that is due to offshoring. This is because an *input price index* does not play a role in the computation, since the formula still relies on the current *import price index*, with its associated potential limitations. Fixing the potential problem could entail shifting the construction of GDP to Method 2.[13]

In order to further illuminate why the BLS cannot construct an import price index that directly registers these price changes, it helps to review the current methodology. The procedure for producing import price indexes starts out with a very robust frame from which to draw a sample. It includes nearly the entire set of transactions of all merchandise brought through U.S. Customs and Border Protection and into the United States. It breaks transactions out by individual shipments, product categories, and of course, companies. A sample of specific companies and the items they imported is then drawn from this frame, and the BLS attempts to collect prices on a monthly basis for these items. Note, however, that the sample only consists of goods that are already being imported. It is not practical to ascertain from an importer (who in many cases may only be an intermediary) whether in the past he sourced an item domestically. It would also be hard to get information in the reverse situation, asking an importer who no longer imports whether the sampled good is now produced domestically and, if so, what the price is. Presumably, constructing an input price index may potentially provide some indication of the magnitude of any differences in price trends being missed by import prices or producer prices as sourcing shifts from one to the other. This might be possible if, as the pricing data is being collected, the respondent is able to report whether the item was bought domestically or from a foreign source. From a practical standpoint, however, it is not clear how this information could be properly and effectively incorporated into the producer or import price index production process.

It should also be pointed out that an input price index will not alleviate problems arising when goods and services that had been previously produced in-house are now shifted to being outsourced (either domestically or to a foreign source). This, too, is considered a growing phenomenon, but unless data on prices associated with the in-house cost of producing an item can be directly compared with the outsourced price, it is not clear how the BLS could evaluate shifts in prices associated with this phenomenon.

STEPS TO PRODUCE AN INPUT PRICE INDEX

While there is little dispute over the potential advantages of adding an input price index to the family of price indexes produced by the BLS, there are the fundamental questions of both the feasibility and the cost of producing a usable and comprehensive set of indexes.

Developing a Sample

From a practical standpoint, the first and perhaps the biggest hurdle in developing an input price index is developing a frame from which to draw a sample of establishments. While U.S. manufacturing only accounts for approximately one-seventh of the value-added output of the U.S. economy, I determined that, in part because of data availability, this would be the first sector where I would attempt to develop a sample. An earlier work (Alterman 2009) cited the Economic Census produced by the U.S. Census Bureau, which that agency conducts every five years (in years ending in “2” and “7”). In that survey, all U.S. manufacturing firms are asked to include detailed data on their cost of materials, parts, and supplies consumed in the reference year.

In addition, the less comprehensive but timelier ASM, which is based on a sample of 50,000 manufacturing establishments, includes a limited amount of data on purchases, providing one category for total cost of materials, parts, containers, packaging, and other expenses.

One shortcoming of these surveys is that, while data on capital expenditures are also collected, they are only split three ways: into expenditures on 1) motor vehicles, 2) computers, and 3) other. Another potential shortcoming is the timeliness, or lack thereof, of these sources of data. Since the detailed data are only collected once every five years, it may be that by the time the BLS is able to draw a sample and initiate these establishments into a market basket, the establishments or the products that they buy may be out of date and no longer reflective of their current market.

Although much of the focus has been on the manufacturing sector, the service sector represents nearly two-thirds of GDP. Unfortunately, currently the amount of detailed cost data collected by census for the service industry surveys is more limited. In general, the collection forms include some detailed data on purchased services, but only limited data on purchased equipment and materials.[14] Interestingly, while the census collects very little detailed data on material costs in the noncensus years for manufacturing industries, the level of detailed data collected on the cost of business services, though limited, is roughly the same, whether it is for the Service Annual Survey or the quinquennial Census of Service Industries. In general, the surveys break out the purchases of business services into five categories: 1) computer services, 2) communication services, 3) advertising and related services, 4) professional and technical services, and 5) repair and maintenance services.

Until recently, BLS staff have only been able to access the manufacturing data from the Economic Census while on-site at the Research Data Center at Census Bureau headquarters in Suitland, Maryland. In April 2012, however, the BLS and the Census Bureau signed a memorandum of understanding (MOU) that allowed the BLS to bring these data in-house, thus allowing the bureau to more readily determine whether these data can be used to develop an appropriate sample.[15] The first data sets were transmitted to the BLS in mid-December 2012 and included information on the detailed cost of materials for over 67,000 individual establishments (primarily manufacturers but also including some mining and agricultural companies) that reported information as part of the 2007 Economic Census. The data set represented a subset of the roughly 328,000 U.S. establishments that are coded by the census as manufacturing establishments and included breakouts of the cost of materials for approximately 1,340 individual eight-digit material codes.[16]

The first question that needs to be addressed in drawing a sample is, of course, "What do you want to publish?" Presumably one could construct an input price index either by including all inputs for a given industry, or by including only inputs of a specific material. After discussions with staff from the BEA as well as the OPT, it was determined that from a practical standpoint it would be best to, at least initially, construct input price indexes that were product-specific. In the 2009 paper, I stated that a full set of input material price indexes covering material inputs to manufacturers would require sampling and pricing roughly 15,000 individual items and calculating and publishing indexes for 600 six-digit categories.[17] Subsequently, these numbers have been further refined for this exercise.

In attempting to draw a sample, the program would start off with several assumptions:

- The sample would, if possible, use the standard BLS methodology, involving a multistage stratified probability-proportionate-to-size (PPS) method.
- A published price index should contain a minimum of 25 repriceable items.
- Because of refusals, out-of-scopes, nonresponses, and deterioration rates, the bureau would need to oversample.
- A cap would be placed on the maximum number of price quotes requested from any individual establishment.
- The sample would only include establishments coded as manufacturers. However, data requested would also include materials produced by mining and agricultural industries, including a large value for crude petroleum purchases by the petroleum refinery industry.
- Purchases of capital expenditures were beyond the scope of this project.
- The sampling process also would set minimum dollar criteria for a given establishment's annual expenditure on cost of materials.

In accessing the detailed census data, it was apparent that there were some complications with the underlying data. For example, although the census collects the cost of materials by eight-digit material codes, which are roughly based on an NAICS structure, these eight-digit codes do not necessarily aggregate to a specific six-digit NAICS. In fact, of the 473 six-digit NAICS codes in manufacturing, only about one-half had eight-digit material codes mapped to them. In the other cases, the eight-digit material codes were apparently sufficiently broad that they cut across six-digit NAICS industries.[18] This creates a number of problems. For example, it would be difficult to construct a set of indexes at higher levels of aggregation. Also, it would be hard to match up input data with the corresponding domestic output or import data, which would be useful for data verification. Another potential problem with the data stems from the high proportion of the reported values for a given establishment that are not coded to any specific materials category. Approximately one-quarter of the reported value is coded to a "not elsewhere specified" type code.

The strategy used to construct a sampling algorithm for an input price index draws heavily on the algorithms used in the bureau's Producer Price Program and especially on the methodology from the bureau's International Price Program (IPP), which in addition to the import price indexes also produces a set of export price indexes. Like the detailed data collected in the Economic Census, the U.S. Customs and Border Protection (formerly the U.S. Customs Service) database provides a very detailed breakout (through a 10-digit Harmonized System code) of the value of imports by establishment. The customs data are also broken out by month, which permits the BLS not only to sample by detailed product areas but also to sample only those imports of a given company that are consistently traded over time. Unfortunately, the Economic Census data only reflect annual figures, so in using these data there is no way to assess the consistency of a company's purchases over the course of a year.[19]

Although many of the basic methodological challenges associated with producing these new indexes are similar to the issues successfully addressed in the Bureau's current price index programs, there are additional questions that must be addressed. For example, given the once-every-five-years time frame for the Economic Census, are the data too far outdated for reliable use by the time any sample drawn from this census is used to initiate establishments and items into a survey? One possible alternative would be to rely upon the somewhat smaller ASM, which is conducted in every noncensus year. However, while this survey does collect information on an establishment's cost of materials, the ASM does not collect data by eight-digit material categories.[20] Thus, any establishment-specific information on the value of their individual purchases would have to be collected as part of the process of initiating those potential respondents into the program. Of course, the current procedure in drawing an item sample for the producer price indexes already relies heavily on using data supplied by establishments. However, it is unclear whether establishments would have available the same level of detail for their purchases as they have for their sales.

In any event, we did attempt to draw a sample using the data from the 2007 Census of Manufactures. The algorithm relied primarily on the sampling criteria and sample rotation developed for the import price indexes. As did that algorithm, the formula for the proposed input price index made several assumptions:

- A sample would be drawn—and establishments and their selected items initiated into the program—every two years.
- Prices collected from each sample would be collected for four years.
- Each index would consist of data drawn from two samples. (For example, a sample would be drawn in Year One and a separate sample would be drawn in Year Three. The index for Year Four would include data from both the samples drawn in Year One and those drawn in Year Three.)
- In order to draw a sample large enough to support publishing an index, a given product area would need to be sampled for 30 quotes. (Since an index consists of two overlapping samples, this would imply that a given published index would consist of the remaining data available from what had been 60 potential items.)
- Establishments with a cost-of-materials value (for a specific category) of more than $1 million would be treated as being consistent with a maximum burden of six for that category. Where an establishment/category did not meet this threshold, the category would have a maximum quote burden of two.
- Each sample would consist of approximately 2,500 establishments and approximately 15,000 quotes. (Note that the sample could also be staged, which would result in 1,250 establishments being initiated every year.)
- The samples would be drawn to support the publication of any six-digit category with a value of over $3 billion. All product areas, however, would be sampled and would be used in higher stages of aggregation.

Although the eight-digit cost-of-materials codes do not fully nest to six-digit categories, the sample was drawn as if they did. There were a total of 373 six-digit groupings, of which about 100 would be potentially publishable. These 100 six-digit cost-of-materials groups each had a minimum dollar value of $3 billion in 2007. Publication assumptions could, of course, be adjusted depending on the exact requirements of the end users of these data at the BEA and the OPT.

The selection of the actual item that the Bureau would need to reprice on a periodic basis would normally be done by a BLS field economist during a so-called initiation visit to the establishment. This procedure is one that is already done by staffers when collecting data for the bureau's PPI and IPP programs, and it involves a number of trade-offs. Ideally, the selection would be based on a probability proportionate to the value of a given item a company purchases within the selected category. In theory, if a company buys a certain amount of various types of steel, the field economist, using data supplied by the respondent, would be able to select a specific steel product that the BLS would attempt to collect data on. In practice, however, these procedures would likely have to take into account the fact that the selected item may not be purchased on a regular basis, or the respondent may not have any data available on how much of each different type of steel the company purchased in a given period. Since the BLS already has experience in dealing with these types of issues in its current programs, developing an appropriate fallback procedure does not necessarily present a problem. However, it does lead to what is perhaps the key issue to be faced, which is the ability of the program to reprice the same item month after month, quarter after quarter, or year after year, from the same source.

Pricing

Maintaining a constant set of items to reprice over time may prove the most intractable barrier to constructing a comprehensive set of input price indexes. Whereas on the output side companies tend to ship their goods (or offer their services) every month, it is not clear whether they buy the same item on a regular basis, especially for capital equipment such as computers. This may place a heavier burden on the imputation method chosen for valuing prices in missing periods.[21] Alternatively, the BLS may have to use an altogether different approach, such as combining prices from different respondents (in cases where the item specifications are identical). A related question is how to handle changes in the pricing specifications. Here are some factors to consider:

- What is our general approach toward quality adjustment when a buyer switches products or suppliers? That is, in an ideal situation where we can get the exact information that we desire, what would we ask for?
- What are the acceptable fallbacks if we can't obtain the desired information?
- What if, in fact, the buyer uses multiple suppliers? Do we select a specific supplier or use some sort of average?
- If we select one, how and when do we switch to a price from a different supplier?
- Should the price include or exclude transportation costs?
- If other services are bundled with the product (e.g., installation), how do we handle those situations?
- Do we want to include government purchases?
- If so, how would we sample for them, since they wouldn't be included in data at the Census Bureau?
- How do we coordinate requests for buyers' prices with requests for sellers' prices within the same firm?

Eventually, though, the bureau will need to attempt to collect information from a sample of representative companies. A final decision on some of these issues will probably entail balancing the requirements of a price index with the reality of the bureau's sometimes limited ability to collect data from private industry through voluntary surveys.

The BLS determined that a critical first step in this process would be to get feedback from a representative group of establishments on their buying practices, their ability and willingness to voluntarily supply data to the BLS, and their receptivity to, and interest in, the bureau's effort to produce these price index series.[22] To that end, in May 2012, staff at the BLS set up a focus group with members of the Institute for Supply Management (ISM) in conjunction with that organization's annual meeting. Founded in 1915 as the National Association of Purchasing Agents, ISM is considered one of the largest and most respected supply management associations in the world and boasts a total membership of nearly 40,000. Prior to the meeting, the focus group members were sent a set of questions designed to elicit input on the feasibility of the bureau's effort to produce a new set of indexes. In general, the focus group participants indicated that their establishments would almost certainly have the data available that the BLS would need to construct these indexes, and they did not believe cooperation issues would be any different from what the bureau currently experiences with establishments.

Estimation Formula

With one exception, as opposed to the questions associated with sampling and repricing, the issues surrounding the estimation formula are comparatively easy. Weights can either be derived from the sampling frame, from the respondents themselves, or from some combination thereof. One concern with using the weights derived from the sampling frame is the age of the data. Since the detailed data are collected only once every five years, the data may be out of date by the time they are actually used in the calculation of the indexes. A comparison of these values from one census to the next may shed light on the volatility of these figures.

There are various considerations involved in what actual formula to use, such as choosing between arithmetic and geometric mean formulas, but these do not present intractable barriers. One interesting aspect of the formula relates to theoretical differences between the price index formula for the output from a production function and the price index formula for inputs into a production function. The theory assumes that a firm will attempt to maximize profits by minimizing costs while maximizing revenue. On the output side, theory tells us that an establishment will attempt to shift sales to its goods or services that over time are becoming relatively more expensive compared to its other outputs. On the input side, the firm would attempt to shift costs toward its expense categories that are becoming relatively cheaper. Consequently, all else being equal, the price index of firms' outputs would tend to show at least no decline in the relative quantity of the more expensive goods being sold, while on the cost side, the index should in theory reflect at least no increase in the purchase of goods or services that are more expensive. What is interesting, however, is that these assumptions are based on partial equilibrium models where the model is only looking at one side of the equation. But of course one establishment's sales are another establishment's purchases, and in a general equilibrium model, there is no a priori theory of exactly what constitutes the correct direction of substitution.[23]

One notable issue in estimating these indexes relates to how one goes about constructing industry-specific price indexes. Note that in calculating GDP, Method 2 relies on collecting data for both outputs and inputs by industry. While a product-based input price index would use every establishment's purchases of a specific good (or service), an industry-specific input price index would only use goods or services purchased by establishments in that specific industry. For example, presumably all establishments must purchase energy, be it electricity, gas, petroleum products, or other forms. Would the BLS attempt to calculate a separate energy index for each industry, or would it combine all energy data into one generic input energy index? For now the approach is based on practical consideration—i.e., do we have enough data for separate energy series, or does each of the different energy series trend nearly the same? Of course, a proxy for an industry-specific input price index could be constructed using individual product-level price indexes but aggregating them using the proportions appropriate for a particular industry's purchasing patterns.

Developing a Pilot

A longer-term effort to produce input price indexes can be broken down into four phases, based on availability of data. This effort will require additional approvals and funding as well. The four phases include

1) Input indexes covering manufacturers' material costs,
2) Input indexes covering manufacturers' capital equipment costs,
3) Input indexes covering manufacturers' business services costs, and
4) Input indexes covering service industries' material, capital equipment, and business services costs.

Ideally, each phase would start with a pilot prior to going into production. For each pilot, the BLS would conduct research and develop the methodology, procedures, and systems associated with each of the following steps:

- Obtain permission from the Office of Management and Budget.
- Select a set of industries for the pilot.
- Evaluate the data sources that are available for a sampling frame. Because of the availability of detailed cost data from the quinquennial Census of Manufactures, the first phase would focus on input indexes of cost of materials for manufacturing industries.
- Develop the collection materials and procedures and train staff.
- Select a sample of establishments for the pilot.
- Conduct the pilot test and evaluate the results.
- Based on the results of the pilot, finalize resource and data requirements for developing and maintaining an input price index, including publication goals, required sample size, expected burden, and estimated time frame for publication.

SUMMARY

There has been a long-standing interest in both producing an input price index and obtaining prices from buyers. The dramatic growth in imports as a source of domestic supplies has also served to underscore the increasing need for these data. There would be, however, a significant cost to developing these new series data, and it would take some time to put them into production. As resources permit, the bureau will continue its research on this topic.

Notes

1. This paper was the result of combining works from two related conferences. The first conference was called “Measurement Issues Arising from the Growth of Globalization” and was held November 6–7, 2009, in Washington, D.C. The second conference was “Measuring the Effects of Globalization,” held February 28–March 1, 2013, also in Washington, D.C. I would like to thank Mike Horrigan, John Greenlees, Steve Paben, Maureen Doherty, Ted To, Mina Kim, Jenny FitzGerald, and David Friedman for their contributions and comments. I would also like to thank Shawn Klimek and Lynn Riggs at the U.S. Census Bureau for their assistance in gaining access to census data. All views expressed in this paper are those of the author and do not necessarily reflect the views or policies of the U.S. Bureau of Labor Statistics or the U.S. Census Bureau.
2. Note that the Consumer Price Index is designed to pick up these price changes but is only used to adjust estimates of domestic consumption.
3. This assumes that the prices of chairs A, C, and D do not decrease in response to the change in the price of Chair B resulting from the switch from domestic production to being imported. The bureau, however, has conducted an analysis of PPI data that provides some evidence that prices from domestic producers are influenced by the degree of import penetration in their industry. See Doherty (2012).
4. Note that the PPI does currently construct output price indexes for wholesalers and retailers; these indexes presumably include data on both imported and domestically produced goods. However, these indexes are only gross margin indexes, and as such they only represent the difference between their selling price of a good and the acquisition price for that same item. In addition, the data collected do not delineate between import goods and domestic goods.
5. Information on the Sloan Foundation study, and the subsequent conference, can be found here: http://research.upjohn.org/cgi/viewcontent.cgi?article=1006&context=externalpapers. A summary of the conference was included in the February 2011 issue of the *Survey of Current Business*.
6. If the rate of change was consistent over time, it might have been easier to model a “discount” factor to apply to import prices in order to adjust for this shift.
7. Price indexes, for example, must take into account ongoing shifts in the market basket of items being priced, as some products are discontinued and new items enter into consumption.
8. Actually, prior to the Stigler Report, the PPI had done some work in evaluating the use of buyers’ prices. In 1942, the PPI did a study of buyers’ prices for eight selected items of steel mill products for six time periods and compared them to list prices. The results of the study showed that the buyers’ prices moved differently from list prices for short periods of time but that longer-term list and invoice prices were comparable.
9. Note that the bureau does have extensive experience with constructing price indexes that, in theory, are input price indexes, since both the import price indexes and the Consumer Price Index are constructed from buyers’ prices.

10. Labor input for private business and private nonfarm business estimates include labor composition effects. These labor composition effects reflect the fact that the hours worked are adjusted for changes in the composition of workers over time.
11. Note that the BLS makes use of product-specific data in constructing deflators for a set of input price indexes for a given industry's material costs. Ideally, an input price index would be industry-specific, but that may prove cost-prohibitive.
12. There is also a third approach, commonly referred to as the Income Approach, which is not directly relevant to this discussion.
13. In practice, Method 1 is actually more effective at measuring total domestic consumption. Indeed, the deflator for "C" uses the CPI, which does include imported consumer goods. However, Method 1 is not as effective in estimating domestic production. Note, however, that even if the BLS had a complete set of input price indexes, Method 2 might still have some data problems, as information currently collected on purchases by industry and related information may not be as timely or as detailed as the data currently collected for Method 1.
14. For example, in contrast to the forms for the furniture manufacturing industry, the collection form for the parallel furniture wholesale sector does not provide the same level of detail on material costs, while the collection form for the retail furniture industry does not collect *any* information on the cost of materials.
15. "Memorandum of Understanding between the U.S. Bureau of Labor Statistics and the U.S. Census Bureau 61-12-MOU-06," signed on April 12, 2012. Under the terms of the agreement, the BLS does not have access to firms consisting of only one establishment, as their information is considered to fall under the purview of Title 26 of the United States Code, comprising federal tax regulations, and cannot be made available to the BLS.
16. Note that a company can consist of more than one establishment and that the data set analyzed at the BLS only included data from approximately 19,000 multiestablishment manufacturers (referred to as "enterprises"). However, these multiestablishment enterprises were estimated to account for roughly 93 percent of materials that were purchased by all manufacturers in 2007. The published data from the census Web site puts the total cost of "materials, parts, containers, packaging, etc., used" in 2007 at approximately $2.63 trillion (U.S. Census Bureau 2013). For comparison purposes, in 2007 the United States exported goods valued at $1.15 trillion and imported goods worth $1.97 trillion. In 2007 domestic manufacturers shipped products with a gross value of $5.34 trillion.
17. For comparison purposes, the BLS's International Price Program collects prices for approximately 25,000 items and publishes 1,050 series, whereas the BLS's Producer Price Program includes approximately 100,000 quotes and publishes 9,500 series.
18. It should be noted that in the new 2012 NAICS manual, the number of six-digit NAICS industries has been reduced to 364. One follow-up project would be to attempt to revise the eight-digit material codes so they accord more readily to six-digit NAICS codes.
19. The BLS price indexes come out monthly, which enables researchers to know how sporadic trade is. This helps in developing a repriceable market basket of items.

20. As part of the MOU signed by the Census Bureau, the BLS also requested access to the detailed multiestablishment data from the Annual Survey of Manufactures. These data were delivered during the second quarter of Fiscal Year 2013 and are being analyzed by the BLS in order to assess the survey's utility in drawing a sample for an input price index.
21. In constructing a sample for the import price index, the International Price Program has the advantage of accessing the universe of import transactions from the U.S. Customs and Border Protection agency, which allows for drawing a sample only of those items and importers who trade consistently over the course of a year.
22. Data collection for all BLS price programs is conducted on a voluntary basis.
23. For further elucidation, see Kim and To (2009).

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Measuring Globalization

Better Trade Statistics for Better Policy

Susan N. Houseman and Michael Mandel
Editors

Volume 2

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Factoryless Manufacturing, Global Supply Chains, and Trade in Intangibles and Data

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and
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Editors

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1
Introduction

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Why should economists care about correctly measuring globalization? Obviously having a better picture of the global economy is a desirable end in itself. But more important is the relationship between good data and good policy: An accurate description of the global links among nations, businesses, and individuals is essential to optimal decision making by policymakers. Without such knowledge, policymakers are essentially flying blind.

Consider policy toward manufacturing enterprises. The federal, state, and local tax codes contain quite a few explicit beneficial provisions for manufacturing, in addition to direct and indirect subsidies. Moreover, there's an intense debate about whether manufacturing in countries such as the United States has been hollowed out or remains robust.

From this perspective, policymakers at every level of government would find it helpful to have direct information about the sorts of jobs that are created when manufacturers outsource production but keep the highly paid research and development (R&D), product development, and marketing jobs at home. Yet very little such data has existed heretofore.

This volume covers three topics where current statistical methodologies for tracking trade don't provide enough information for policymakers. These areas are "factoryless manufacturing," value-added trade in supply chains, and trade in services, intangibles, and data.

These areas are connected by a common thread: Rapid changes in the global economy have outstripped the traditional statistical presentation of export and import data by commodity and industry, as published by national and international statistical agencies. This has meant that such agencies no longer provide enough information for policymakers and researchers. The traditional presentation of trade statistics does not allow economists to trace out the implications of global supply chains, which disaggregate production among countries in new and unexpected ways. Moreover, economists have very little data on cross-border flows of intangibles and data, which are poorly reported in the conventional trade statistics and yet increasingly important.

Chapters 2, 3, and 4 describe a way of augmenting the conventional industrial classifications by creating a new category called "factory-less goods producers" (FGP). Such a change—and the data collection changes that would accompany it—would have the effect of providing policymakers with a new source of information about the impacts of global supply chains in manufacturing.

Chapters 5, 6, and 7 examine the measurement of value-added trade. In a world of global supply chains, policymakers need to know more than straightforward gross exports and imports for each commodity. An export may contain large amounts of imported components, while a particular imported commodity may be an essential part of high-value exports. As a result, trade negotiators would greatly benefit from having access to value-added trade statistics so they can determine which categories of exports are most beneficial to the domestic economy.

Similarly, value-added trade statistics would be invaluable for state and local economic development policy. Governments often offer tax and training incentives to companies without being able to correctly measure the true spillover benefits to the local economy.

Even domestic macroeconomic policy relies heavily on a good understanding of globalization. As we saw during the financial crisis, the credit contraction leapt across national borders in unanticipated ways. Today, U.S. consumption, investment, and production are heavily dependent on global supply chains. A credit or political shock in China, for example, could plausibly have large effects on inflation or consumption in the United States and other countries.

Finally, Chapters 8 and 9 address the difficult issues of measuring cross-border flows of intangibles and data. Like value-added trade, getting better measurements of these increasingly important components of the global economy could significantly affect trade policy, tax policy, economic development policy, and even macro policy.

FACTORYLESS GOODS PRODUCTION

Chapters 2, 3, and 4 deal with correctly measuring the increasingly important phenomenon of factoryless goods production and contract manufacturing services (CMS). Companies such as Apple and Nike—which do research in new technology, design new products, market the products, and receive the profits from the sale of the products—are subcontracting out most or all of their actual production to other companies, either in the United States or globally. The issue is whether the first type of company—which may own no factories but may perform all the high-end functions of manufacturers—should be classified in the manufacturing industry.

On one level, this is a straightforward classification question. Under the North American Industry Classification System (NAICS) currently used in the United States, a company that outsources production could be classified in either manufacturing, wholesaling, or some other industry altogether. What's needed is a consistent way of identifying such firms that the main statistical agencies—the U.S. Census Bureau, the Bureau of Labor Statistics (BLS), and the Bureau of Economic Analysis (BEA)—can agree on. Then the FGPs would buy manufacturing services from other companies (providers of CMS), which would do the actual factory production.

But the topic of FGPs turns out to raise some profound theoretical, practical, and policy issues as well, going beyond the narrow sphere of economic statistics. Manufacturing is important as a source of high-paying jobs and innovation for the economy. By separating out the production aspect of manufacturing from the product development and marketing aspect, FGPs make it possible to understand where the value-added and high-paying jobs are created in the research/product development/production/marketing chain.

In turn, if FGPs are buying manufacturing services from overseas contract manufacturers, the statistical agencies have to explicitly measure the quantity and price of purchased manufacturing services as part of imports.

At the time of the conference that these volumes grew out of, "Measuring the Effects of Globalization," held February 28–March 1, 2013, in Washington, D.C., U.S. statistical agencies were operating under a

2011 mandate from the Office of Management and Budget (OMB) to integrate the concept of FGPs into the sprawling U.S. system of economic statistics. As a result, agencies began planning and researching how to best track FGPs, and the three chapters in this volume reflect that effort.

However, since then, the OMB has relaxed its mandate. An August 8, 2014, OMB directive in the *Federal Register* notes the following:

> The Economic Classification Policy Committee (ECPC), which advises OMB on periodic revisions to NAICS, recently reported to OMB that results of preliminary research on the effectiveness of survey questions designed to identify Factoryless Goods Producers (FGPs) [show] inconsistent results. These results indicate that questions tested in the 2012 Economic Census fail to yield responses that provide accurate and reliable identification and classification of FGPs. The ECPC has advised that additional research, testing, and evaluation are required to find a method for accurate identification and classification of FGPs, and that this process could take several years. Given these initial research results and the large number of public comments submitted on the topic of FGPs, OMB here announces that the FGP recommendation will not be implemented in 2017. (*Federal Register* 2014, p. 46558)

The *Federal Register* note goes on to say this:

> Without the deadline imposed by the 2017 NAICS revisions, the relevant statistical agencies will now have the opportunity to complete the additional research, testing, and evaluation needed to determine the feasibility of developing methods for the consistent identification and classification of FGPs that are accurate and reliable. (Ibid.)

From this perspective, the chapters in this volume stand as a road map for future research. In Chapter 2, “Reflecting Factoryless Goods Production in the U.S. Statistical System,” Maureen Doherty gives a brief history and overview of the rationale behind creating the category of factoryless goods production. She shows how the United States chose a somewhat different approach from international statistical organizations.

In Chapter 3, “Measuring ‘Factoryless’ Manufacturing: Evidence from U.S. Surveys,” Fariha Kamal, Brent R. Moulton, and Jennifer Ribarsky identify data that the BEA and the Census Bureau are already collecting on both producers and users of CMS. Using this data, the chapter provides a snapshot of companies that are engaged in these activities.

Chapter 4, "The Scope of U.S. 'Factoryless Manufacturing,'" by Kimberly Bayard, David Byrne, and Dominic Smith, estimates the extent of U.S. factoryless manufacturing using corporate financial reports and Economic Census microdata. The authors calculate that manufacturing value-added would have been 5 to 20 percent greater for 2007 if all FGPs were reclassified to manufacturing, and that value-added would have been 20 to 30 percent greater for 2007 for semiconductor manufacturing if FGPs were included.

VALUE-ADDED TRADE

Factoryless goods producers make up only one aspect of global supply chains, however. The next three chapters take a more general look at value-added measures of trade. Value-added measures of trade acknowledge that exports of many goods and services are actually heavily dependent on imported intermediates. For example, a smartphone exported from China may contain chips originally made in Japan or South Korea (Kraemer, Linden, and Dedrick 2011). Similarly, exports of financial services from New York investment banks may in theory rely on intermediate services generated in the London offices of these banks.

Value-added measures of trade, rather than reporting gross exports, account for these imported intermediates by subtracting them out. Thus, value-added trade in theory represents the actual domestic value generated by exports.

Value-added trade measures are a very useful conceptual step forward. They are not a full solution, however. First, most countries do not have the right surveys in place to directly track usage of imported intermediates by industry. Second, value-added trade measures do not solve the import price bias issues raised in the first volume. For example, consider a piece of electronics assembled in China from imported components, and then exported to the United States. China's share of the final sales price might be quite low in this calculation. However, that assumes Chinese wages for the cost of assembly. If assembly was shifted to the United States, then the cost of assembly at U.S. wages would be a much bigger share of the final sales price.

Nevertheless, major steps have been made in assessing value-added trade, as described in the chapters in this volume. In Chapter 5, "Incomes and Jobs in Global Production of Manufactures: New Measures of Competitiveness Based on the World Input-Output Database," Marcel P. Timmer, Bart Los, and Gaaitzen J. de Vries analyze global value chain income ("GVC income") for 20 countries, including the United States, Japan, Brazil, China, India, Russia, and the major economies of Europe. The authors define GVC income as the income generated in a country by participating in global manufacturing production, including the large contribution of nonmanufacturing industries.

The authors show that in advanced countries, GVC income generated by capital and high-skilled labor is rising. This fits the common story that global shifts in manufacturing have benefited workers with more education. Some of these gains are coming in service jobs, since the authors demonstrate that the manufacturing sector is the direct source of only half of the GVC income. On the downside, the same analysis shows that high-skilled-job opportunities have declined in the United States since 1995, while rising in Europe and Japan.

The methodology described in the chapter relies on tracing out cross-border flows of intermediates, as described in the World Input-Output Database (WIOD), an effort funded in part by the European Commission (Timmer 2012). A similar effort, funded by the Organisation for Economic Co-operation and Development (OECD) and the World Trade Organization (WTO), is described in Chapter 6, "Measuring Trade in Value-Added and Beyond," by Nadim Ahmad. This chapter describes the methodology behind the Trade in Value-Added (TiVA) database, the assumptions behind the methodology, and the initiatives launched to improve the quality of those assumptions and the underlying data.

An August 2013 report that draws on the TiVA database, published subsequent to the 2013 globalization conference, estimates that between 30 and 60 percent of the value of the exports of G20 countries are either composed of imported inputs or are intermediate inputs for other countries (OECD, WTO, and UNCTAD 2013). In addition, 42 percent of the value-added of exports for G20 economies are made up of services, which closely matches the estimate in the previous chapter.

Finally, there's a broader policy point that often escapes policymakers—succeeding in international markets requires an ability to import high-quality intermediate inputs, as countries such as China have done.

From both a political and economic framework, China represents one particularly important application of the value-added framework. In Chapter 7, "Import Uses and Domestic Value-Added in Chinese Exports: What Can We Learn from Chinese Microdata?," Shunli Yao, Hong Ma, and Jiansuo Pei estimate China's domestic value-added share in exports by combining two enterprise-level sources of microdata. The chapter provides an excellent background for the types of data that the Chinese statistical authorities are collecting, as well as upper and lower bounds for domestic value-added shares.

INTANGIBLES AND DATA

The next two chapters address the difficult questions of measuring cross-border flows of intangibles and data. Chapter 8, "A Formulary Approach for Attributing Measured Production to Foreign Affiliates of U.S. Parents," by Dylan G. Rassier and Jennifer Koncz-Bruner, focuses on the proper geographical attribution of the income generated by intangible capital such as patents, software, and other intellectual property. The problem is that the knowledge embodied in intangible capital is a "shared input" across an entire enterprise. The return on intangible capital could in theory be attributed to the country where the capital was created, the country where the intangible capital was used for production, the country where the product that incorporates the intangible capital is sold, or the country where the intangible capital is nominally located for legal or tax purposes.

The BEA publishes data on income and assets by country for foreign affiliates of U.S. multinationals. The current methodology is to attribute the income generated by intangible capital owned by a multinational to the country where the capital resides for legal or tax purposes. That results in apparent anomalies where certain countries such as Bermuda and Ireland show relatively high levels of assets and income for the foreign affiliates of U.S multinationals, apparently out of proportion with the actual economic significance of those countries.

Rassier and Koncz-Bruner propose using proxy measures such as compensation, net physical assets, and sales in order to provide a better estimate of the location of income and economic activity of foreign affiliates of U.S multinationals. The proposed methodology results in only a small shift of income, in the aggregate, between foreign affiliates and U.S. parents. But the global location of income outside the United States shifts significantly. In particular, the proposed methodology shifts income across global regions including Africa, Asia, Europe, Latin America, and the Middle East by more than 10 percent of value-added.

The proposed methodology, however, does not actually deal with some of the conceptual problems raised by shared inputs. It would be better, in some sense, to be able to measure the creation and use of intangible capital separately, and provide some theoretical guidance for how the data can be used

In the final chapter, “Data, Trade, and Growth,” Michael Mandel examines a topic that is rarely considered—how to measure cross-border flows of data. These days no international commerce can be conducted without an associated flow of data. That includes financial data, entertainment, the data that accompanies back-office functions such as human resources, sales data, and production data. Estimates from TeleGeography suggest that cross-border data flows rose at an average annual rate of 49 percent between 2008 and 2012.

The problem is that these cross-border flows of data, while clearly economically valuable, are often not picked up by the trade statistics. In the current methodology used by the BEA and most other statistical agencies globally, data is classed as a service—and a service export by definition occurs when a foreign person pays a domestic person for a service. Similarly, an import of services by definition occurs when a domestic person pays a foreign person for services.

However, the global architecture of the Internet allows and even encourages data to cross national borders without leaving a significant monetary footprint. In particular, major Internet providers exchange data without exchanging money, opening up the possibility of a packet of data traveling around the world without leaving a single monetary trace.

As a result, Chapter 9 offers evidence that economically important cross-border data flows are simply not being counted by current international economic statistics. It is likely that both the level and the rate of growth of data trade are being significantly understated.

This mismeasurement issue has several important policy implications. First, it seems likely that the data sector, and the companies making up the data sector, are bigger contributors to domestic and global growth than policymakers realize. That in turn leads to the second implication: To the degree that trade negotiators for the United States (and for other countries) prioritize their negotiation objectives according to the relative economic importance of different sectors of the economy, the undermeasurement of the data sector will adversely affect policy. To put it a different way, if wheat exports are easier to measure than trade in data, then U.S. trade policy will place too much emphasis on reducing barriers to agriculture exports and not enough on maintaining the free flow of data.

The second policy implication is that international tax policy may be distorted by undermeasurement of cross-border data flows. Tax policy is, at base, a balancing act between revenue raised and distortions to market outcomes. But it requires good information about the economy in order to make good choices.

And third, attempts by various countries to implement barriers to the free flow of data may do considerably more economic damage than the current trade statistics show.

Taken together, these two volumes show that progress is being made in the difficult problems of measuring globalization. However, there's a long way to go before global trade statistics truly provide policymakers with the information that they need.

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Part 1

Factoryless Manufacturing

2
Reflecting Factoryless Goods Production in the U.S. Statistical System

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BACKGROUND

The goal of a country's national statistical agencies is to provide relevant, timely, and accurate information on that country's economy.[1] Over time, as technology changes and organizations mature and change the way they operate, there can be changes in both the mix of outputs produced in an economy and in the way firms operate to achieve their goals. One of the biggest challenges faced by producers of national economic statistics is to adapt to these structural changes in the economy in order to continue to provide relevant data. Usually, structural economic alterations occur gradually over time; however, with the continual rapid technological advances of the past 20 years, there have been significant shifts in the way firms operate. Two of the biggest changes are the growth of global value chains and the fragmentation of production.

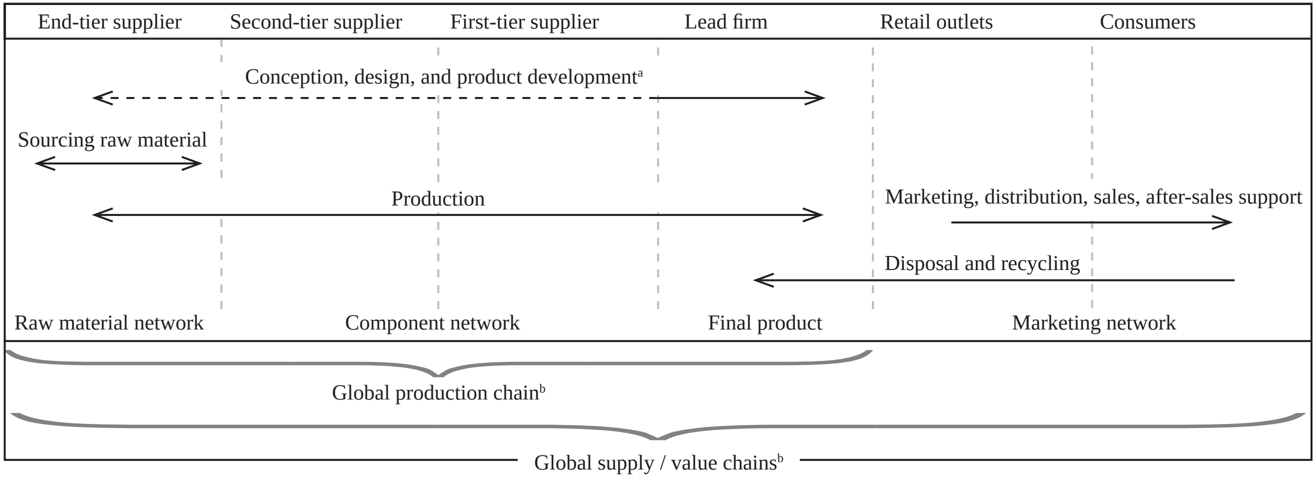
Global value chains and production fragmentation are interrelated phenomena. A value chain is the set of interrelated economic activities that contribute to the provision of a good or service, starting with product development and ending with customer service. When some of the economic activities occur in different countries, the chain is considered a global value chain (Center on Globalization, Governance, and Competitiveness 2006). A production chain is the set of economic activities within or among firms in a global value chain that are required to produce specific products. A production chain is typically controlled by a lead firm and is considered to be global when the production activities are dispersed across countries (Chang, Bayhaqi, and Yuhua 2012). The relationship between production chains and global value chains is illustrated in Figure 2.1.

Traditionally, product development and at least some transformation activities of the production chain for manufactured products were performed by establishments classified as manufacturers. Over the past two decades, vast improvements in technology, communications, and transportation have allowed firms to share intellectual property and closely control all steps of the transformation process without directly performing any of the transformation steps. This allowed firms to improve profitability by focusing on innovation and product and marketing decisions instead of on the generic services and volume production portions of the value chain, which were then outsourced (Gereffi, Humphrey, and Sturgeon 2005). As a result, some establishments revolutionized their business processes even further and began to perform all of the functions typically associated with manufacturing except for the transformation steps.

These changes have introduced complexities into the production of economic statistics, forcing a reexamination of traditional economic measurement concepts related to industry classification for establishments and to the value of a country's outputs, exports, and imports by both the U.S. and international statistical communities. Economic activity classification systems did not address how to handle the output of establishments that outsourced certain production tasks. In addition, to the extent that production tasks were outsourced internationally, questions were raised concerning how the outsourced activities were handled in national accounts and balance of trade statistics.

This chapter will first look at the response of international statistical organizations to these phenomena and then turn its attention to the U.S. response, highlighting how the latter differed in some aspects from the international response. The chapter will then review implementation planning and issues within the U.S. statistical system.

Figure 2.1 Global Value/Supply/Production Chains



[a] Traditionally, conception, design, and product development are controlled by the lead firm; nowadays, however, some of these activities are outsourced to other firms, as is indicated by the dashed line. Arrows on both ends of a line indicate that a process can go in either direction.

[b] The players in the global production/supply/value chain include domestic and foreign firms.

SOURCE: Chang, Bayhaqi, and Yuhua (2012) of the Asia-Pacific Economic Cooperation (APEC) Policy Support Unit.

INTERNATIONAL RESPONSE

The United Nations Statistics Division and the International Monetary Fund (IMF) Statistics Department set standards and produce manuals and guidelines for a number of different international economic statistics. These groups routinely evaluate their standards and make periodic updates in order to stay current as businesses change the way they operate over time. In the past decade, each undertook an extensive multiyear evaluation and update of their processes, at least in part to reflect the impact of globalization. There were some differences in the timing of these efforts, but there was a great deal of collaboration across projects, and each project included widespread outreach to both gather input and obtain comments on drafts.

One of the standards that the United Nations Statistics Division is responsible for is the International Standard Industrial Classification of All Economic Activities (ISIC). As the name implies, this classification is the international standard for the classification of productive economic activities. The main purpose is to provide a standard set of economic activities so that entities can be classified according to the activity they carry out. The United Nations Statistics Division, along with the Technical Subgroup of the Expert Group on International Economic and Social Classifications, began planning a regularly scheduled update of ISIC in 2001. A draft of ISIC Revision 4 was approved in 2006 by the United Nations Statistics Division and released in 2008 (United Nations Statistical Commission 2006).

Clarification of the classification of an establishment that outsources its principle economic activity was one of the many issues addressed in this revision of the ISIC. With respect to outsourcing, it was determined that if any establishment outsources part but not all of its production activities, it should be classified as if it were carrying out the complete process. If an establishment outsources its complete production process, it is also classified as if it were carrying out the complete production process, as long as the output of the production process is not goods. Goods producers that outsource their entire production process are classified as if they were carrying out the complete process only if they are the economic owner of the output. Under these rules, an establishment is the economic owner of an output only if they are the legal owner of the physical input materials (Becker and Havinga 2007). If an establishment engaged in a goods-producing activity has all the production done by others and does not legally own the material inputs, it is considered to be buying the completed goods from the contractor with the intent to sell them and would usually be classified in the appropriate trade activity (European Commission et al. 2009).[2]

The System of National Accounts (SNA) is the internationally agreed-upon standard set of recommendations on how to compile measures of economic activity and is produced by the National Accounts section of the United Nations Statistics Division. It describes a coherent, consistent, and integrated set of macroeconomic accounts in the context of a set of internationally agreed-upon concepts, definitions, classifications, and accounting rules. In 2003, the United Nations Statistical Commission identified the need for a comprehensive update of the 1993 System of National Accounts manual based, at least in part, on the impact of globalization.

The main issue related to globalization was the treatment of goods that are sent from one country to another without a change in economic ownership. Under the 1993 SNA, when goods are sent abroad for processing and the processed goods are later returned, a change in ownership is imputed in each case, even when there is none, and the values of imports and exports reflect this imputed ownership change. The 2008 SNA recommended that imports and exports should be recorded on a strict change-of-ownership basis, with imputed changes no longer assumed. Economic ownership is the criterion that is used to determine whether a change in ownership takes place. For establishments involved in goods production activities, the SNA uses the ISIC criteria that an establishment must be the legal owner of input materials for the material used in the production process in order to be considered the economic owner of the output of that process.

According to the 2008 SNA, when goods are transferred from the economic owner in one country to an establishment in another country for further processing and the processed goods are then returned to the economic owner, the goods sent for processing should not be recorded as an export from the economic owner or an import to the processor in national accounts treatment. In addition, the returned processed goods should not be recorded as an export of the processor or as an import to the economic owner. Instead, the fee paid to the processing unit should be recorded as the import of processing services by the country owning the goods and an export of processing services by the country providing it (European Commission et al. 2009).

The IMF Statistics Department produces standards for concepts, definitions, classifications, and conventions for the compilation of balance of payments and international investment position statistics. As the international standard, its *Balance of Payments Manual* serves as a guide for IMF member countries that regularly report balance of payments data to the IMF. In 2003, the IMF Statistics Department also began working on an update to its *Balance of Payments Manual* in response to changes in the economic and financial environment. The final *Balance of Payments and International Investment Position Manual, Sixth Revision* (BPM6), was adopted in November 2008 (IMF 2009, p. 4).

Because BPM6 (IMF 2009) and SNA2008 (European Commission et al. 2009) were updated simultaneously, BPM6 reflects the same changes in the treatment of goods sent for processing and completed processed goods as described in the national accounts discussion above. BPM6, however, is not entirely consistent with SNA2008 in that it explicitly includes some additional guidelines related to the ownership of materials to be processed and to the location of the buyer of the goods after processing—these are not mentioned in SNA2008. As long as the economic owner of the processed goods is also the economic owner of the material inputs to be processed, that owner may obtain the materials from the owner's economy, the economy of the processor, or a third economy. Additionally, the fee charged by a processor to the owner of a processed good may cover the cost of materials purchased by the processor. When the goods for processing are obtained from a different economy than that of the economic owner, the value of those goods should be recorded as an import to the economic owner. Furthermore, the economic owner of the processed goods does not need to physically take possession of them before ownership is transferred to a buyer. If ownership of the goods is transferred to a buyer in a different economy than that of the economic owner, the sale should be recorded as an export from the economic owner's country (IMF 2009, pp. 161–163).

The International Merchandise Trade Statistics (IMTS), produced by the United Nations Statistics Division, is a set of official statistics that provides data on the movement of goods between countries and serves many different users with a wide variety of needs. In 2007, the need for a revision of these statistics was recognized because of many factors, including the impacts of globalization and the changes in related statistical frameworks like the *System of National Accounts Manual* and the *Balance of Payments and International Investment Position Manual*. As a result of these efforts, IMTS2010 was adopted in February 2010.

The need for compatibility with SNA2008 and BPM6 was one of the goals of the IMTS revision; however, when the needs of all data users were considered, priority was given to the need for statistics that reflect the physical cross-border movement of goods. As a result, IMTS differs conceptually from BPM6 and SNA2008 with respect to goods for processing and the return of processed goods. Specifically, IMTS recommends that goods for processing be recorded when they enter or leave the economic territory, irrespective of whether a change in ownership takes place. Because of these differences, it was recognized that adjustments to IMTS data would be necessary prior to use in the compilation of other statistics. In order to support the need to make such adjustments, IMTS2010 encourages the identification (preferably by special coding) of goods for processing and goods resulting from such processing in trade statistics. IMTS2010 also encourages the identification and special coding of goods that cross borders as a result of transactions between related parties (United Nations Department of Economic and Social Affairs 2011).

U.S. RESPONSE

The North American Industry Classification System (NAICS) is the standard used by U.S. statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. It was developed jointly by the U.S. Economic Classification Policy Committee (ECPC 2010),[3] Statistics Canada, and Mexico's Instituto Nacional de Estadistica y Geografia to allow for a high level of comparability in business statistics among the North American countries, and it was adopted in 1997. NAICS did not explicitly include guidance for the classification of establishments that owned the design and controlled the production and sale of goods but outsourced all the production. From 1997 through 2007, the NAICS manual indicated that establishments that were engaged in the mechanical, physical, or chemical transformation of materials, substances, or components into new products should be classified in the manufacturing sector. Furthermore, it suggested that manufacturing establishments may process materials or may contract with other establishments to process their materials for them (OMB 2007, p. 197).[4] NAICS has historically classified as belonging to the manufacturing sector apparel jobbers who perform entrepreneurial functions involved in other apparel and accessory manufacture; however, the manual did not define exactly what was meant by entrepreneurial functions, nor did it differentiate between establishments that contract out some versus all of the transformation activities (p. 246).

By the late 1990s, individual U.S. statistical programs were beginning to adapt in response to the changes in the economy, but there was no consistent approach—particularly with respect to establishments that perform entrepreneurial functions related to production but don't perform transformation activities. Some programs interpreted the NAICS manual's statement related to contracting with other establishments as applying only to the specifically mentioned apparel jobbers and classified other such establishments in wholesale trade or management of corporations. Others interpreted this statement more broadly but provided their own interpretation of what was meant by "performing entrepreneurial functions." This led to inconsistent NAICS classification decisions across statistical programs for some establishments, making it difficult to draw conclusions when analyzing NAICS data across programs.

In response to these inconsistencies, the ECPC formed the Manufacturing Transformation Outsourcing Subcommittee in July 2008 and charged its members with defining manufacturing transformation outsourcing and identifying characteristics of establishments that outsource manufacturing transformation activities. The team was also responsible for researching international classification efforts and developing classification options for both establishments that outsource transformation activities and those that perform transformation activities for others. The group identified three different types of establishments that could be involved in the production of goods: 1) the traditional integrated manufacturer (IM), 2) the manufacturing service provider (MSP), and

3) the factoryless goods producer (FGP). The characteristics of each type of goods-producing establishment are depicted in Table 2.1.

The team's report also described a wide variety of classification options along with the strengths and weaknesses of each, based on the appropriateness of product valuations and whether the option would support analysis. The team focused on five basic classification options, with variations for some of them. The classification options are described in detail below.

1) Classification in manufacturing

Under the assumption that outsourcing the transformation steps of the manufacturing process is no different than outsourcing other steps, all FGPs could be classified in the manufacturing sector, along with IMs and MSPs. This allows the full value of all goods, including returns to intellectual property, to be included in the manufacturing sector, whether produced by an IM or an FGP.

Within the manufacturing sector, several potential options for classifying establishments were described. All three types of establishments could be included in the appropriate manufacturing industry, with or without breakouts by type of establishment. Breakouts by establishment by type, where possible, would facilitate data analysis of the same types of products but would require the collection of some new data. To the extent that special aggregations excluding FGP activity could be calculated, this option would also allow continuous series to be created in industries with significant amounts of FGP activity. Other possibilities were to create a new manufacturing subsector for all FGPs that would include breakouts for industries that had a significant number of FGP

Table 2.1 Characteristics of Types of Manufacturing Establishments

	Integrated manufacturer	Manufacturing service provider	Factoryless goods producer
Owns intellectual property	Yes	No	Yes
Owns inputs	Yes	May or may not	May or may not
Performs transformation activities	Yes	Yes	No
Owns and sells or transfers finished product	Yes	No	Yes

SOURCE: Author's compilation.

establishments or add six-digit NAICS codes into the current manufacturing structure where warranted. If separate industries were created, it would be important that the new FGP industry product details be collected at the seven-digit product level of the manufacturing numerical list to allow for data analysis. This option would allow for the creation of continuous data series for currently existing manufacturing industries. To the extent that the creation of separate FGP industries might result in unpublishable data, it would not be a very useful distinction for data users.

2) Classification in wholesale trade

All FGP establishments could be classified in the wholesale trade sector, since the composition of labor and capital expenses for FGPs is similar to that in wholesale trade. This classification option would also be consistent with the concept that the primary economic activity of an FGP is the selling aspect of the production process. On the other hand, wholesale trade margin is for the service of goods distribution only. The margin for an FGP would include the value of the services related to design and those related to overseeing transformation in addition to goods distribution. Two possibilities were also considered within the wholesale trade classification option.

In the first possibility, FGP establishments could be classified in the appropriate merchant wholesale industry with or without separate data below that level for own-brand importers, own-brand marketers, and domestic FGPs in addition to the current breakouts for wholesale distributors. Including this additional detail supports calculations and analysis by allowing FGPs to be identified separately from traditional wholesalers; however, data may be unpublishable for some of the breakouts, which would hinder usefulness. It is unlikely that the wholesale trade detail could be expanded to match the current manufacturing detail, making comparisons between FGP and manufacturing data difficult.

A second possibility would be to classify FGP establishments in wholesale trade either in one industry or in three separate industries: 1) own-brand importers (those that arrange transformation by overseas contractor and import and distribute the final good), 2) own-brand marketers (those that arrange transformation by overseas contractor and that drop-ship the output to customers), and 3) domestic FGPs (those that arrange transformation by domestic contractors). This second possibility supports calculations and analysis by allowing FGPs to be identified separately from traditional wholesalers. The potential benefit of this method is offset by the fact that it is unlikely that the wholesale trade detail could be expanded to match the current manufacturing detail, making comparisons between FGP data and manufacturing data difficult.

3) Split classification between manufacturing and wholesale trade

This option would classify establishments according to whether they outsource overseas in wholesale trade or whether they outsource domestically in manufacturing. This option prevents goods transformed by foreign contractors from being included in domestic manufacturing when it is possible that the only domestic input was the intangible capital owned or leased by a domestic entity; however, it does not handle the situation where both domestic and international contractors are used. The production process for FGPs is exactly the same whether the transformation is contracted out domestically or internationally, so having different classifications based on the location of the contract manufacturer is inconsistent with a NAICS classification system based on production processes. In addition, switches between domestic and foreign contractors would result in classification changes that would lessen the stability of the classification system.

4) Classification in professional, scientific, and technical services

This option would classify FGPs in research and development, since this is the first step in the production process. If research and development is determined to be the primary activity of FGPs, they should be classified in this sector. However, if an FGP acquires the design of the product from another company, no research and design (R&D) activity would be performed at the establishment. Since FGPs are responsible for the sale of products, this option would require an expansion of the definition of this sector to include the selling process, and FGPs would report the value of the good as well as the value of the R&D.

5) Classification in management of companies and enterprises

This option would create a new three-digit industry code (defined as "managing the production process") within the "Management of

Companies and Enterprises" sector. Input costs for FGPs are probably similar to those associated with other establishments in this sector. If management of production is determined to be the primary activity of FGPs, they should be classified in this sector. On the other hand, this option focuses only on the management of the production process, not on the design or selling of the product. The amount of product detail would be significantly less than would be available in manufacturing, limiting its usefulness for analysis purposes.

ECPC RECOMMENDATION

The ECPC evaluated the report and used it as a basis for a January 2009 Federal Register notice that outlined the issues surrounding offshoring and described some of the available classification options. The ECPC used the Manufacturing Transformation Outsourcing Subcommittee's paper, the Federal Register responses, and an examination of international classification guidance to aid its members in forming a final classification decision.

The ECPC decided that all factoryless goods producers should be classified in manufacturing with the specific industry classification that is based on the transformation production process used by the contractor. Furthermore, the committee encouraged programs to provide breakouts for IMs, FGPs, and MSPs within each industry to support data analysis needs. The ECPC carefully considered the ISIC4 classification recommendation to base classification solely on legal ownership of material inputs, but it decided that control of the entrepreneurial aspects of the production process, including economic ownership of material inputs, was more appropriate. In doing so, it put forth the following argument:

> A strict adherence to the international recommendation to classify FGPs based solely on ownership of materials was considered and rejected as impractical. If the definition of ownership required physical possession, the ability to substitute between input sources in different countries to obtain the lowest cost could change sector classification in NAICS if the inputs were sent directly from the producer in country B to a manufacturing service provider in

> country C. The establishment that arranged for the production in country A would never take physical possession of the materials. If the definition of ownership were based on separate transactions, problems would still arise. Contracts between FGPs and their manufacturing partners change with market conditions. Payment terms and the allocation of risk can shift based on variations in the availability of credit and the market power or capacity of the individual parties. Classification of an establishment should not change simply because [that establishment has] the market power to shift the timing of payment for the inputs from the front of the process to the end of the process or because critical shortages of transformation capacity provide outsized negotiating power to a manufacturing service provider. By focusing on the entrepreneurial aspects of the process (and therefore ownership of the goods being produced) rather than ownership of materials, the ECPC eliminates the aforementioned ownership of materials issues. (ECPC 2010)

IMPLEMENTATION PLANNING

Both the U.S. and international statistical communities realized that even after all of the extensive research, outreach, and guideline update efforts had been completed, there was still a significant amount of work to do in order to implement the decisions that had been made and to continue analyzing the best methods to measure national and international transactions in a global economy. In response, implementation groups were formed both internationally and in the United States.

In 2007, the Conference of European Statisticians (CES) created an Expert Group on the Impact of Globalization on National Accounts. Specifically, the goal of this group was to analyze the impact of the updated guidelines on existing statistical measures, with a particular focus on national accounts, and to identify and propose solutions for problem areas. The group completed an extensive review of the topic and produced a detailed guide, "The Impact of Globalization on National Accounts," which was finalized in June 2011 (United Nations Economic Commission for Europe 2011). The guide documented a wide variety of issues and offered solutions to many problems; however, the authors recognized that there was still a need for additional research and included a chapter at the end outlining work still to be done. As a follow-up to this effort, the CES requested that Statistics Netherlands elaborate on the remaining issues, and this work resulted in the paper “In-Depth Review on Global Manufacturing” (Statistics Netherlands 2011). It also led to the formation by the CES of a Task Force on Global Production, which is responsible for developing guidance on unresolved issues related to SNA2008 and BPM6 and on aspects related to implementing these standards.

In early 2012, this Task Force on Global Production developed and prioritized a list of conceptual and measurement issues that needed to be addressed. In October 2012, the task force prepared an interim report that focused on the top-priority issues and presented a draft report on all issues to the Group of Experts on National Accounts in April 2012. The task force received feedback from the Group of Experts on National Accounts that there was a need for more emphasis on specific guidance and practicality, so the output will be finalized in the form of a practical guide to be used in the preparation of statistics on global-production-related activities (ECE 2013). The task force also produced a report on factoryless goods production that questioned whether ownership of material inputs is an appropriate criterion for classifying an FGP in manufacturing (Task Force on Global Production 2013). That report was presented to the Expert Group on International Statistical Classifications in May 2013.

In the United States, the ECPC recognized that the NAICS classification decisions the committee adopted would affect multiple U.S. agencies, as well as programs within those agencies. Furthermore, the ECPC realized that, as with any new concept, there would likely be some differences in interpretation across agencies during the implementation process, and that these differences might lead to data inconsistencies. As a result, the ECPC sponsored a multiagency task force to ensure consistent implementation of the inclusion of FGPs in the manufacturing sector in the 2012 NAICS. The team is composed of representatives from the Bureau of Economic Analysis (BEA), the Bureau of Labor Statistics (BLS), the Census Bureau, the Federal Reserve, and the International Trade Commission.

The FGP Implementation Planning Group began meeting in late June 2010, with the goal of defining a set of rules that agencies could use to implement the ECPC recommendation for classification of FGPs in the 2012 NAICS. The group's analysis of the issues relating to implementation of this concept indicated that these changes must first be implemented in conjunction with a quinquennial economic census in order to survey establishments in the appropriate sector. Given the complexity of the changes and the timing within the planning for the 2012 Economic Census, the group determined that it did not seem feasible to implement in 2012. The team considered partial or sequential implementation on a pilot basis by applying the new rules to only some establishments or industries or by applying only some of the rules, but it determined that this approach would be problematic since it would result in multiple series breaks over time, especially at aggregate levels. As a result, the planning group recommended that full implementation of the outsourcing redefinitions should be delayed, the new goal being to implement them for the 2017 Economic Census.

This recommendation was accepted by the ECPC and the OMB in November 2010. Implementation was deferred, and the interagency group was asked by the ECPC to continue the work of coordinating the implementation of this change. Then, in a further delay, the OMB announced in August 2014 that it was rescinding its earlier decision requiring that statistical agencies implement the classification change of assigning FGPs to the manufacturing sector by 2017, because the agencies "need an opportunity to perform additional research, testing, and evaluation." The remainder of this chapter will discuss the work of the FGP Implementation Planning Group.

U.S. IMPLEMENTATION ISSUES

Internationally, the concept of economic ownership was integral to many of the decisions made relating to the handling of transactions. The ECPC decision to classify FGPs in manufacturing did not explicitly mention the concept of economic ownership, but it did focus on control of the entrepreneurial aspects of production, which is in essence the acceptance of the risks and rewards of the production process. To be the economic owner of a product, an establishment must control the intellectual property (IP) or design, control the production process, control the sale of the product and assume entrepreneurial risk. A more detailed description of each of those four criteria, however, is required for an in-depth understanding of the concept.

Control of the IP or design means that the establishment either has developed it internally, has purchased it from another firm, or has negotiated to lease it from another firm. For a domestic establishment with a foreign affiliate, it is possible that the U.S. establishment could be leasing the IP or design from its affiliate. It is also possible that it could be leased to more than one economic owner. From a business-function standpoint, an establishment is the economic owner of the IP or design if it has the right to use it in its products, redistribute it, and can independently change the design of the final product.

There are many aspects to controlling the production process, including controlling inputs, product quality, and production levels. With respect to inputs, the economic owner can control inputs for the final product in a number of different ways. The owner could purchase the inputs and ship them to the MSP, arrange to have them shipped to the MSP from another domestic or foreign location, or merely approve the selection of input providers and the quality of the inputs. The economic owner also makes decisions about which products to produce and controls production levels and product quality. An economic owner can decide whether to add or delete product lines, expand his or her business, move into a different business, or leave the business entirely. Finally, the economic owner must also be able to report the cost of manufacturing service.

The economic owner of a product arranges to sell (or transfer in the case of an affiliate) the product to buyers (consumers, government, wholesalers, retailers, or other types of businesses, including manufacturers) and sets the price associated with the transaction. The economic owner does not need to take physical possession of the product or arrange the details of shipments to purchasers, but the owner must be able to report the value of those shipments.

There are a number of indicators that an establishment has taken on the entrepreneurial risk related to a product. The economic owner absorbs the loss for any unsold final products. It is also responsible for losses due to final products that fail to meet the customer's satisfaction, for which an unsatisfied customer would return the product to the economic owner (or a representative of the economic owner) for a refund, rather than to the establishment that performed the transformation.

Finally, it is legally responsible for legal problems related to defects or other problems in the final product.

The criteria for determining economic ownership apply in the same way whether the relationship is between a U.S. establishment and a foreign establishment that performs transformation activities or between a foreign establishment and a U.S. establishment performing transformation activities.

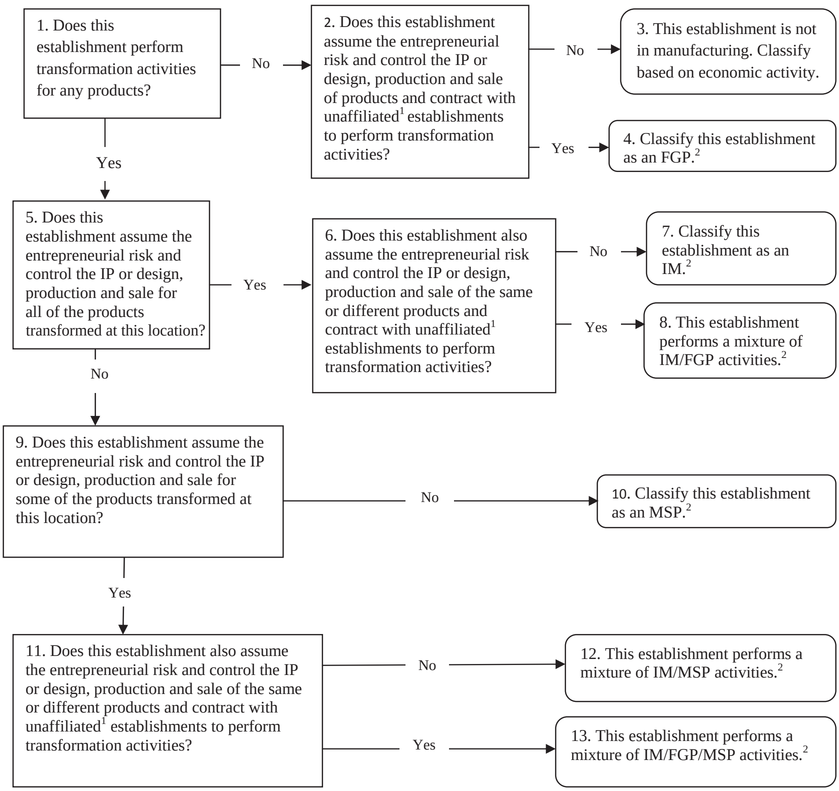
Defining Decision Rules

The FGP Implementation Planning Group determined that the best way to ensure a consistent understanding of how the classification decision-making process that is related to outsourcing should be implemented was to consider various scenarios and determine the appropriate classification for each. Based on these discussions of potential scenarios, the team reached conceptual agreement on classification outcomes and created an outsourcing decision tree that reflected the implementation of those concepts. In creating the scenarios, it became clear that a single establishment might perform both integrated manufacturing and manufacturing service–providing activities and at the same time have a factoryless goods production relationship with an unaffiliated transforming establishment. As a result, those possibilities are found in the decision tree. The decision tree reflects what the team considered would be the "ideal" implementation from a conceptual standpoint and is displayed in Figure 2.2.

There may be practical difficulties in implementing this ideal scenario because of external factors such as the differences between international and U.S. recommendations or issues reporting establishments might have in providing the information required to support classification decision making. There could also be internal limitations to implementation procedures related to the availability of resources within statistical agencies.

Several different agencies or programs currently make independent classification decisions for establishments. As long as a potential FGP and an MSP don't belong to the same enterprise, decision making using the decision tree is fairly straightforward and would routinely result in consistent decision making across agencies and programs. Multi-

Figure 2.2 Outsourcing Decision Tree—Ideal Definitions



[1] All foreign establishments should be treated as unaffiliated.
[2] If an establishment performs a mixture of integrated manufacturer (IM), manufacturing service provider (MSP), and factoryless goods producer (FGP) activities, it should be classified into one of the three unique subindustries, IM, MSP, or FGP, based on where most of its activity occurs.
SOURCE: Author's compilation.

establishment enterprises in manufacturing industries generally include establishments that perform transformation activities and establishments that control or provide support to the production activities. When all of the establishments of an enterprise are in the United States, the decision-making process is still fairly straightforward, since an establishment can only have FGP activity if it assumes the entrepreneurial risk and controls the IP or design, the production, and the sale of products, and if it contracts with *unaffiliated* establishments to perform transformation activities.

The ideal definitions, however, specify that all foreign establishments should be treated as unaffiliated. Thus, there is a potential FGP/MSP relationship whenever a product is transformed by a foreign affiliate. In recent years, multinational enterprises (MNEs) have responded to improved communications and a need to manage global operations by unbundling management functions in the same way they have unbundled production functions. Global enterprises may spread typical headquarters functions across locations, even in different countries, based on local regulations and proximity to labor sources, customers, and suppliers. This can result in different locations for the financial, legal, and decision-making functions of an enterprise (Desai 2009). As a result, assigning economic ownership to a specific establishment is particularly difficult when analyzing the relationship between headquarters-type and transforming-type establishments of the enterprise. Within an enterprise, an establishment that doesn't perform transformation may meet all the criteria for economic ownership of a product, but the transaction may be recorded on another establishment's books for reasons such as tax purposes. In addition, it is possible that some of the decision-making tasks that are included in the economic ownership criteria may be split across more than one headquarters-type establishment.

The U.S. interagency group has expressed concern that the complexity of classification decisions when MNEs are involved will result in an inefficient allocation of resources if each agency or program works independently to resolve these issues, and that will make it difficult for agencies or programs to make consistent decisions about the establishments of individual enterprises, as well as to make consistent decisions across enterprises. Some of the countries in the European Union (EU) have begun to form groups to work together to ensure that the transactions of MNEs are treated consistently across national accounts and national economic statistics. The U.S. interagency group has proposed a similar approach as part of the plan for the implementation of the FGP concept, with the formation of a standing cross-agency group to make classification recommendations for the major multinational enterprises that operate in the United States. The Census Bureau, the BEA, and the BLS each collect a different set of detailed statistical data from enterprises and establishments. Analysis of the combination of those data would likely result in the best decisions related to the classification of the establishments of these enterprises and the amount of revenue that should be attributed to each. Given the organization of U.S. statistical programs, the formation of such a group would require new data-sharing agreements and potentially new funding sources, and thus this proposal might be very difficult to implement. In the meantime, efforts to develop other approaches for handling these challenges will continue.

Understanding Data Needs

There are many data interdependencies among U.S. statistical agencies and the programs within them. In order to successfully implement the manufacturing redefinition clarification, statistical agencies have some special needs related to the data inputs that they receive from one another so they can accurately calculate statistics that reflect the inclusion of factoryless goods manufacturers in manufacturing.

Integrated manufacturers, manufacturing service providers, and factoryless goods producers each have a different mix of inputs and operating constraints. As a result, it may be necessary to produce separate data for each type of operation in many statistical series, either as unpublished components of published aggregate data or as published series. In order to support these data analysis needs, statistical programs will need values for inputs and outputs broken out by type of operation.

Some statistical agencies use the customs data provided by the IMTS in the production of statistics related to imports and exports. Since IMTS2010 gave priority to the need for statistics that reflect physical border-crossing of goods, customs data provided by the IMTS differ conceptually from the ECPC definition of FGP with respect to goods for processing and the return of processed goods. In order to use customs data in compiling other statistics that follow the ECPC definition, data will need to be obtained from other sources to adjust customs data to reflect the ECPC concept.

It is important both to statistical agencies and to other data users to be able to distinguish between definitional and economic changes so that these users of the data can create continuous time series and analyze data changes over time. As a result, individual statistical programs will need access to conversion, or bridge data, for various data series in order to produce historically consistent time series.

Statistical agencies rely on businesses to provide the data required to calculate economic statistics. For this reason, the interagency group also recognized the importance of understanding the types of data that establishments involved in outsourcing would likely be able to supply. In order to obtain this information, the group met with associations and companies and analyzed publicly available company data (particularly Form 10-Ks) to determine how companies manage and record their outsourcing activities. Another method used to determine data availability was the inclusion of "special inquiry" questions on current survey forms for some statistical programs. These questions serve the dual purpose of testing potential questions and identifying establishments that would likely be classified as FGPs when the manufacturing redefinition is implemented. The results of this research will be used as input to the creation of updated data collection instruments.

EXPECTED IMPACT ON ECONOMIC STATISTICS

The classification of factoryless goods producers in manufacturing is expected to have an impact on a number of different statistical programs, some of which are listed below:

- **U.S. Census Bureau**—Economic Census, annual and monthly wholesale trade surveys, Annual Survey of Manufacturers, several other NAICS-based series.
- **Bureau of Economic Analysis—**industry accounts, international accounts, National Income and Product Accounts, regional accounts.
- **Bureau of Labor Statistics—**Current Employment Statistics program, Quarterly Census of Employment and Wages, Producer Price Index program, International Price Program, Major Sector Productivity program, and Industry Productivity program.
- **Federal Reserve**—industrial production.

General Expectations by Type of Measure

The exact impact of these changes will depend on the classification decisions that are made for individual establishments when the new rules are applied, as well as on the size of those establishments at the time the rules take effect, whenever that may be. As a result, there is currently not enough information to quantify the exact impact, and there won't be until that information becomes available. We do have enough information, however, to describe the types of changes that are expected for a number of different economic measures. These expectations are described in Table 2.2.

Impact on Specific Manufacturing Industries

Although exact impact measures cannot currently be calculated, existing data can be analyzed in an attempt to identify which industries are most likely to be affected by these changes and to make some estimates related to the size of some of the changes. The data expectations described above indicate that changes within manufacturing will be centered on specific industries. For planning purposes, it would be helpful to economic programs to identify which industries will likely be most affected by the inclusion of FGPs in manufacturing in order to support any required decision making.

In order to develop measurement statistics, I make the following four assumptions related to manufacturing industries:

1) Manufacturing industries that currently purchase a relatively large amount of contract work have a production process that is consistent with the outsourcing of transformation tasks.
2) Under current procedures, if a manufacturing establishment outsources all of the transformation for its products, the sales of those products are coded as resales. Therefore, manufacturing industries with relatively high levels of resales are likely to have FGP activity under the new rules.
3) The ratio of production employees to total employees will be lower for manufacturing industries that outsource transformation activities.
4) Manufacturing industries with relatively high levels of imports for their products are likely to be involved in outsourcing.

Based on these assumptions, data from the 2007 Economic Census and the 2002 benchmark I-O tables were examined to find measures that might help identify industries that currently have characteristics that could be indicative of FGP activity. No single measure was identified that could reflect the criteria in all four assumptions. As a result, five different measures were identified, and analysis focused on the full set of measures rather than on any individual measure. For each measure, values were calculated for each six-digit NAICS manufacturing industry along with weighted average values for all manufacturing industries. For most of the measures, values higher than the average were considered indicative of potential FGP activity. For the number of production workers divided by total employment, values lower than the averages were considered indicative of potential FGP activity. In order to further support analysis, a level was judgmentally selected for each measure to indicate a value that was significantly higher or lower than the average, so that about half of the above- or below-average industries were considered to be significantly above or below. The formulas for each measure are displayed in Table 2.3, along with the percentage level significantly above or below.

The goal of the analysis was two-pronged. At a high level, the goal was to provide a big picture of the impact of this change on the manufacturing sector. At an industry level, the goal was to provide early support for agency planning processes by systematically identifying those specific industries that are most likely to be affected by the inclusion of FGPs in manufacturing and thus may need special processing. Industries were assigned to one of three categories based on the number of measures above average and significantly above average (or, as noted earlier, below average, in the case of number of production employees divided by total employment). Although the five measures were selected because of their expected relationship to potential FGP activity, the level of each of the measures for a particular industry could be affected by other factors as well. As a result, criteria were set for the three categories, assuming that an industry with fewer than five measures above average could have a high likelihood of being affected by the inclusion of FGPs in manufacturing, while those industries with only one measure above average would be unlikely to be affected. Table 2.4 displays the exact criteria that were used to assign industries to categories, as well as statistics for each of the three categories.

Table 2.2 Expected Changes to Economic Measures

Measure	Expected change
Total U.S. employment and wages	U.S. totals will not change.
Sector U.S. employment and wages	Values will shift across sectors, with manufacturing growing and other sectors, primarily wholesale trade, shrinking. Increases in manufacturing are expected to be centered on specific industries. This will result in regional shifts within sectors, including manufacturing.
Production employees	U.S. totals will not change. Sector total changes will be minimal, since FGPs would have few, if any, production employees.
Total U.S. revenue values	The total will likely change, but the direction and amount of the change are unknown. 1. FGPs may report revenues from products that would have previously been treated as imports. 2. For an FGP manufacturing establishment previously classified in wholesale trade, revenues will increase by the difference between the wholesale trade margin and the full value of the products for some statistical measures. 3. For manufacturing establishments that are determined to be MSPs rather than IMs, revenues will decrease by the difference between the full value of the product and the value of the manufacturing service they provided.
Sector U.S. revenue values	Sector totals will change, with increases expected in manufacturing and decreases in other sectors. The manufacturing changes will likely be in specific industries.
Value of U.S. imports	The total will likely change, but the direction and amount of the change are unknown. The mix between goods and services will also change. The changes will be centered in specific product areas. For products transformed by foreign MSPs for domestic FGPs: 1. The full value of the products that the foreign MSPs transformed and returned to the U.S. FGPs will be excluded from imports.

	2. The value of the manufacturing service that they performed and any inputs they provided will be included in imports.
	For products transformed by U.S. MSPs for foreign FGPs:
	1. The full value of the products that they transformed that remain in the U.S. are included in imports.
	2. The value of any inputs that they received from the foreign FGP will be excluded from imports.
Value of U.S. exports	The total will likely change, but the direction and amount of the change are unknown. The mix between goods and services will also change. The changes will be centered on specific product areas.
	For products transformed by foreign MSPs for domestic FGPs:
	1. The value of products that have remained in a foreign MSP's country or that were shipped by a foreign MSP to another country will be added to exports.
	2. The value of the inputs that the domestic FGP provided to the MSP will be excluded from exports.
	For products transformed by U.S. MSPs for foreign FGPs:
	1. The full value of any product that they transformed and returned to the foreign FGP will be excluded from exports.
	2. The value of the manufacturing service that they performed and any inputs they provided will be included in exports.

SOURCE: Author's compilation.

Table 2.3 Industry Impact Analysis Measures

Measure	Average for all manufacturing industries (%)	Significantly above/below average level (%)
2007 Economic Census		
(Cost of contract work) / (payroll)	9.7	15
(Cost of contract work) / (cost of materials and parts)	5.9	10
(Cost of resales) / (total cost of materials)	2.3	5
(Number of production workers) / (total employment)	70.1	60
2002 benchmark I-O tables		
(Imports) / (domestic production + imports − exports)	23.2	30

SOURCE: 2007 Economic Census and 2002 benchmark input-output (I-O) tables.

In order to summarize the industry results, the industry categorization was further analyzed by aggregating the industries by subsector and calculating the percentage of each subsector's value of shipments (VOS) that is attributable to industries in each of the three categories. These percentages are displayed in the Table 2.5, along with a count of the number of industries in the category. The analysis indicates that the apparel manufacturing and computer and electronic product manufacturing subsectors had the highest portion of their VOS from industries in the highest-likelihood category. This is consistent with the generally accepted assumption that these two subsectors will be strongly affected by the manufacturing redefinition.

Analysis of Wholesale Trade for Own-Brand Importer-Marketers

The wholesale trade survey forms for the Economic Census include a question related to the type of operation. One of the operation types is, "own-brand importer-marketer." Own-brand importers-marketers deal primarily or exclusively in the parent company's own branded products manufactured outside the United States. The products are either imported into the United States and then sold, or they are sold and then drop-shipped directly from a foreign location to the U.S. customer. It is expected that many of the wholesale trade establishments categorized

Table 2.4 Results of Manufacturing Industry Impact Analysis

Category	Criteria	Number of industries	% of total manufacturing establishments	% of total manufacturing employment	% of total manufacturing VOS
Highest likelihood	4 or 5 measures above average, or 3 above average with more than one significantly above average	150	33	30	25
Medium likelihood	3 measures above average with fewer than 2 significantly above, or 2 above average	160	40	34	39
Lowest likelihood	0 or 1 measure above average	161	27	36	36

NOTE: "VOS" stands for value of shipments.
SOURCE: Author's calculations based on 2007 Economic Census and 2002 benchmark input-output (I-O) tables.

in this operation type will be classified in manufacturing using the new classification rules. In the 2007 Economic Census, about 3 percent of all wholesale trade establishments were own brand importer-marketers.[5] Those establishments accounted for about 4 percent of wholesale trade sales and employment. If all those establishments had been classified in manufacturing, the number of manufacturing establishments would have increased by about 3 percent, sales would have increased by about 4 percent, and employment would have increased by about 2 percent. The wholesale trade industry groups that have the largest proportion of their sales from own-brand importer-marketers are officially known as "Apparel, piece goods, and notions merchant wholesalers" and "Electrical and electronic goods merchant wholesalers."

Table 2.5 Analysis of the Impact of Inclusion of FGPs in Manufacturing by NAICS Subsector

		% of subsector VOS from industries by likelihood of impact			No. of subsector industries by likelihood of impact		
Sector	Title	High	Medium	Unlikely	High	Medium	Unlikely
311	Food manufacturing	3.0	20.0	76.9	2	8	37
312	Beverage and tobacco product manufacturing	0.0	52.1	47.9	0	5	4
313	Textile mills	25.2	41.7	33.1	4	4	4
314	Textile product mills	47.9	48.4	3.7	5	2	1
315	Apparel manufacturing	86.8	11.7	1.5	17	5	2
316	Leather and allied product manufacturing	43.6	56.4	0.0	5	4	0
321	Wood product manufacturing	4.1	8.3	87.6	1	2	11
322	Paper manufacturing	0.5	5.5	94.0	1	3	16
323	Printing and related support activities	21.1	65.7	13.2	4	5	3
324	Petroleum and coal product manufacturing	0.0	96.2	3.8	0	2	3
325	Chemical manufacturing	30.7	48.8	20.5	4	19	11
326	Plastics and rubber product manufacturing	0.0	13.3	86.7	0	4	13
327	Nonmetallic mineral product manufacturing	17.3	28.0	54.6	7	10	7
331	Primary metal manufacturing	40.6	24.2	35.2	2	11	13
332	Fabricated metal product manufacturing	33.1	51.4	15.5	17	19	7
333	Machinery manufacturing	46.9	38.6	14.5	27	17	5
334	Computer and electronic product manufacturing	77.4	20.3	2.3	21	7	2
335	Electrical equipment, appliance, and component manufacturing	25.1	35.9	39.0	5	9	8
336	Transportation equipment manufacturing	23.3	22.2	54.5	5	12	13
337	Furniture and related product manufacturing	17.0	35.6	47.4	4	5	4
339	Miscellaneous manufacturing	75.6	23.9	0.5	14	8	1

NOTE: "VOS" stands for value of shipments.
SOURCE: Author's calculations based on 2007 Economic Census and 2002 benchmark input-output (I-O) tables.

IMPORTANCE OF CHANGES FOR DATA USERS

Over the past 20 years, U.S. economic statistical programs recognized that there have been major changes in the way businesses operate, particularly with respect to production fragmentation and globalization, but individual agencies and programs in those agencies made different methodological decisions in response to those changes. There was not an integrated comprehensive examination of how these economic changes should be reflected in the entire set of economic statistics.

Business and governmental decision makers use a wide variety of U.S. economic statistics from different agencies and programs on a daily basis. To the extent that these statistics are inconsistent with one another or have not kept pace with changes in the economy, they may make it difficult for data users to make sound decisions. This problem has been recognized by both government and business data users and has been characterized as "using a 1950s dashboard to operate a 21st-century machine" (Karabell 2013, p. G1).

The collaborative effort of U.S. statistical agencies to reach agreement on how to identify and handle factoryless goods producers and manufacturing service providers will result in more data consistency across agencies. In addition, it will allow statistical agencies to provide data about the three different types of manufacturing establishments, at least at an aggregate level, allowing data users to see changes over time and to analyze differences across the three types of establishments. These benefits will support the need of business and government leaders to make informed decisions.

Notes

1. All views expressed in this chapter are those of the author and do not necessarily reflect the views or policies of the U.S. Bureau of Labor Statistics.
2. For a detailed description of the usual classification rules, refer to United Nations Department of Economic and Social Affairs (2008).
3. More information about the ECPC can be found at http://www.census.gov/eos/www/naics/ecpc/ecpc.html (accessed November 12, 2013).
4. The following link includes links to various sectors of the manual: http://www.census.gov/cgi-bin/sssd/naics/naicsrch?chart=2007 (accessed April 21, 2014).

5. Detailed data on wholesale trade by type of operation can be found at U.S. Census Bureau (2007).

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3
Measuring “Factoryless” Manufacturing

Evidence from U.S. Surveys

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Globalization has created new opportunities and competitive challenges, forcing producers to seek more efficient ways to make their products. It has become increasingly common for producers seeking more efficient means of production to divide the traditional vertically integrated production model into stages or tasks (known as fragments), thus allowing them to outsource part of their production process. When the resulting production arrangement is interlinked across different countries, the measurement challenges facing national economic statistics programs increase dramatically.

Many economic forces are driving the fragmentation of production to specialized establishments, both foreign and domestic. Improvements in information technology have allowed firms to relocate production to new and often distant locations. International cost differences (such as lower relative wage costs and lower trade and transport costs), improved logistics, and improved intellectual property rights protection and contract enforcement have facilitated the use of global supply chains and global value chains, or GVCs (U.S. International Trade Commission 2011).

A supply chain is a system of organization, technology, activities, information, and resources involved in moving a good or service from supplier to customer. It can be within an enterprise, between enterprises in a local economy, or among a group of countries. The supply chain is a network where the activities involved can be grouped using the traditional broad stages of production—from upstream research and development (R&D) and design, through manufacturing, to downstream logistics, marketing, and sales. The complexity of the supply chain and the business relationship between the various stages can vary by industry and by enterprise. A global supply chain consists of a worldwide network of these activities.

A value chain refers to the value-added activities required to bring a good or service from its conception, design, production, marketing, distribution, and support to final customers.[2] It is the value added to the good or service at each stage of the network. Similar to the supply chain, the complexity of the value chain and the business relationship between the various stages can vary by industry and by enterprise. A value chain can be between enterprises in a local economy or span enterprises across a group of countries.

The fragmentation of production through the use of GVCs raises many issues for economic measurement, including classifying the firms within these chains, measuring and classifying trade in goods and services, and measuring and classifying trade in intermediate inputs. The recently updated international guidelines for compiling national and international accounts include new guidelines to better capture the impacts of GVCs on the economy.[3] The U.S. Census Bureau, the Bureau of Economic Analysis (BEA), and the Bureau of Labor Statistics (BLS) have been studying ways to classify and collect data from entities that are part of GVCs. A key element in identifying the relationship between firms that outsource the fabrication of products—while still controlling the production process—and firms that perform the processing is contract manufacturing services (CMS).

This chapter focuses on efforts to collect data on CMS and the challenges with identifying and collecting data on entities that are part of GVCs. In particular, it identifies data that the BEA and the Census Bureau are already collecting on both producers and users of CMS. In this way, the chapter not only demonstrates that it is feasible to identify and collect data on these activities but also provides a snapshot of companies that are engaged in these activities. Although the descriptive data presented in this chapter do not provide the full accounting of these activities that is recommended by the latest U.S. and international statistical guidelines, they do provide an indication of the potential scope and magnitude of the measurement task before us. The statistical agencies will use this and other information to guide their efforts to improve the measurement of these activities in order to implement the latest statistical guidelines and provide more useful data on manufacturing value chains. This will enable them to cover both the firms that outsource fabrication services and the CMS producers that provide these services.

The chapter’s remaining sections describe new U.S. and international guidelines and relevant data on CMS activities. Section Two, “Classifying ‘Factoryless’ Manufacturers,” looks at U.S. and international recommendations on the industry classification of “factoryless” manufacturers—units that entirely outsource the fabrication of their products. Section Three, “Data Collection on Contract Manufacturing Services,” describes the BEA and Census Bureau surveys and discusses data collection efforts on CMS. Section Four, “Analysis of Contract Manufacturing Services on the BEA’s BE-10 Survey,” discusses the BEA’s analysis of the CMS data reported in its surveys. Section Five, “Analysis of Contract Manufacturing Services on Census Bureau 2011 COS,” treats the Census Bureau’s analysis of the CMS data reported in the Report of Organization Survey. Section Six, “Future Work,” concludes with a discussion of future data collection endeavors.

CLASSIFYING “FACTORYLESS” MANUFACTURERS

The North American Industry Classification System (NAICS) is an industry classification system for establishments based on a production-oriented conceptual framework in which establishments are grouped together by common production processes. A production process describes any activity in which inputs, including types of labor and related skills, capital equipment, raw and intermediate materials, and, in many cases, intangible inputs such as intellectual property, are used to fabricate a material good or to render a service.[4] Establishments are the smallest operating entity for which records provide information on the cost of resources—materials, labor, and capital—employed to produce the units of output (OMB 2007, p. 19).

With the rise of global competition, economies are becoming more integrated, and the use of global supply chains is rapidly increasing. This has complicated the application of the production function classification principle to units that control intellectual property and perform underlying entrepreneurial components of arranging the factors of production, but outsource all of the actual transformation activities to other specialized units. The Office of Management and Budget (OMB) calls these units "factoryless" goods producers, or FGPs (OMB 2010).

Units in the manufacturing sector arrange for and bring together the factors of production necessary to produce a good. They accept the entrepreneurial risk of producing and bringing goods to market. As the Economic Classification Policy Committee (ECPC) states in the 2012 NAICS manual's supporting documents,

> when individual steps in the complete process are outsourced, an establishment should remain classified in the manufacturing sector. For example: 1) a decision to produce or purchase raw materials does not change the classification; 2) a decision to use contractors or a professional employer organization (PEO) rather than a traditional employment contract does not change classification; and 3) a decision to outsource marketing and distribution to a wholesaler does not change classification. In each case, the decision to perform or outsource a function changes the establishment production function but does not change the classification. (ECPC 2010, p. 6)

The ECPC defines the characteristics of FGPs to include the following (OMB 2010, p. 4):[5]

- Owns rights to the intellectual property or design (whether independently developed or otherwise acquired) of the final manufactured product.
- May or may not own the input materials.
- Does not own production facilities.
- Does not perform transformation activities.
- Owns the final product produced by manufacturing service provider partners.
- Sells the final product.

International Recommendations

The NAICS classification, employed in the United States, does not use ownership of material inputs as a basis for industry classification. However, the International Standard Industrial Classification of All Economic Activities (ISIC), Revision 4, which is promulgated by the United Nations and forms the basis for industrial classification systems used by many other countries, bases classification of units that outsource transformation solely on ownership of material inputs. "A principal who completely outsources the transformation process should be classified into manufacturing if and only if it owns the input materials to the production process—and therefore owns the final output," the ISIC says (United Nations Statistics Division 2008, p. 30). According to the ISIC, a unit that outsources transformation but owns the material inputs is a manufacturer; a unit that outsources transformation and does not own the material inputs is engaged in wholesale or retail trade.

The ECPC considers a strict adherence to the ownership of materials as impractical because a slight change in how the materials were acquired would change the industry classification. For example, the principal could purchase the inputs and do one of two things: 1) take physical possession of the inputs and ship them to the contract manufacturer or 2) arrange to have the inputs shipped directly to the contract manufacturer from another domestic or foreign location. Under ISIC rules, the contractual arrangement of the case in which the principal purchases the materials directly would result in the principal being classified in the manufacturing sector even if the principal did not take physical possession of the materials. However, rather than purchasing the inputs, the principal may simply approve the input providers from whom the contract manufacturer must buy and monitor the quality of the inputs acquired by the contract manufacturer. Under ISIC rules, this contractual arrangement would most likely result in the principal being classified in a trade sector because the principal did not directly purchase the material inputs. The ECPC considers controlling the production process a more important criterion than owning the material inputs.

The ISIC classification based on ownership of the material inputs is consistent with the treatment recommended in both the *System of National Accounts 2008* (referred to in this chapter as SNA 2008) and the sixth edition of the *Balance of Payments and International Invest-*

ment Position Manual (referred to in this chapter as BPM6) for goods sent abroad for processing (European Commission et al. 2009; IMF 2009).[6] According to this treatment, goods sent abroad for processing without a change in ownership should be excluded from goods trade; the processing fee charged by the manufacturing service provider should be recorded as services trade. The fee for this service is related to the difference between the value of the goods exported for processing and the value of the goods returned (imported) after processing.[7] When goods are shipped abroad for processing and subsequently sold abroad, the processed goods should be recorded as U.S. merchandise exports at the time they are sold, and any inputs purchased abroad by the U.S. firm and processed abroad should be recorded as U.S. merchandise imports.[8] The new international guidelines state that the recording of imports and exports of goods should be based on the transfer of economic ownership. For example, if a U.S. shoe company sent soles and leather to a contract manufacturer in another country for assembly of its athletic shoe, the U.S. shoe company—the principal—is importing manufacturing services from the contract manufacturer. Because the U.S. shoe company owns the soles, leather, and assembled athletic shoe, there is no international transaction; therefore, the soles and leather should not be recorded as U.S. exports and the assembled athletic shoe should not be recorded as a U.S. import.

It is important to note that although the NAICS does not base its classification of "factoryless" goods producers strictly on change in ownership, the change-in-ownership principle is still the most relevant criterion for measuring international transactions. It is desirable to define international transactions as transactions between residents and nonresidents, thus focusing on the change in ownership, regardless of whether the establishments engaged in the transactions are classified in manufacturing or in another industry. Thus, adoption of the NAICS recommendation for FGP does not preclude the adoption of the SNA 2008/BPM6 recommendation for the treatment of goods sent abroad for processing.

DATA COLLECTION ON CONTRACT MANUFACTURING SERVICES

Identifying CMS is a key element in identifying the relationship between firms that outsource the fabrication of products—while still controlling the production process—and firms that perform the processing. Through preliminary outreach conducted by the Census Bureau, respondents appear to understand the concept of CMS and the need for U.S. statistical agencies to collect the data. Collecting data, however, could be challenging. Some respondents indicated that they were generally unable to provide CMS data because either accounting or production management systems did not include a searchable characteristic that would distinguish these services.

To determine whether data collection can be robust, the Census Bureau and the BEA have added questions to their respective surveys to determine whether U.S. businesses can accurately report purchases and sales of CMS. See Table 3.1 for a list of all surveys conducted by these two agencies that contain CMS-related questions. This section describes three surveys that include questions about CMS.

Bureau of Economic Analysis Surveys

The first two surveys we cover are conducted by the Bureau of Economic Analysis; the third is done by the Census Bureau.

Benchmark Survey of U.S. Direct Investment Abroad

Every five years, the BEA conducts the Benchmark Survey of U.S. Direct Investment Abroad (BE-10) to track the economic activity of U.S. multinational companies and their foreign affiliates.[9] The BE-10 benchmark survey covers the entire universe of U.S. direct investment abroad in terms of value and is the BEA's most comprehensive survey of such investment in terms of subject matter. The survey collects detailed information on the financial structure and operations of U.S. parent companies and their foreign affiliates and on the transactions and positions between the parents and their affiliates.

Any U.S. person that had a foreign affiliate is required to report.[10] If the respondent is a U.S. corporation, the respondent reports transactions

Table 3.1 List of Surveys Containing CMS-Related Questions

Form number	Survey name	Year	Sponsoring organization	Used in this chapter?
BE-10A	Benchmark Survey of U.S. Direct Investment Abroad for U.S. Parents	2009	Bureau of Economic Analysis	Y
BE-120	Benchmark Survey of Transactions in Selected Services and Intellectual Property Products with Foreign Persons	2011	Bureau of Economic Analysis	N
NC-99001	Company Organization Survey	2011	Census Bureau	Y
MC31101–MC33975[a]	Census of Manufactures	2007, 2012	Census Bureau	N
WH42101–WH42237[a]	Census of Wholesale Trade	2007, 2012	Census Bureau	N

[a] Only industries where the CMS question is applicable.
SOURCE: Authors' compilation.

for the fully consolidated U.S. domestic enterprise, which excludes foreign branches and other foreign affiliates. The BEA defines an entity as a foreign affiliate if it meets the following criteria:

- If it is incorporated abroad, it is always considered a foreign affiliate. Most affiliates meet this criterion.
- If the entity is not incorporated, it is a foreign affiliate if it
    - is subject to a foreign income tax, has a substantial physical presence abroad as evidenced by employees permanently located abroad, etc.;
    - has separate financial records that would allow the preparation of financial statements; or
    - takes title to the goods it sells and receives revenues from the sale, or receives funds from customers for its own account for services it performs.

To understand the activity of U.S. multinationals with respect to manufacturing services, the BEA added questions on purchases and performance of contract manufacturing to the 2009 Benchmark Survey of U.S. Direct Investment Abroad for U.S. parents that are not banks (BE-10A).[11] The questions were added to identify a group of firms engaged in manufacturing services that could be used either as a sample frame for a special survey on that topic or as a way to identify firms engaged in CMS that may be linked to data collected by the Census Bureau. A data link is performed when company identification codes from the BEA files are matched to the corresponding companies in the Census Bureau files. A data link project provides access to additional data items that the BEA did not collect.

The BE-10 survey defines contract manufacturing as "contracting with a firm to process materials and components, including payments for fabricating, assembling, labeling, and packaging materials and components." Because the BEA was trying to identify a group of firms that engaged in contract manufacturing, only yes/no questions were added to the survey. The BE-10 CMS definition was broader than the international guidelines' definition of "manufacturing services" as constituting the processing of materials and components owned by others. However, the BEA requested respondents to answer the question of whether they owned some or all of the materials used by the contract manufacturers or whether they did not own the materials.

Benchmark Survey of Transactions in Selected Services and Intellectual Property Products with Foreign Persons

The BEA conducts the Benchmark Survey of Transactions in Selected Services and Intellectual Property Products with Foreign Persons (BE-120) to track U.S. imports and exports of services and intellectual property products. The BE-120 benchmark survey collects information on U.S. international trade in all types of services and intellectual property for which information is not collected on other BEA surveys and is not available to the BEA from other sources. The major types of services transactions *not* covered by the BE-120 survey are travel, transportation, insurance (except for payments for primary insurance), financial services (except for payments by nonfinancial firms), and expenditures by students and medical patients that are studying or seeking treatment in a country different from their country of residence.

The survey covers U.S. persons that have engaged in services or intellectual property transactions with foreign persons. As with the U.S. direct investment abroad reporting unit, the respondent is required to report transactions for the fully consolidated U.S. domestic enterprise. Questions separately identifying receipts and payments for CMS were added to the 2011 BE-120 survey.[12] Contract manufacturing services, as defined in the BE-120, are "manufacturing services on materials and components owned by others and covers processing, assembly, labeling, packing and so forth undertaken by businesses that do not own the goods concerned."

The BEA is in the process of collecting these data to determine whether respondents can separately identify the costs of the manufacturing service as well as the destination of the goods after processing. Reporting by companies on the contract manufacturing questions is voluntary, and initial review of these questions indicates a low response rate.

Census Bureau Surveys

To date, there are three data sources that cover explicit questions about CMS. Jarmin, Krizan, and Tang (2011) analyze the CMS-specific questions in the 2007 economic censuses, which include both the Census of Manufactures and the Census of Wholesale Trade. Fort (2013) utilizes the CMS question in the 2007 Census of Manufactures to study the role of communication technology on a firm's decision to fragment its production process within and outside national boundaries. Bayard, Byrne, and Smith (Chapter 4, this volume) present a case study of "factoryless" goods–producing firms in the semiconductor industry using the 2002 and 2007 Census of Wholesale Trade. A third survey, the 2011 Report of Organization Survey (Form NC-99001, called the Company Organization Survey, or COS), has heretofore been unexplored by researchers. This chapter will focus on analyzing the 2011 COS, which asks detailed questions about both providing and purchasing CMS.[13]

2011 Company Organization Survey

The COS covers all multiunit companies with 250 or more employees and a selection of smaller companies to support other Census Bureau surveys. Companies with fewer than 250 employees are only selected for the COS when administrative records indicate that the company may be undergoing organizational change and is adding or dropping establishments. The COS is conducted annually in the four years between economic censuses.[14] The COS is designed primarily to maintain the Business Register, a current list of business establishments in the United States that is used to conduct establishment-level economic surveys every five years.[15] Therefore, it has heretofore not directly been used to conduct economic research. However, the 2011 COS included a section that asked firms about their activities pertaining to purchasing and providing CMS.[16] These questions are some of the most detailed questions pertaining to the CMS activities of a firm from any survey currently in use. Although not nationally representative, analyzing responses to these questions furthers our understanding of the characteristics of firms engaged in CMS activities.

The survey unit in the COS is the company, which is linked to a firm identification code.[17] However, the unique identifier is the survey unit identifier. It would be useful to create a firm-level data set that can be linked to other Census Bureau data sets for further analysis. It is not possible to achieve this simply by aggregating the data by firm identifiers, since CMS activities are indicated by categorical variables. Therefore, "Y" is assigned to a firm in response to a question (that requires "Y" or

"N"—"yes" or "no") where multiple survey units under that firm identifier responded differently to the question. For example, if survey unit A responds "Y" to question 2 in the 2011 COS under Section 3D while survey unit B responds "N" (or does not respond), then "Y" is assigned to the firm to which both units belong. After the preceding adjustments have been made, the COS contains records for 34,228 unique firms.

Using the firm identifier, the firm-level data set is then linked to the 2010 Longitudinal Business Database (LBD) to identify three key firm characteristics: 1) firm age, 2) total employment, and 3) sector. The LBD is a longitudinally linked data set of all business establishments that operate in the United States except for farms, government-owned or government-operated entities, and private households (Jarmin and Miranda 2002). For multiunits or firms with multiple plants, age is calculated as the difference between the year of interest and the year of establishment of its oldest plant. Since multiunit firms may operate in several sectors of the economy, the firm is considered to be operating in the sector where the largest share of its employment is housed.[18] Since the LBD is an establishment-level data set, employment is first aggregated up to the firm level by sector. The firm is then assigned its "predominant" sector, and its employment is aggregated to the firm level.[19] Finally, the firm-level data, which now include information about firm age, total employment, and sector, are linked to the 2011 COS. Of 34,228 firms in the COS data set, 34,191 firms are linked to the LBD.

The final analysis data set is a firm-level data set that includes information about the firm's age, total employment, the sector in which it operates, and several indicator variables based on responses to the CMS-related questions.[20] The firms are categorized into four mutually exclusive categories: 1) provides CMS only, 2) purchases CMS only, 3) both provides and purchases CMS, and 4) does none of the aforementioned. Within the category of firms that purchase CMS, the analysis further distinguishes among those that purchase CMS in three ways: 1) within the United States only, 2) outside the United States only, and 3) both within and outside the United States. Among firms that purchase CMS outside the United States, it is possible to further identify whether a firm does so from its foreign affiliates. Analysis of the responses to the second part of Question 2 and Question 3d is done only for survey units that belong to a unique firm identifier, because there is no straightforward yes-or-no rule that can be implemented in this instance. There are 33,865 such observations.

The 2011 COS is further linked to the 2007 Census of Manufactures (CM) and the 2009 Linked/Longitudinal Foreign Trade Transactions Database (LFTTD) to create two separate data sets: the COS-CM and the COS-LFTTD.[21] The COS-CM provides data on the total value added and the total value of shipments of each firm in the COS that belongs to the manufacturing sector. These firms represent about 27 percent of firms in the final COS analysis data set. The COS-LFTTD provides data on the total value of exports and the total value of imports of each firm in the COS because the LFFTD links the universe of export and import transactions to firms and considers all 10-digit Harmonized Commodity Description and Coding System (commonly called Harmonized System, or HS) products. The Harmonized System is an internationally standardized system of names and numbers for classifying traded products. Approximately 33 percent of the firms in the final COS analysis data set exported in 2009, and 24 percent imported that year.

ANALYSIS OF CONTRACT MANUFACTURING SERVICES ON THE BEA's BE-10 SURVEY

The results presented in this chapter are based on reported data for 3,830 U.S. parent companies. CMS questions were only included on the parent's survey form, and no corresponding questions were included on the foreign affiliate's form. Specific examples of a firm's purchase or performance of CMS cannot be described, because the data are confidential. However, hypothetical examples of purchases of CMS include the manufacturing of Company A's computer based on specifications of the design of the computer provided by Company A, and the assembly of Company B's semiconductor chips by a foundry. In each case, a firm is contracting with another unit to process materials and components based on specifications supplied by the purchasing firm.

Each U.S. parent is classified by industry using the International Survey Industry (ISI) classification system. For the most part, the ISI classifications are equivalent to NAICS four-digit industries; at its most detailed level, the NAICS classifies industries at a six-digit level. The ISI system is less detailed than the NAICS because it is designed for classifying enterprises rather than establishments (or plants). Each U.S.

parent is classified in a sector that accounted for the largest percentage of its sales. The sector classification is chosen first because many direct investment enterprises are active in several industries; it is not meaningful to classify all their data in a single industry if that industry is defined too narrowly.[22]

The first step in the analysis was to analyze how U.S. parents responded to the question of whether they purchased or provided CMS. The respondents were asked to consider CMS activity performed by their foreign affiliates as purchasing CMS from others. As shown in Table 3.2, approximately a quarter of U.S. parents reported purchases of CMS from foreign or domestic contract manufacturers, while three-fourths reported no purchases of CMS. Only 8 percent of U.S. parents reported performing CMS for nonresidents. Not surprisingly, the majority, or 72 percent, of U.S. parents that reported purchases of CMS are classified in the manufacturing sector. As shown in Table 3.3, the other two sectors with significant purchases of CMS are wholesale (13 percent) and information (5 percent).

Table 3.4 presents the characteristics of U.S. parents who are classified within the manufacturing sector by three-digit NAICS-based ISI industry classification and by firm size (measured as total domestic employment of the U.S. parent). Table 3.4 shows that U.S. parents that purchased CMS were large firms with more than 250 employees and

Table 3.2 U.S. Parents Who Purchased or Performed Contract Manufacturing Services (CMS), 2009

	No. of respondents	% of respondents
Parents who purchased CMS:		
Yes	888	23
No	2,860	75
No response	82	2
Parents who performed CMS:		
Yes	324	8
No	3,423	89
No response	83	2

NOTE: Percentages may not sum to 100 because of rounding.

SOURCE: BEA's 2009 Benchmark Survey of U.S. Direct Investment Abroad, http://www.bea.gov/surveys/pdf/2009be10i_web.pdf.

Table 3.3 U.S. Parents Who Purchased Contract Manufacturing Services (CMS), by Sector, 2009 (%)

Manufacturing	Wholesale	Information	Professional, scientific, technical services	Other
72	13	5	1	9

NOTE: "Manufacturing" includes all two-digit NAICS industries in sectors 31–33; "Wholesale" includes NAICS industries in sector 42; "Professional, scientific, and technical services" includes NAICS industries in sector 54; "Other" includes all other industries.
SOURCE: BEA's 2009 Benchmark Survey of U.S. Direct Investment Abroad.

Table 3.4 U.S. Parents Who Purchased Contract Manufacturing Services (CMS), by Manufacturing Subsectors, 2009

	Total	Small	Med.	Large
All manufacturing industries (NAICS sectors 31–33)	642	93	104	445
Computer and electronic product mfg. (334)	153	30	32	91
Machinery mfg. (333)	82	17	14	51
Chemical mfg. (325)	80	9	13	58
Miscellaneous mfg. (339)	61	10	15	36
Transportation equipment mfg. (336)	54	2	4	48
Food mfg. (311)	36	6	3	27
Electrical equipment, appliance, and component mfg. (335)	33	2	6	25
Fabricated metal product mfg. (332)	31	7	4	20
Plastics and rubber products mfg. (326)	28	2	3	23
Primary metal mfg. (331)	22	2	1	19

NOTE: "Large" includes firms with 250 or more employees, "Medium" includes firms of between 100 and 249 employees, and "Small" includes firms of between 1 and 99 employees.
SOURCE: BEA's 2009 Benchmark Survey of U.S. Direct Investment Abroad.

were concentrated in industries that are known for outsourcing transformation activities to contract manufacturers. Examples of these industries include computer and electronic product manufacturing, machinery manufacturing, chemical manufacturing (includes pharmaceutical manufacturing), and transportation equipment manufacturing.

Because the international guidelines consider ownership of the materials used by the contract manufacturer in determining whether the contract manufacturer is selling manufacturing services or selling a good, questions were added to the BE-10 survey to determine whether U.S. parents could separately identify such transactions. U.S. parents who purchased CMS were asked to indicate whether they owned the materials used by contract manufacturers and whether the services were purchased from businesses inside or outside the United States. A respondent could answer "yes" to more than one type of arrangement; about 10 percent of U.S. parents that purchased CMS responded "yes" to all four types of arrangements, indicating that they used contract manufacturers located both in the United States and abroad and that they both owned the materials and did not own the materials used by the contract manufacturer. As shown in Table 3.5, U.S. parents were more likely to purchase CMS from U.S. contract manufacturers and to provide the material inputs to them (65 percent) than to purchase CMS from foreigners (about 37 percent). Interestingly, U.S. parents were just as likely to own the material inputs as to not own them when purchasing CMS from foreigners. Of the approximately 325 U.S. parents that reported purchasing CMS from outside the United States, nearly half of the respondents answered "yes" to both owning the material inputs and not owning the material inputs used by the contract manufacturer. This suggests that separately identifying purchases of CMS based on the ownership of the materials used by the contract manufacturer may be difficult to collect on an enterprise survey.

Table 3.5 U.S. Parents Who Purchased CMS, 2009

Category	*N*
U.S. parents who purchased CMS	888
U.S. parents who owned materials used by contract manufacturers located inside U.S.	579
U.S. parents who owned materials used by contract manufacturers located outside U.S.	330
U.S. parents who did not own materials used by contract manufacturers located inside U.S.	369
U.S. parents who did not own materials used by contract manufacturers located outside U.S.	323

SOURCE: BEA's 2009 Benchmark Survey of U.S. Direct Investment Abroad.

Table 3.6 Selected Statistics for U.S. Parents and for All U.S. Companies, by Sector, 2009

	Value-added (in $ millions)[a]	Employees (in thousands)[b]	Value-added per employee ($)
U.S. parents who purchased CMS[c]			
All industries	585,366	4,112	142,366
Manufacturing	400,369	2,413	165,910
Wholesale trade	44,286	307	144,240
Information	33,338	141	236,555
Other industries	107,374	1,251	85,859
All U.S. parents[c]			
All industries	2,595,776	22,933	113,191
Manufacturing	1,034,139	6,864	150,655
Wholesale trade	124,433	1,065	116,795
Information	287,628	1,712	168,056
Other industries	1,149,576	13,292	86,490
All U.S. companies			
All private industries	12,018,095	112,139	107,171
Manufacturing	1,540,226	11,856	129,911
Wholesale trade	768,548	5,620	136,752
Information	615,445	2,814	218,708
Other industries	9,093,876	91,849	99,009

NOTE: Figures may not sum to total because of rounding.

[a] Statistics on value-added for all U.S. companies are from the BEA's GDP by Industry series, as published in Table 3, p. 55 of Barefoot (2012).

[b] Statistics on employees for all U.S. companies are from the BEA's National Income and Product Accounts (NIPA) Table 6.4D, "Full-Time and Part-Time Employees by Industry," http://www.econstats.com/nipa/NIPA6_6_4D_.htm.

[c] Statistics for U.S. parents are from the BEA's 2009 Benchmark Survey of U.S. Direct Investment Abroad, as published in Table 3, p. 55 of Barefoot (2012).

SOURCE: See table notes a, b, and c.

Table 3.6 compares selected statistics of U.S. parents who purchased CMS with those of all U.S. parents and all U.S. companies. Table 3.6 shows that U.S. parents classified in manufacturing, wholesale trade, and information that purchased CMS had a higher value-added per employee compared to the value-added per employee of all U.S. parents and of all U.S. companies. This finding suggests that firms

Table 3.7 U.S. Trade in Goods (in $ millions) Associated with U.S. Parents, 2009

	U.S. parents who purchased CMS	All U.S. parents
Exports of goods to all foreigners	204,467	535,409
To foreign affiliates	102,768	207,479
For further manufacture	63,747	117,624
For resale without further manufacture	31,027	66,632
Other	7,993	23,223
To other foreigners	101,699	327,930
Imports of goods from all foreigners	194,879	679,521
From foreign affiliates	97,659	233,578
From other foreigners	97,220	445,943

SOURCE: BEA's 2009 Benchmark Survey of U.S. Direct Investment Abroad.

that use contract manufacturers to make their products may be more productive than firms that do not use contract manufacturers, though it is also possible that firms that use contract manufacturers have high value-added per employee by contracting out low value-added tasks, without any difference in output per quality-adjusted unit of inputs.

As was stated earlier, no corresponding CMS questions were included on the foreign affiliate's survey forms. Thus, a direct linkage cannot be made as to whether the U.S. parent purchased CMS from its foreign affiliate or from an unaffiliated foreigner. Table 3.7 shows that U.S. parents that purchased CMS exported a higher share of their total exports to their foreign affiliates (50 percent) than did all U.S. parents to their foreign affiliates (39 percent). In addition, U.S. parents that purchased CMS had a slightly higher share of export of goods sent for further processing to foreign affiliates (62 percent) than did all U.S. parents (57 percent).

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Table 3.8 presents the distribution of firms by various CMS activity categories in the linked COS-LBD data set. Panel A of Table 3.8 shows

Table 3.8 Percentage Distribution of Firms by CMS Activity

Panel A: All firms	
No CMS activity	92
Provide CMS only	3
Purchase CMS only	4
Provide and purchase CMS	1
Panel B: Firms that purchase CMS	
Inside U.S. only	39
Outside U.S. only	20
Inside and outside U.S.	37
Panel C: Firms that purchase CMS outside U.S.	
From affiliates	53

NOTE: This table provides the percentage share of the count of firms within each CMS activity category. Panel A is computed as a share of the total number of unique firms in the data; Panel B is computed as a share of the total number of unique firms that purchase CMS (the rows "Purchase CMS only" and "Provide and purchase CMS" from Panel A); and Panel C is computed as a share of the total number of unique firms that purchase CMS outside the United States (the rows "Outside U.S. only" and "Inside and outside U.S." from Panel B). Panel B does not add up to 100 percent because some firms did not respond and so could not be categorized.
SOURCE: Linked COS-LBD data set.

that 92 percent of the firms in the survey do not engage in any CMS activity. Among the remaining firms, there is an almost even share that either provide or purchase CMS, and only 1 percent that both provide and purchase CMS. Panel B shows that within the group of firms that purchase CMS, about 39 percent do so within the United States only, 20 percent do so outside the United States only, and 37 percent purchase CMS both inside and outside the United States. Finally, Panel C shows that of the firms that purchase CMS outside the United States, more than half of these firms do so from their foreign affiliates. Overall, a small share of firms engage in CMS activities, and among those that purchase CMS, a larger share purchase domestically. These observations are consistent with those made in Fort (2013) using the 2007 Census of Manufactures.

Table 3.9 presents two key firm characteristics associated with firms engaged in various CMS activities: size (measured as total employ-

Table 3.9 Average Firm Size and Age by CMS Activity

	Employment	Age
Panel A: All firms		
No CMS activity	1,366	23
Provide CMS only	761	26
Purchase CMS only	1,871	25
Provide and purchase CMS	4,315	25
Panel B: Firms that purchase CMS		
Inside U.S. only	1,065	25
Outside U.S. only	1,817	25
Inside and outside U.S.	4,427	24
Panel C: Firms that purchase CMS outside U.S.		
From affiliates	5, 054	25

NOTE: This table provides the average employment and age of firms within each CMS activity category; Panel A is computed for the total number of unique firms in the data; Panel B is computed for the firms that purchase CMS (the rows "Purchase CMS only" and "Provide and purchase CMS" from Panel A); and Panel C is computed for firms that purchase CMS outside the United States (the rows "Outside U.S. only" and "Inside and outside U.S." from Panel B).
SOURCE: Linked COS-LBD data set.

ment) and age. Panel A of Table 3.9 reports the average employment and age at firms within each CMS category. Firms that both provide and purchase CMS are the largest in terms of average employment, while those that provide CMS only are the smallest. Panel B shows that firms that purchase CMS both inside and outside the United States are much larger than those that purchase CMS either inside or outside the United States only. Finally, Panel C shows that firms that purchase CMS from their affiliates located abroad are the largest. An average firm in the survey is about 24 years old, and the average firm age does not vary greatly by CMS activity. The overwhelming majority of firms in the COS have been in existence for 10 or more years.

Table 3.10 provides further detail on the size distribution of firms in the survey by CMS activity. Firms with 250 or more employees are considered to be large, those with 100 to 249 employees to be medium, and those with one to 99 employees to be small. Since the COS primarily

Table 3.10 Distribution of Firm Size by CMS Activity

	Large	Medium	Small
Panel A: All firms	60	18	22
No CMS activity	61	18	22
Provide CMS only	41	34	25
Purchase CMS only	58	22	20
Provide and purchase CMS	55	24	21
Panel B: Firms that purchase CMS			
Inside U.S. only	45	27	28
Outside U.S. only	64	19	17
Inside and outside U.S.	66	20	14
Panel C: Firms that purchase CMS outside U.S.			
From affiliates	74	17	9

NOTE: This table provides the percentage share of firms in three size categories within each CMS activity category. "Large" includes firms with 250 or more employees, "Medium" includes firms of between 100 and 249 employees, and "Small" includes firms of between 1 and 99 employees.
SOURCE: Linked COS-LBD data set.

surveys large firms, the results in this table are not directly comparable to those in Table 3.4 and should be interpreted with the COS survey frame in mind. Within the group of firms that do not engage in any CMS activity, well over half the firms are large, and the remainder can be almost evenly divided between small and medium-sized firms. This pattern also holds for those that purchase CMS only or both provide and purchase CMS. Three-quarters of firms that provide CMS only are large or medium, and a quarter are small. Among firms that purchase CMS, those that do so outside the United States only and those that purchase CMS both outside and inside the United States exhibit similar firm-size distributions. As shown in Table 3.9, an overwhelming share of firms that purchase CMS from their foreign affiliates are large. However, of the firms that provide CMS only, about 40 percent are large and 30 percent are medium-sized. Firms that purchase CMS inside the United States only have a similar size distribution.

Tables 3.10 and 3.11 show the sectoral distribution of firms engaged in various CMS activities. The COS asked firms whether they operated

Table 3.11 Distribution of Firm Response to Operating a Manufacturing Facility, by CMS Activity

	% that answered "Yes"
Panel A: All firms	
No CMS activity	22
Provide CMS only	97
Purchase CMS only	77
Provide and purchase CMS	97
Panel B: Firms that purchase CMS	
Inside U.S. only	85
Outside U.S. only	77
Inside and outside U.S.	81
Panel C: Firms that purchase CMS outside U.S.	
From affiliates	85

NOTE: This table provides the percentage share of firms that responded "Yes" to Question 1 under Section 3D of the 2011 Company Organization Survey (COS) within each CMS activity category. The left-out category is "No," except for under "No CMS activity." Four percent of the responses are missing.
SOURCE: Linked COS-LBD data set.

a manufacturing facility where products are completed or partially produced. Table 3.11 reports the share of firms within various categories that responded "Y" or "N" or had missing data. Table 3.12 shows the distribution of firms within one of three broad sectors: 1) manufacturing, 2) wholesale and retail, or 3) all remaining sectors of the economy. Panel A in Table 3.11 and Panel A in Table 3.12 show that an overwhelming majority of firms that report engaging in some CMS activity also operate a manufacturing facility. Seventy-four percent of the firms that do not engage in any CMS activity report not operating a manufacturing facility; this finding is corroborated by the finding that 76 percent of these firms operate in sectors other than manufacturing, wholesale, or retail. In addition, 97 percent of the firms that provide CMS only or both provide and purchase CMS reported operating a manufacturing facility, and over 80 percent of them operate in the manufacturing, wholesale, or retail sectors. However, within the group of firms that purchase CMS only, 77 percent report operating a manufacturing

Table 3.12 Distribution of Sectors by CMS Activity

	Manu-facturing	Wholesale/retail	Other
Panel A: All firms			
No CMS activity	18	16	76
Provide CMS only	76	7	17
Purchase CMS only	58	16	16
Provide and purchase CMS	75	7	18
Panel B: Firms that purchase CMS			
Inside U.S. only	66	10	24
Outside U.S. only	56	22	22
Inside and outside U.S.	62	15	23
Panel C: Firms that purchase CMS outside U.S.			
From affiliates	64	15	21

NOTE: This table provides the percentage share of firms in three broad sectors of the economy within each CMS activity category. "Manufacturing" includes all two-digit NAICS industries in sectors 31–33; "Wholesale/retail" includes two-digit NAICS industries in sectors 42, 44, and 45; and "Other" includes all other industries.
SOURCE: Linked COS-LBD data set.

facility and operate in the manufacturing, wholesale, or retail sectors; the share is smaller compared with firms only providing CMS or both providing and purchasing CMS.

Table 3.13 is based only on responses of survey units that have a one-to-one link to a firm identifier.[23] It shows the percentage share of revenues (costs) generated (incurred) from providing (purchasing) CMS as a share of total revenues and net sales (cost of sales from expenses). Three-quarters of the firms providing CMS report less than a quarter of total revenues and net sales originating from providing CMS. A little over three-quarters of firms purchasing CMS also report less than a quarter of the total cost of sales from expenses originating from purchasing CMS. This suggests that for most firms engaged in some CMS activity, the activity constitutes a relatively small share of total revenues or total costs.

Table 3.13 Distribution of Percentage Share of Revenue and Costs by CMS Activity

% of operating revenues and net sales (cost of sales from expenses) from (for) CMS	Provide CMS	Purchase CMS
Less than 25	75	79
25 to 49	5	9
50 to 74	4	5
75 to 99	8	5
100	8	2

NOTE: This table provides the percentage share of firms in five mutually exclusive categories in response to Questions 2 and 3d from the 2011 COS form (see Appendix 3A, Illustration 3A.1). The second column shows the percentage share of firms that receive *x* percent of operating revenues and sales from providing CMS; the third column shows the percentage share of firms that incur *x* percent of cost of sales from expenses for purchasing CMS.
SOURCE: Linked COS-LBD data set.

Finally, Table 3.14 shows the average output per employee as well as export and import values of firms by various CMS activities. The first column shows the log of value-added per employee (VA/L), and the second column shows the log of total value of shipments per employee (TVS/L). Firms that engage in some type of CMS activity exhibit both higher (VA/L) and (TVS/L) than those that do not. Among firms that purchase CMS, those that purchase both inside and outside the United States exhibit the highest average output per employee, using both measures.

The last two columns show the average export and import values, in millions of dollars, respectively. Focusing on the third column, firms that both provide and purchase CMS have higher average export value compared to all other firms in the sample. Firms that do not engage in any CMS activity and firms that provide only CMS have very similar average export values. Firms that purchase CMS inside and outside the United States have the highest average export values among firms that purchase CMS. Focusing on the last column, firms engaged in some CMS activity display much higher average firm import values compared to those that do not, and, of these, firms that both purchase and provide CMS have the highest value. Firms that purchase CMS inside and outside the United States have the highest average import value among firms that purchase CMS. Among firms that purchase CMS outside the

Table 3.14 Output per Employee and Trade Value by CMS Activity

	Log (value added/ employment)	Log (total value of shipments/ employment)	Export value (in $ millions)	Import value (in $ millions)
Panel A: All firms				
No CMS activity	4.23	4.98	29	82
Provide CMS only	4.45	5.19	30	232
Purchase CMS only	4.63	5.31	113	190
Provide and purchase CMS	4.61	5.30	241	289
Panel B: Firms that purchase CMS				
Inside U.S. only	4.58	5.27	32	104
Outside U.S. only	4.53	5.22	68	144
Inside and outside U.S.	4.73	5.40	284	327
Panel C: Firms that purchase CMS outside U.S.				
From affiliates	4.75	5.44	334	417

NOTE: The above statistics are calculated for manufacturing firms only.
SOURCE: Linked COS-CM and COS-LFTTD data sets.

United States, those that do so from their affiliates are larger traders and have higher value-added per employee than those that do not.

FUTURE WORK

This chapter analyzes existing data on firms' activities relating to providing or purchasing CMS as a means to measure "factoryless" manufacturing, where the manufacturer undertakes the entrepreneurial steps in the global supply chain but does not transform any of the material inputs. Our primary goal was to analyze the characteristics of firms that report engaging in various CMS activities to provide a preliminary glimpse into factoryless goods producers. However, comprehensive work is needed, and indeed is underway, as described below, to do three things: 1) quantify the scope of FGP activity, 2) look at how the CMS data discussed in this chapter compare to CMS data in other existing surveys, and 3) evaluate the feasibility of the proposed changes in the definitions to the manufacturing sector and import and export flows.

The recently updated international guidelines for services on physical inputs owned by others (goods for processing) are designed to better capture the impacts of GVCs on the economy. The BEA is evaluating whether implementation of the new guidelines is feasible. Successful implementation of this recommendation requires detailed information on not only the processing fees received and paid by U.S. firms for CMS but also the underlying goods transactions. Data for these transactions are currently either not available in the U.S. statistical system or not separately identifiable. Despite these data challenges, the BEA continues to investigate options for implementing this new treatment of manufacturing services.

The results from the BEA BE-120 survey will be available soon. Once the results are available, the BEA can evaluate whether the value of receipts and payments for CMS can be reported along with the destination of the goods after processing. To determine the feasibility of adjusting the merchandise trade statistics to remove goods that cross the border without a change in ownership, the BEA is also continuing to work with the Census Bureau to explore options for identifying the merchandise trade transactions of U.S. firms that purchased manufacturing services from overseas contractors or that provided manufacturing services to foreigners.

The CMS questions on the enterprise-level COS discussed in this chapter represent initial steps in determining whether further data collection is likely to be robust and whether the Census Bureau can identify “factoryless” manufacturers in its surveys. As a next step, the Census Bureau added special inquiries to the 2012 Economic Census to collect information at the establishment level that will better identify “factoryless” manufacturers and assess whether sufficient data can be collected on the value of the manufacturing service and the associated revenue on sales of products produced by contract manufacturers.[24]

An interagency effort across the Census Bureau, the BEA, and the BLS is underway to analyze census microdata in support of consistent and accurate implementation of the decision to classify FGPs in the manufacturing sector as soon as the agencies can perform the research, testing, and evaluation necessary to do so. One of the main goals of this effort is to estimate the number of establishments, the total value of shipments, and the total employment that will be moved across various sectors with the eventual implementation of the FGP concept in the Economic Census. Furthermore, comparisons will be made between the results from the special inquiry questions in the economic censuses and the COS in order to refine the questions that will be used by agencies and programs to identify FGPs on data collection instruments. The agencies must take care that as changes are made in the measurement of manufacturing activities, whether in the production of services or in the shipments of goods, these changes are implemented in a way that consistently and correctly allocates manufacturing value-added to the domestic and nonresident producers, in order to avoid overstating or understating U.S. gross domestic product.

Notes

Any opinions and conclusions expressed herein are those of the authors and do not necessarily represent the views of the U.S. Census Bureau or the Bureau of Economic Analysis. All results have been reviewed to ensure that no confidential information is disclosed. We thank Susan Houseman for helpful comments on an earlier version. We also thank Mai-Chi Hoang for preparing the BEA data tables and providing valuable feedback, Raymond Mataloni for providing guidance on the BEA data, and Anthony Caruso, C.J. Krizan, Shawn Klimek, and William Powers for helpful comments.

1. The research in this chapter was undertaken while this author was at the U.S. Bureau of Economic Analysis.
2. For more information on GVCs, see APEC Policy Support Unit (2012).
3. The *System of National Accounts 2008* (European Commission et al. 2009) provides recommendations for compiling the national accounts, and the sixth edition of the *Balance of Payments and International Investment Position Manual* (IMF 2009) provides recommendations for compiling the international accounts.
4. For more information, see the Economic Classification Policy Committee's "Issue Paper No. 1" (ECPC 1993).
5. See Doherty (Chapter 2 of this volume) for a discussion of identifying FGPs in the U.S. Statistical System.
6. The *System of National Accounts 2008*, published by five international organizations, is the international guideline for compilation of gross domestic product and other national accounts statistics (European Commission et al. 2009), and the *Balance of Payments and International Investment Position Manual*, published by the International Monetary Fund, is the international guideline for compilation of balance of payments and international investment position statistics (IMF 2009).
7. In practice, this may not hold. Maurer and Degain (2010) state that, for most cases, the value of the manufacturing service or the processing fee is not simply the difference between the value of the goods before processing and the value after processing.
8. For more information, see BPM6, Chapter 10, Sections 10.65–10.66 (IMF 2009, p. 162). For a discussion of the measurement issues related to goods for processing, see United Nations Economic Commission for Europe (2011), pp. 71–84.
9. The term "affiliated" refers to a direct investment relationship, which exists when a U.S. person has ownership or control, directly or indirectly, of 10 percent or more of a foreign business enterprise's voting securities or the equivalent, or when a foreign person has a similar interest in a U.S. business enterprise.
10. A U.S. "person" includes companies.
11. See questions 28–30 on the 2009 Benchmark Survey of U.S. Direct Investment Abroad for U.S. parents that are not banks (BE-10A) at http://www.bea.gov/surveys/pdf/be10a_web.pdf.
12. See Schedule D on the 2011 Benchmark Survey of Transactions in Selected Services and Intellectual Property with Foreign Persons (BE-120), at http://www.bea

.gov/surveys/pdf/be120.pdf, p. 12. Prior versions of the survey recorded receipts and payments for contract manufacturing services within the “other services” category.

13. The 2012 Economic Census includes a similar set of questions to those in the 2011 COS. It will provide the richest set of information at the establishment level once the data collection process is completed.
14. See http://www.bea.gov/surveys/pdf/be120.pdf. for further details.
15. The COS data are unedited and have had no adjustments for survey nonresponse.
16. Form NC-99001, Section 3D, Questions 1–3; see https://www.census.gov/econ/overview/mu0700.html for a description of the survey. Also see Appendix 3A.
17. A company is an economic unit comprising one or more establishments under common ownership or control. The COS may survey different subsidiaries of the same company, so several survey units may belong to one firm identification code.
18. Industry assignments remain qualitatively unchanged if payroll information is used instead to assign sectors.
19. Sales data are not readily available for all firms in the sample. Therefore, employment is used to assign a sector.
20. The LBD contains information on employment within the United States only; therefore, figures on employment at foreign subsidiaries of U.S. parent companies are not available in the linked LBD-COS data set.
21. The 2007 CM and 2009 LFTTD are the most recent available years. See Bernard, Jensen, and Schott (2009) for an overview of LFTTD, including match rates.
22. For more on the BE-10 U.S. Direct Investment Abroad methodology, see http://www.bea.gov/international/pdf/usdia_2004f/Text%20sections/methodology.pdf.
23. See the subsection of this chapter titled “Census Bureau Surveys,” pp. 54–55, for details.
24. See Question 26 on the 2012 Economic Census manufacturing sample forms, located at http://bhs.econ.census.gov/ec12/php/census-form.php. An example of such a form is found at https://bhs.econ.census.gov/2012forms/MC31101.pdf.

Appendix 3A

Excerpts from Three Survey Forms Used in This Chapter

Questions on contract manufacturing services activities included these from the 2011 Report of Organization Survey (Form NC-99001):

Illustration 3A.1 Excerpt from Form NC-99001

❸ COMPANY ACTIVITIES - continued

D. MANUFACTURING ACTIVITIES

In 2011, did your company do any of the following activities related to manufacturing?

1. Operate manufacturing facilities (such as a factory, plant, or mill) where products are completed or partially produced?

9709 ❒ Yes - *Go to line 2*

9710 ❒ No - *Go to line 3*

2. Provide contract manufacturing services to other companies incorporating their patents, trade secrets, or proprietary technology?

9711 ❒ Yes

9712 ❒ No - *Go to line 3*

Estimate the percent of operating revenues and net sales, as reported in ❸B, from contract manufacturing services.

9713 ❒ Less than 25%

9714 ❒ 25 to 49%

9715 ❒ 50 to 74%

9716 ❒ 75 to 99%

9717 ❒ 100%

3. Purchase contract manufacturing services from other companies or foreign subsidiaries of your company incorporating your company's patents, trade secrets, or proprietary technology?

9718 ❒ Yes

9719 ❒ No - *Go to* ❹*, CERTIFICATION*

a. Use 3rd party contract manufacturing services inside the U.S.?

9720 ❒ Yes

9721 ❒ No

b. Use 3rd party contract manufacturing services outside the U.S.?

9722 ❒ Yes

9723 ❒ No

(continued)

Illustration 3A.1 (continued)

c. Use your company's foreign subsidiaries' or affiliates' contract manufacturing services at locations outside the U.S.?

9724 ❐ Yes

9725 ❐ No

d. Estimate the percent of the cost of sales from expenses for contract manufacturing services.

9726 ❐ Less than 25%

9727 ❐ 25 to 49%

9728 ❐ 50 to 74%

9729 ❐ 75 to 99%

9730 ❐ 100%

Questions on purchases of contract manufacturing services included these from the 2009 Benchmark Survey of U.S. Direct Investment Abroad for U.S. parents (Form BE-10A):

Illustration 3A.2 Excerpts from Form BE-10A

1. Did this U.S. reporter purchase contract manufacturing services from others (including foreign affiliates)? (Yes/No)
2. The U.S. reporter **owned** some or all of the materials used by the contract manufacturers and the companies providing the manufacturing services were:
   a. Located **inside** the U.S. (Yes/No)
   b. Located **outside** the U.S. (Yes/No)
3. The U.S. reporter **did not own** the materials used by the contract manufacturers and the companies providing the manufacturing services were:
   a. Located **inside** the U.S. (Yes/No)
   b. Located **outside** the U.S. (Yes/No)

This survey also included a question on performance of contract manufacturing services for others:

1. Did this U.S. reporter **perform** contract manufacturing services for others (including foreign affiliates) outside the U.S.? (Yes/No)

Questions on purchases of contract manufacturing services included these from the 2011 Benchmark Survey of Transactions in Selected Services and Intellectual Property Products with Foreign Persons (Form BE-120):

Illustration 3A.3 Excerpts from Form BE-120

1. Did you purchase contract manufacturing services from foreign persons in Fiscal Year 2011?

2. Are you able to report the fee you paid for contract manufacturing services?
- If yes—enter the amount you paid foreign persons for contract manufacturing services.

3. The payments for manufacturing services in Question 2 were (check the appropriate box):
- ❒ Based on accounting records.
- ❒ Estimated by persons knowledgeable regarding these transactions.

4. Destination of goods produced after you purchased contract manufacturing (check the appropriate box):
- ❒ Goods do not enter United States.
- ❒ Goods are imported into the United States.
- ❒ A portion of the goods remain abroad and a portion are imported into the United States.
- ❒ Destination is unknown.

Questions on receipts for contract manufacturing services include the following:

1. Did you perform contract manufacturing services for foreign persons in Fiscal Year 2011?

2. Are you able to report the fee you received for performing contract manufacturing services?
- NOTE: This may include the cost of the materials you purchased to perform this service.
- If yes—enter the amount received from foreign persons for contract manufacturing services you performed on goods owned by foreign persons and go to Questions 3 and 4.

3. The receipts for manufacturing in Question 2 were (check the appropriate box):
- ❒ Based on accounting records.
- ❒ Estimated by persons knowledgeable regarding these transactions.

4. Destination of goods produced after you performed contract manufacturing (check appropriate box):
- ❒ Goods remain in the United States.
- ❒ Goods are exported from the United States.
- ❒ A portion of the goods remain in the United States and a portion are exported from the United States.
- ❒ Destination is unknown.

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4
The Scope of U.S. "Factoryless Manufacturing"

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The "factoryless manufacturing" (FM) business model is employed by a rising share of U.S. firms. Factoryless manufacturers outsource the fabrication of products but maintain control of the production process, own the associated intellectual property, and bear the entrepreneurial risk. FM is an important component in the role of U.S. firms in global manufacturing value chains. Currently, U.S. Census Bureau programs assign establishments engaged in factoryless manufacturing, known as factoryless goods producers (FGPs), to the wholesale trade sector. U.S. statistical agencies are considering classification of FGPs in the manufacturing sector in the future, if collecting data on FM is shown to be feasible.

This chapter estimates the scope of U.S. factoryless manufacturing using three approaches. First, we use financial reports for S&P 500 companies to show that FM is prevalent and increasing in the United States and that FM, once only common in the production of apparel, electronics, toys, and pharmaceuticals, has spread to a broader array of products. Second, we use Economic Census microdata to estimate that manufacturing value-added would have been 5 to 20 percent greater for 2007 if all FGPs were reclassified to manufacturing. Third, using a list of FM semiconductor companies matched to Economic Census microdata, we estimate that value-added would be 20 to 30 percent greater for semiconductor manufacturing, an industry where FM is especially prevalent, if FGPs were included. These results suggest that outsourcing and offshoring of product fabrication by U.S. firms is coupled with significant domestic production management. Thus, identifying FGPs in economic data is important for the study of fragmentation and globalization.

In the next section, "Defining and Measuring Factoryless Manufacturing and Factoryless Goods Producers," we define factoryless manufacturing (a company concept) and discuss the treatment of factoryless goods producers (an establishment concept) in U.S. economic statistics. In the third section, "The Extent of U.S. Factoryless Goods Production," we look at the extent of FM using company reports, and we examine the prevalence of FGPs using Economic Census establishment data. The fourth section, "The Structure of Factoryless Manufacturing Firms in the Semiconductor Industry," presents a close look at the establishment structure of FM firms in the semiconductor industry. Alternative estimates of the size of the manufacturing sector when FGPs are included are found in the fifth section, "U.S. Manufacturing with Factoryless Goods Producers Included," with a particular focus on semiconductor manufacturing. In Section Six, "Selected Effects of Reclassification and Relevance for Economic Analysis," we speculate on the effects of reclassifying FGPs for selected economic measures, and we discuss the role that better data on factoryless manufacturing may play in the study of economic issues. Section Seven offers a conclusion.

DEFINING AND MEASURING FACTORYLESS MANUFACTURING AND FACTORYLESS GOODS PRODUCERS

In 1997, the Office of Management and Budget (OMB) introduced the North American Industry Classification System (NAICS), an approach to classifying establishments into industries "according to similarity in the processes used to produce goods or services" (OMB 1998, p. 13).[1] NAICS defines the manufacturing sector to be the set of establishments "engaged in the mechanical, physical, or chemical transformation of materials, substances, or components into new products." Yet NAICS acknowledges that the relevant transformation may happen outside the establishment: "Manufacturing establishments may process materials or may contract with other establishments to process their materials for them. Both types of establishments are included in manufacturing” (OMB 1998, p. 105)

Since the introduction of NAICS in 1997, the outsourcing of processing materials into products—hereafter, “fabrication” for convenience—has risen dramatically, elevating the importance of consistent treatment of this practice across statistical programs. The Economic Classification Policy Committee (ECPC) of the OMB studied the issue and defined three types of establishments:

1) Integrated manufacturers (IMs)

2) Manufacturing service providers (MSPs)

3) Factoryless goods producers (FGPs)

FGPs have the following characteristics (OMB 2009): They

- own the rights to the intellectual property or design (whether independently developed or otherwise acquired) of the final manufactured product,
- may or may not own the input materials,
- do not own production facilities,
- do not perform transformation activities,
- own the final product produced by MSP partners, and
- sell the final product.

In contrast, IMs and MSPs own production facilities and perform transformation activities, and MSPs do not own the intellectual property or the final product.

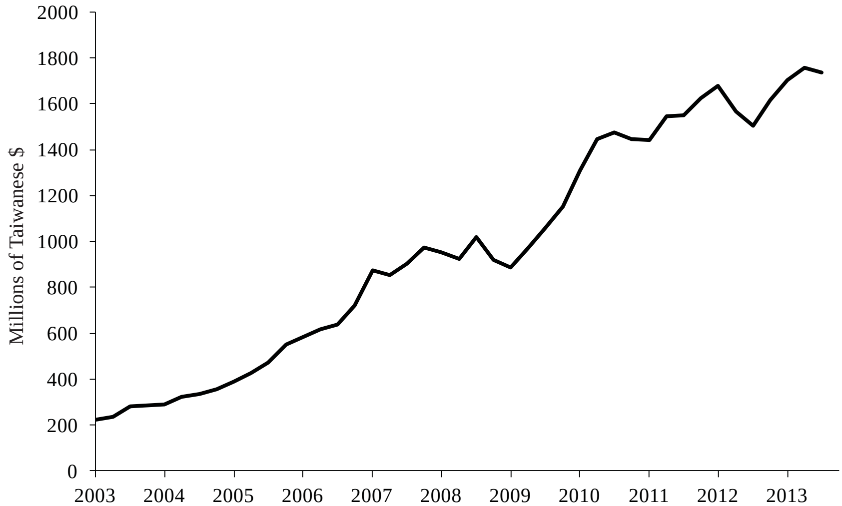
In the absence of clear guidance from NAICS, the approach used to classify FGPs has differed across statistical agencies. U.S. Census Bureau practice has been to classify such establishments in the “Wholesale trade” sector.[2] In contrast, the Bureau of Labor Statistics’ (BLS) Producer Price Index (PPI) program collects prices from FGPs for use in some manufacturing PPIs, and the BLS’s Current Employment Statistics (CES) program classifies some reporting FGP establishments in the “Management of companies and enterprises” sector.[3] In 2011, the OMB adopted the ECPC’s proposal to classify FGP establishments in the manufacturing sector “beginning no later than 2017” (OMB 2011); however, in August 2014 the OMB backed off from that decision, saying that “agencies need an opportunity to perform additional research, testing, and evaluation.” U.S. statistical agencies are currently studying the feasibility of this proposal.[4]

As noted above, the NAICS definition of the manufacturing sector is flexible enough to allow for a manufacturing establishment to be “engaged” in fabrication even if the fabrication takes place at another establishment. But the notion that an establishment can be in manufacturing if no fabrication takes place on-site is somewhat controversial (OMB 2011).[5] The BLS’s Business Processes and Business Functions (BPBF) classification system provides a helpful framework for considering the characteristics that distinguish manufacturing establishments from those in other sectors. The manufacturing “operations” business process includes the tasks of producing goods, assembling products, and fabricating components, as well as those of managing production and conducting quality assurance (Brown 2008).[6] In this scheme, FGPs perform the production management and quality assurance portions of manufacturing operations. In addition, other business processes may be performed by the FGPs as well, such as product design and development.[7]

For the purpose of characterizing *companies* (groups of establishments under common ownership), we define the term “factoryless manufacturing” (FM) to be the use of contract manufacturing to produce some or all of the final products sold by a company, provided the company controls the intellectual property or design. We expect that at least one of the establishments of an FM company will be an FGP.

Factoryless manufacturing emerged in the U.S. apparel sector in the 1950s when U.S. companies shifted fabrication to Japan (Gereffi 2002). In the 1970s, FM became common for consumer goods, especially toys (Steiner 1995).[8] The role of contract manufacturing in the production of final goods in electronics has risen dramatically over time as well—in particular, the revenue of major offshore final electronics MSPs has risen markedly over the past 10 years (Figure 4.1).[9] Finally, the use of factoryless manufacturing has surged for semiconductors: The share of semiconductor sales accounted for by FM firms, predominantly U.S. companies, climbed from 3 percent in 1993 to 25 percent in 2012 (Figure 4.2).

Figure 4.1 Sales of Selected Taiwanese Contract Electronics Manufacturers



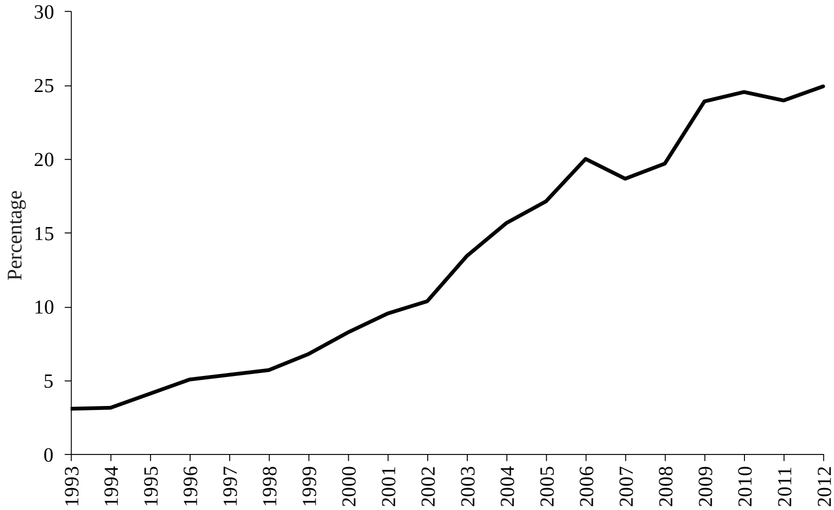
SOURCE: Authors' calculations based on public financial reports. Companies included are contract electronics firms traded on the Taiwan Stock Exchange: Hon Hai (Foxconn), Quanta, Compal, HTC, Inventec, WNC, and ASUS.

THE EXTENT OF U.S. FACTORYLESS GOODS PRODUCTION

Evidence from Company Financial Reports

In financial reports filed with the Securities and Exchange Commission (SEC), manufacturing companies often indicate that they use factoryless manufacturing for some or all of their production.[10] For example, the 2012 annual report for Nike Inc. notes, "Our principal business activity is the design, development, and worldwide marketing and selling of high quality footwear, apparel, equipment, accessories, and services" and that "virtually all of our footwear is produced by factories we contract with outside of the United States." Similarly, the 2012 annual report for electronics manufacturer Juniper Networks Inc. states, "Our manufacturing is primarily conducted through contract

Figure 4.2 Share of Global Industry Shipments for Factoryless Manufacturing of Semiconductors



SOURCE: Global Semiconductor Alliance.

manufacturers," and goes on to say that Juniper employees "manage relationships with contract manufacturers, manage our supply chain, and monitor and manage product testing and quality." These companies report that they outsource some or all of their fabrication activity, but that they manage production and perform product design in-house. Other examples are shown in Table 4.1.

To get a sense of the breadth of factoryless manufacturing by U.S. companies, we searched for evidence of FM activity in the annual reports of all firms in the Standard and Poor's (S&P) 500 for both 2002 and 2012.[11] Specifically, we reviewed the reports for references to the use of contract manufacturing for fabrication of the companies' final products.[12] Table 4.2 summarizes the results of our review of the annual reports. For 2012, we find that about half (46 percent) of firms reporting manufacturing of any kind use FM. This is substantially higher than the 31 percent share observed for 2002. About four-fifths of the FM companies use MSPs for only a portion of their output, and approximately one-fifth rely exclusively on MSPs for fabrication.

Table 4.1 Selected S&P 500 Companies Reporting Factoryless Goods Production, by Primary Product Grouping, 2012

Toys and games
Hasbro Inc.
Mattel Inc.
Apparel
Abercrombie & Fitch Co.[a]
Nike Inc.[a]
Electronics
Advanced Micro Devices Inc. (semiconductors)[a]
Qualcomm Inc. (semiconductors)[a]
Amazon.com Inc. (electronic readers)[a]
Apple Inc. (computing, communications, consumer)
Cisco Systems Inc. (communications)[a]
Pharmaceuticals
Bristol-Myers Squibb Co.
Eli Lilly and Co.
Chemicals excluding pharmaceuticals
Clorox Co.
Colgate-Palmolive Co.
Food, beverage, and tobacco
Campbell Soup Co. (food)
Monster Beverage Corp. (beverage)[a]
Philip Morris International (tobacco)
Paper, plastic, and wood products
Avery Dennison Corp. (paper products)
Newell Rubbermaid Inc. (plastics products)
Electrical equipment
General Electric Co.
Machinery
Applied Materials Inc.
Transportation equipment
Delphi Automotive
Medical supplies excluding pharmaceuticals
Boston Scientific Corp.

[a] Company using FGP exclusively—i.e., a company with no integrated manufacturing activity.

SOURCE: Classification based on authors' analysis of 2012 annual reports filed with the Securities and Exchange Commission.

Table 4.2 Prevalence of Factoryless Manufacturing among Companies in the S&P 500 Index with Manufacturing Activity

	2002		2012	
	Count	Share (%)	Count	Share (%)
No factoryless manufacturing	172	70	120	54
Any factoryless manufacturing	74	30	104	46
Exclusively factoryless manufacturing	12	16	21	20
Mixed factoryless and integrated manufacturing	62	84	83	80
	n = 246		n = 224	

SOURCE: Classification based on authors' analysis of annual reports filed with the Securities and Exchange Commission.

As we expected from the evidence reviewed at the end of Section Two, in both 2002 and 2012, factoryless manufacturing was used by a very high share of firms manufacturing toys, apparel, and most electronic products (Table 4.3). For example, in both 2002 and 2012, all companies in the "Toys and games" category of the S&P 500 employed FM practices. Firms in the "Toys and games" sector represented 2 percent of all manufacturing companies in the index in both years. The FM business practice is also quite common among firms producing pharmaceuticals and medicine.

Also of note is the degree to which factoryless manufacturing spread to a broader array of goods from 2002 to 2012. For example, only 9 percent of large cap firms in the "Food, beverage, and tobacco" sector used FM in 2002, but the share had soared to 52 percent by 2012. Several other industries also experienced strong growth in the share of firms using FM over the past decade: notable gains were recorded for the sectors "Paper, plastic, and wood products," "Chemicals excluding pharmaceuticals," "Transportation equipment," and "Electrical equipment."

Evidence from Economic Census Data

The Economic Census collects extensive information on U.S. *establishments* every five years, and questions on the 2002 and 2007 Economic Censuses shed light on the prevalence of FGPs. Wholesale trade establishments were asked whether they sold products manufac-

Table 4.3 S&P 500 Sector Distribution and Share of Companies Using Factoryless Manufacturing (%)

Sector	Share of companies using factoryless manufacturing[a] 2002	Share of companies using factoryless manufacturing[a] 2012	Sector share of total S&P manufacturing 2002	Sector share of total S&P manufacturing 2012
Toys and games	100	100	2	2
Apparel	86	100	3	4
Electronic components (including semiconductors)	77	94	9	7
Computers and communications equipment	70	82	11	8
Pharmaceuticals and medicine	48	70	10	9
Food, beverage, and tobacco products	9	52	10	14
Paper, plastic, and wood products	6	45	7	5
Chemicals excluding pharmaceuticals	15	37	8	8
Other final electronics (industrial, defense, aerospace, etc.)	15	37	5	8
Medical excluding pharmaceuticals (including electromedical equipment)	10	23	4	6
Transportation equipment	0	22	7	4
Electrical equipment	0	17	3	3
Machinery	6	17	8	11
Metal, nonmetallic mineral, and petroleum products	6	0	7	8
Unclassified (conglomerates, miscellaneous production)	43	33	6	3

[a] Includes companies employing a mix of factoryless manufacturing and integrated manufacturing.

SOURCE: Authors' classification based on company reports filed with the Securities and Exchange Commission.

tured for them by contract manufacturers and whether they engaged in product design.[13] We consider an affirmative answer to either question to be supporting evidence for classifying the establishment as an FGP, though the questions are not definitive.[14] More than 30 percent of establishments answered "yes" to at least one of these questions in a majority of wholesale industries in 2002 (Tables 4.4 and 4.5).

Table 4.4 Performance of Product Design/Engineering and Use of Contract Manufacturing Services Share of Merchant Wholesale Establishments, 2002 (%)

NAICS Code	Industry description	Design/ engineer products sold	Purchase contract manufacturing services	Both	Either
	Durable goods				
4231	Motor vehicles and parts	8	13	3	18
4232	Furniture and home furnishings	25	26	10	41
4233	Lumber and other construction materials	14	20	4	30
4234	Professional and commercial equip. and supplies	19	18	7	30
4235	Metal and mineral	15	26	5	36
4236	Electrical and electronic goods	21	20	7	34
4237	Hardware, plumbing, heating equip. and supplies	15	17	4	28
4238	Machinery, equip. and supplies	19	22	7	34
4239	Miscellaneous durable goods	25	21	10	36
	Nondurable goods				
4241	Paper and paper products	22	25	10	37
4242	Drugs and druggist sundries	22	26	11	37
4243	Apparel, piece goods, and notions	42	35	21	56
4244	Grocery and related	13	14	4	23
4245	Farm product raw material	6	6	1	11
4246	Chemical and allied products	24	24	8	40
4247	Petroleum and petroleum products	3	8	1	10

4248	Beer, wine, distilled alcoholic beverages	5	14	1	18
4249	Miscellaneous nondurable goods	21	17	7	31
	Total, durable and nondurable	18	20	6	32
	Memo:				
	Establishments of FGP semiconductor companies	51	22	18	55
	Firms of FGP semiconductor companies	67	56	48	75

NOTE: Response rate was approximately 50 percent. Special question was on all Census of Wholesale Trade forms in 2002. Establishments reclassified to wholesale trade during census processing did not receive a survey form with this question.

SOURCE: 2002 Census of Wholesale Trade.

Table 4.5 Performance of Product Design/Engineering and Use of Contract Manufacturing Services Share of Merchant Wholesale Establishments, 2007 (%)

NAICS Code	Industry description	Design/ engineer products sold	Purchase contract manufacturing services	Both	Either
	Durable goods				
4231	Motor vehicles and parts	6	8	3	11
4233	Lumber and other construction materials	12	16	4	24
4234	Professional and commercial equip. and supplies[a]	23	20	12	31
4235	Metal and mineral	13	23	5	31
4236	Electrical and electronic goods	15	16	7	24
4238	Machinery, equipment, and supplies[a]	15	15	7	23
4239	Miscellaneous durable goods	18	17	8	27
	Nondurable goods				
4241	Paper and paper products	17	16	7	26
4242	Drugs and druggist sundries	22	27	14	35
4243	Apparel, piece goods, and notions	35	29	16	48
4244	Grocery and related	13	12	4	21
4245	Farm product raw material	5	6	1	10
4248	Beer, wine, distilled alcoholic beverages	4	5	2	7
4249	Miscellaneous nondurable goods[a]	17	12	6	23
	Total, durable and nondurable	15	15	7	23

Memo:				
Establishments of FGP semiconductor companies	52	40	35	57
Firms of FGP semiconductor companies	68	42	47	63

NOTE: 2007 response rate was approximately 53 percent for establishments receiving forms. Survey forms for some wholesale trade industries did not include these questions. Statistics are shown for covered six-digit industries within each four-digit industry group. Industry groups marked with an asterisk have omitted industries. Industry groups with no coverage are 4232, 4237, 4246, and 4247. Establishments reclassified to wholesale trade during census processing did not receive a survey form with this question. The “Purchase contract manufacturing services” column combines results for separate questions on domestic and foreign CMS.

SOURCE: 2007 Census of Wholesale Trade.

Prevalence among pharmaceutical and apparel wholesalers is particularly high, as we expected in light of our company report analysis. Interestingly, "Electrical and electronics wholesaling" is not among the industries with the highest prevalence of FGPs. However, when we matched known semiconductor FM companies to census firm records (as discussed in the next section), we found that 75 percent have at least one wholesale establishment reporting design or use of contract manufacturing.[15]

Results for prevalence of contract manufacturing use and product design by industry were similar in 2007 to what they were in 2002; unfortunately, the questions asked were somewhat different in the two years, making it hard to discern trends. Furthermore, in 2007 the questions were not asked of establishments in all industries, as they had been in 2002 (Bernard and Fort 2013).

Estimates in Related Work

Other studies have estimated the scope and scale of factoryless manufacturing using the Economic Census and other data. No survey contains an ideal set of questions for identifying FM, and consequently approaches in studies of FM have varied significantly.

Doherty (Chapter 2 of this volume) focuses on wholesalers who reported their type as "own-brand importer-marketer" (OBM), a term that is similar to FGP, but one that only applies to the use of offshore contract manufacturing. In the 2007 Economic Census, 3 percent of wholesale establishments self-identified as OBMs, which is a reasonable lower bound on FGP prevalence. However, because domestic outsourcing is much more common than offshore outsourcing (Fort 2011), FGPs are likely to be substantially more common than OBMs. Kask, Kiernan, and Friedman (2002) note that the OBM share of wholesalers was 3 percent for the 1997 Economic Census as well. In light of other evidence on the rising prevalence of offshore MSPs between 1997 and 2007, the stable share for OBMs is somewhat puzzling.

Jarmin, Krizan, and Tang (2011) look at outsourcing and offshoring using the same Economic Census special questions used in this study, but they employ a different FGP classification rule, which requires that establishments report "resales" as their primary activity in addition to reporting use of contract manufacturing and performance of product design. Conditioning on resale—the sale of products *bought* and sold without further processing—is problematic in that we expect that FGPs may contract for the service provided by the MSP, rather than purchasing the good itself. Also, as noted above, creating the product design is sufficient to establish ownership of the intellectual property, but not necessary—designs can be purchased or licensed by FGPs. Jarmin, Krizan, and Tang estimate that FGPs account for 1 percent of establishments within the manufacturing and wholesale trade sectors combined.

Bernard and Fort (2013) use a definition of FGP that differs from the ECPC standard in that a wholesale establishment that fabricates products on-site and does not use contract manufacturing can be counted as an FGP. We view reports of fabrication at wholesale trade establishments as evidence of one of two possibilities: 1) misclassification of an IM to wholesale trade, or 2) an FGP establishment with secondary IM activity. Despite the conceptual differences, Bernard and Fort find that the inclusion of FGPs in manufacturing leads to an increase in gross output ranging from 5.2 to 19.4 percent—estimates that are similar to ours. The range in Bernard and Fort depends on the assumptions made about respondents who did not answer the key questions.

Kamal, Moulton, and Ribarsky (Chapter 3 of this volume) examine company-level data from surveys conducted by the Census Bureau and the Bureau of Economic Analysis (BEA) and report results broadly consistent with ours, in that they find that the use of contract manufacturing is common in a wide array of industries and that companies with a mixed FGP/IM approach are far more common than pure FM companies.[16]

THE STRUCTURE OF FACTORYLESS MANUFACTURING FIRMS IN THE SEMICONDUCTOR INDUSTRY

Semiconductor manufacturing is a prominent example of an industry with extensive factoryless manufacturing—in 2012, 25 percent of global semiconductor sales came from FM companies (Figure 4.2).[17] By matching directories of FM firms in the semiconductor industry to Economic Census microdata, we are able to study the establishment structure of FM firms for this industry.[18] In this section, we discuss the results of that matching exercise.

We find that the footprint of semiconductor FM firms in the Economic Census is complex. Single-unit firms account for about 90 percent of the company observations in our data, and of these, only about 30 percent are located in the wholesale trade sector (Table 4.6).[19] This is a surprising result in light of the Census Bureau directive to treat FGPs as wholesalers. However, the classification process depends on a broad review of an establishment's activities. The sole establishment of a single-unit firm would likely be engaged in multiple business processes in addition to production management, such as product, process, and technology development; marketing and sales; strategic management; and any general management "back office" operations that have not been outsourced. If one of these other activities is the primary activity of the establishment, as "determined by its relative share of current production cost and capital investment," the establishment may be classified to an industry outside of "Wholesale trade" (OMB 1998, p. 17). Still, establishments in the wholesale trade sector account for two-thirds of the value of sales for these firms for 2007 (Table 4.7). About one-half of the 2007 employment for FM semiconductor firms is found in the wholesale trade sector. Among the smaller number of multiunit firms, the majority have units in multiple sectors (Table 4.6).

The establishments of these FM firms are highly concentrated in a few key information technology industries, corroborating our matching process (Table 4.8). Many units are found outside of the whole-

Table 4.6 Firms by Establishment Structure

Category	2002	2007
Total	525	525
Single-unit	450	470
Manufacturing	105	100
Wholesale	130	120
Services	220	245
Multi-unit	70	55
3 Sectors	15	10
2 Sectors	25	20
1 Sector	30	20

NOTE: Excludes management establishments. Rounded to nearest 5. Numbers may not sum to totals because of rounding.
SOURCE. Economic Census, 2002 and 2007.

Table 4.7 Sector Distribution of Semiconductor FM Firm Activity

Sector	Sales ($ billions)	Employment (000s)
	2002	
Total	22	55
Wholesale	15	27
Services	2	10
Manufacturing	5	18
	2007	
Total	26	55
Wholesale	19	29
Services	2	12
Manufacturing	5	14

NOTE: Sales and employment rounded to whole numbers. Numbers may not sum to totals because of rounding.

SOURCE: Matched Economic Census and company data, 2002 and 2007. See data appendix.

sale trade sector, but note that while Census Bureau practice is to classify FGPs (establishments) in wholesale trade, establishments of FM companies may have primary activity in other sectors and be properly classified there. Wholesale trade establishments for the FM firms are almost exclusively in "Other electronic parts and equipment wholesalers" (which includes semiconductor wholesalers) and in "Computers, peripherals, and software wholesalers." The service establishments for these firms are predominantly in "Custom computer programming and systems design services," in "Physical, engineering, and life sciences R&D services," and in "Engineering services." Manufacturing establishments for the FM firms are heavily concentrated in "Semiconductor and related device manufacturing," with a small but notable share in other electronics manufacturing industries. These manufacturing establishments are an indication that the associated company employs a hybrid FGP/IM approach to production.

Focusing on establishments in the two key wholesale industries, we find that semiconductor FGPs are significantly larger with respect to the value of revenue and the number of employees than non-FGPs within these industries (Table 4.8).[20, 21] The difference in log revenue between FGPs and non-FGPs is 1.5, and the difference in average log

Table 4.8 Mean Establishment Characteristics by Firm Type and Sector, 2002

	Sector	
	Wholesale trade[a]	
	FM firm	Other
Log revenue ($ 000s)	8.7	7.2
Log employment	2.4	1.8
Log avg. earnings ($ 000s)	4.4	3.7
	Services[b]	
	FM firm	Other
Log revenue ($ 000s)	7.8	5.8
Log employment	2.9	1.5
Log avg. earnings ($ 000s)	4.4	3.7
	Manufacturing[c]	
	FM firm	Other
Log revenue ($ 000s)	9.6	7.9
Log employment	4.2	2.8
Log avg. earnings ($ 000s)	4.1	3.8

[a] Dominant industries (and their NAICS codes) for the wholesale trade sector include “Other electronic parts and equipment” (423690) and “Computers, peripherals, and software” (423430).

[b] Dominant industries (and NAICS codes) for the services sector include “Custom computer programming services” (541511) and “Computer systems design” (541512).

[c] Dominant industries (and NAICS codes) for the manufacturing sector include “Semiconductor and related device manufacturing” (334413) and other industries within “Computer & electronic product manufacturing” (334).

SOURCE: 2002 Matched Economic Census and company data. See data appendix.

employment is 0.6. The average earnings for employees of FM firms is substantially higher as well—the mean of the log earnings distribution is 4.4 for FGPs and 3.7 for non-FGPs. We speculate that FGPs are more likely than conventional wholesalers to employ engineers and other technical professionals with relatively high earnings and are less likely to employ lower-skilled laborers, such as those devoted to managing warehouse inventories.

Establishments of the semiconductor FM firms in the two wholesale industries identified in the previous paragraph and in superscript note [a] of Table 4.8 display a striking tendency to cluster geographically. Approximately two-thirds of wholesale revenue for semiconductor FGPs comes from plants located in just three metropolitan statistical areas (MSAs), and the top 10 MSAs for FGP activity account for 87 percent of FGP revenue (Table 4.9). In contrast, the other establishments within the two key wholesale trade industries are more geographically diverse. The top three MSAs account for only 26 percent of revenue, and the top 10 MSAs account for only 56 percent. We conjecture that in contrast to wholesalers as conventionally defined—a warehouse or sales office—which are drawn to centers of business activity and transportation hubs, FMs locate FGPs close to other establishments in their industry to benefit from active local markets for specialized labor and other inputs. Silicon Valley for electronics and New York City for apparel are well-known examples (Porter 1998).

The composition of employment in the semiconductor manufacturing industry would be much different with FGPs included in its scope. The mean of the log earnings distribution is 4.4 for FGPs in "Wholesale trade," noticeably greater than the 3.8 average for log earnings in the "Electronics manufacturing" sector (NAICS 334), excluding semiconductor FGPs.

Table 4.9 Geographic Concentration of Wholesale Sales, 2002

FM semiconductor firms		Other firms	
MSA	Sales share	MSA	Sales share
1	43	1	10
2	11	2	8
3	11	3	8
4	6	4	7
5	3	5	6
6	3	6	5
7	3	7	3
8	3	8	3
9	2	9	3
10	2	10	3
Total	87	Total	56

NOTE: MSA rankings generated separately for FM and non-FM companies. "FM" stands for "factoryless manufacturing." See text for definition.
SOURCE: 2002 Matched Economic Census and company data. See data appendix.

U.S. MANUFACTURING WITH FACTORYLESS GOODS PRODUCERS INCLUDED

Total Manufacturing Using Economic Census Special Questions

As noted in the section beginning on p. 82, the OMB has encouraged economic statistical agencies to assess the feasibility of classifying FGPs in the manufacturing sector. What remains unknown, however, is the effect of this reclassification on the size of the sector. The 2002 and 2007 Economic Censuses of Wholesale Trade both include two questions on contract manufacturing and design that offer an opportunity to assess the difference that classifying FGPs to manufacturing would make. For 2007, we estimate that if one reclassified to manufacturing those establishments answering “yes” to both questions, the value-added for the sector would be greater by $96 billion, or 4 percent (Table 4.10).[22] Using a more lenient assumption—that an affirmative answer to either question suffices to identify an establishment as an FGP, manufacturing value-added would be greater by $303 billion, or 13 percent. For 2002, manufacturing would be 3 percent greater using the strict definition, and 14 percent greater using the lenient definition. Unfortunately, response rates for these questions are quite low, and these results implicitly assume nonresponse is a negative answer. We imputed answers for nonrespondents and found manufacturing value-added would have been 5 to 20 percent higher in both years, which we take to be our most plausible estimate.[23]

Semiconductor Manufacturing Using Matched FM Company Data

Next, we narrow our focus to the semiconductor industry, and we use the matched company-establishment data. We count sales of the wholesale establishments of FM firms as manufacturing revenue and estimate that the value of shipments for the semiconductor industry in 2007 would have been $92 billion—26 percent higher than the $75 billion reported in the 2007 Economic Census. The share of the (broader) semiconductor industry accounted for by plants of FM firms (including those already in manufacturing) would have been 28 percent.[24]

Table 4.10 Total Value-Added for Establishments Reporting Product Design, Use of Contract Manufacturing, or Both ($ billions)

Levels	2002	2007
Baseline		
Either CMS or design	260	303
Both	60	96
Baseline + imputed response		
Either CMS or design	364	413
Both	94	152
Total manufacturing value added	1,888	2,383
Increase to manufacturing (%)		
Baseline		
Either CMS or design	14	13
Both	3	4
Baseline + imputed response		
Either CMS or design	19	17
Both	5	6

NOTE: Selected wholesale trade industries (423690, 423430). Manufacturing value-added from the Census of Manufacturers.
SOURCE: Economic Census, 2002 and 2007.

Interestingly, the FGP share of industry shipments for 2002 is little different from its share for 2007. Consequently, semiconductor industry shipments, including shipments from FGPs, rose 3.7 percent (annual rate) between 2002 and 2007, an increase only slightly greater than the 3.4 percent reported under the current classification system. Meanwhile, the FM portion of the global semiconductor industry ballooned from $15 billion in 2002 to $54 billion in 2007 (Figure 4.2). Because U.S. companies account for a very large share of global FM revenue, this could suggest that U.S. FM companies were expanding rapidly during this period, but that the expansion was primarily at offshore establishments. However, such a scenario could be the result of companies keeping earnings overseas for tax avoidance purposes.

SELECTED EFFECTS OF RECLASSIFICATION AND RELEVANCE FOR ECONOMIC ANALYSIS

Because the impact of the NAICS guidance for FGP classification will reflect not only the effect of conceptual differences but also the significant measurement challenges faced by statistical programs in adopting the change, no definitive analysis can be made of its effect on measures of economic activity. Nevertheless, for the sake of discussion we provide a speculative assessment of the effect on some key economic measures.

Manufacturing Value-Added

To begin with, estimates in this chapter and in other work suggest that classification of FGPs to the manufacturing sector will materially increase that sector's value-added. However, it is important to note that the total nominal value-added of the economy should not change, because the increase in manufacturing will be offset by decreases in other sectors. The expansion of the scope of the manufacturing sector beyond establishments engaged in fabrication on-site will introduce an appreciable discontinuity in statistics for the manufacturing sector. That said, the change has the appeal of introducing continuity in the treatment of production management activities and product development. When those tasks are colocated with fabrication, their value-added is counted as manufacturing, and the outsourcing of fabrication arguably should not move their value-added out of that sector. To quote from the OMB decision on the issue, "Goods producers arrange for and bring together all of the factors of production necessary to produce a good. . . . When individual steps in the complete process are outsourced, an establishment should remain classified in the manufacturing sector." That goal will be served by classifying FGPs in the manufacturing sector, but it would be desirable to also report economic statistics that allow for analysis of manufacturing with FGPs excluded.[25]

In addition, classifying FGPs to manufacturing will change the industry composition of the sector because FGPs are not evenly prevalent across wholesale trade industries (Tables 4.4 and 4.5). For example, we expect the change will temper the long decline in U.S. production of electronics. We consider a provocative example for illustration: Value-added in the "Electronic computer manufacturing" industry (NAICS Industry 334111), as reported by the Census Bureau's Annual Survey of Manufacturers (ASM), dropped from $26 billion to $9 billion between 2008 and 2010, and it fell further, to $3 billion, in 2011. In addition to the economy-wide effects of the recent recession, such as businesses postponing computer investment, the decline can be partially attributed to a shift in the composition of household computer spending toward tablet computers, especially the iPad, produced by Apple Inc., a company that relies primarily on offshore MSPs for fabrication.

To the extent that offshore iPad fabrication is managed by domestic FGPs, a portion of value-added for this type of product will be counted in the U.S. computer industry under the new classification rules. According to Apple annual reports, Apple's global iPad revenue surged from $5 billion to $20 billion between 2010 and 2011. Assuming Apple's gross margin share of overall revenue, approximately 40 percent, applies to sales of iPads, and assuming for the sake of argument that half of that margin is value-added at domestic Apple FGPs, under the new NAICS guidance $6 billion in value-added at these FGPs would be counted in the manufacturing sector and would roughly offset the $6 billion decline in domestic computer manufacturing reported in the ASM. This somewhat fanciful example illustrates how the new classification approach may have first-order effects and change the narrative for some industries where FM is prevalent.

Trade

It is also worth noting that the new treatment of FGPs has the potential to cause significant changes in the composition of U.S. trade flows, though net trade is in principle unaffected. An FGP that purchases contract manufacturing will record as its own production the product fabricated by the MSP. If the MSP is located abroad and the product is delivered to a foreign market, the sale will be treated as a U.S. export, even though the finished good did not cross the U.S. border. In contrast, if the product is shipped to the U.S. market from the foreign MSP, it will not be treated as a U.S. import, even though the good did cross the U.S. border. In both cases, an import of manufacturing services will be recorded. Thus, the relative importance of services and goods in total trade may differ under the new system. The new treatment of FGPs has the potential to cause significant changes in the composition of U.S. trade as recorded in the National Income and Product Accounts (NIPAs), though net trade is in principle unaffected.

Measurement Effects

In addition to the conceptual changes mentioned above, we note two ways in which aggregates conceptually unaffected by the change in treatment of FGPs may nevertheless be affected as measured. First, the accuracy of economic statistics whose construction relies on the combination of data generated by different statistical programs, such as industrial production and labor productivity, will be aided by the better alignment of FGP classification practices. Such statistics are at risk of inadvertent mismeasurement if differences with respect to current FGP classification are not taken into account. The added clarity with regard to the treatment of FGPs will serve to reduce the risk of such errors.

Second, measurement of the prices needed to deflate nominal value-added and trade flows for FGPs and MSPs will require significant attention. Byrne, Kovak, and Michaels (2013) study prices for manufacturing services in the semiconductor industry and find that the well-known challenges faced in quality-adjusting product prices also exist for semiconductor manufacturing services. If the composition of trade shifts from goods to services, the relative quality of price measures for services will affect the resulting real balance of trade.[26]

Economic Issues

Deeper understanding of the use of the FM business model may lead to insights into important economic questions. Among these are the following four:

1) What is the effect of offshoring on domestic activity—do management and design follow fabrication offshore, or does offshoring enhance that domestic activity through gains from trade?[27]
2) What is the impact of this shift in manufacturing approach on manufacturing employment—does the loss of production

worker jobs to offshoring coincide with a gain in domestic knowledge-worker jobs?[28]

3) How much of the substantial contribution of information technology (IT) production to productivity growth can be attributed to FGP activity, and how much to fabrication?[29]

4) What is the role of FGPs in global "trade in tasks"? Can FGP data lead to more appropriate input-output tables for use in the burgeoning work on decomposing product value into contributions from different economies through value-added trade?[30]

CONCLUSION

Using company data, we document our premise that factoryless manufacturing is becoming more prevalent and is employed in the production of an increasingly wide variety of goods. With Census Bureau establishment microdata, we find evidence that factoryless goods producers are present in a broad mix of industries in the wholesale trade sector. We present a case study of the semiconductor industry using a data set constructed by matching company data and census establishment data. Here, we find that FGPs are larger in terms of revenue and employment, have higher average earnings, and cluster markedly more than conventional wholesale trade establishments. Finally, we estimate that shifting FGP activity from wholesale trade to manufacturing may increase manufacturing value-added by 5 to 20 percent. In the case of semiconductors, we find that value-added in 2007 would be 26 percent higher if census data were used. We provide examples of anticipated effects on economic statistics from the clarification of the treatment of FGPs and note several areas of economic study that may benefit from the change.

Implementing the OMB guidance on the treatment of FGPs presents substantial challenges for U.S. statistical agencies going forward (Doherty, Chapter 2 of this volume). As was noted earlier, factoryless manufacturing is far from new, and looking backward, there is the daunting task of building a history consistent with the clarified scope of manufacturing, which will be needed to fully exploit the data. However, bearing in mind the evident size of the FGP phenomenon and the role that better measures of FGPs may play in discussion of pressing economic issues, we consider the clarification of the treatment of factoryless goods producers to be a welcome effort to update the U.S. statistical system.

Notes

This chapter stems from a paper that was prepared for presentation in 2013 at the "Measuring the Effects of Globalization" conference, organized by the Progressive Policy Institute and the W.E. Upjohn Institute for Employment Research and funded by the Alfred P. Sloan Foundation. We are grateful for the feedback we received from participants at the conference. We also benefited from additional feedback from Maureen Donoghue, Teresa Fort, Susan Houseman, Javier Miranda, John Murphy, Bill Powers, Jennifer Ribarsky, Falan Yinug, and participants in a workshop at the U.S. Census Bureau. The Global Semiconductor Alliance and IHS iSuppli provided data, and we also appreciate their guidance on the semiconductor industry. Remaining errors are our own.

All results have been reviewed by the Census Bureau to ensure that no confidential information is disclosed. References to specific companies are based exclusively on purchased data, public financial reports, and news accounts, not on confidential census information. The views expressed are not the views of the Census Bureau.

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1. An establishment is a company unit, such as a plant, warehouse, or office. The Office of Management and Budget defines it this way: "The establishment . . . is the smallest operating entity for which records provide information on cost of resources . . . employed to produce the units of output. . . . The establishment . . . is generally a single physical location" (OMB 1998).
2. A summary of a recent study of the FGP classification issued by the Economic Classification Policy Committee noted, "To the extent that FGPs can be identified, the Census Bureau statistical programs classify them to wholesale trade" (Murphy 2009). However, this guidance does not apply to apparel. (John Murphy, chair of the ECPC, in discussion with author Byrne, September 2013.)
3. Presentation by the FGP Implementation Planning Group at the Semiconductor Industry Association's annual meeting, September 11, 2012. The group's presentation was titled "Redefining Manufacturing in NAICS 2012: The Factoryless Goods Producer (FGP)."

4. For a discussion of the deliberations leading to this decision and the alternatives considered, see Doherty (2013).
5. The *Federal Register* notice from August 17, 2011 (found in *Federal Register* 76[159]: 51240–51243), describes the announced NAICS classification standard for FGP establishments as a clarification, but it also acknowledges that "the inclusion of revenues from FGP activities in manufacturing will effectively change the traditional definition of manufacturing."
6. Although the Business Processes and Business Functions classification system was not referenced in the FGP classification deliberations, it provides a useful framework for thinking about the nature of factoryless manufacturing. BPBF is based on the concepts developed for the Global Value Chains Initiative and was employed in the BLS's Mass Layoff Statistics Program, which was discontinued in June 2013 (Sturgeon 2002; Sturgeon and Gereffi 2008).
7. The NAICS manual notes that "almost all manufacturing has some captive research and development or administrative operations, such as accounting, payroll, or management" (OMB 1998).
8. Steiner (1995, 1997) was an early advocate for modifying classification practices to account for FM activity, though the term "factoryless goods producer" had not been coined at the time. Steiner notes that in the 1970s, for a "host of consumer goods," manufacturing moved offshore but the companies "did the research and development, the production engineering, and were responsible for quality control."
9. In the electronics sector, the complicated web of component production, design, and management cannot always be simplified to an FGP-MSP relationship. (See Dedrick and Kraemer [2002]; Grunwald and Flamm [1985]; and Sturgeon and Lee [2001].)
10. Under Regulation S-K of the U.S. Securities Act of 1933, annual reports to the SEC on Form 10-K are required to include discussion of risks "likely to result in registrant's liquidity increasing or decreasing in a material way."
11. Because the S&P 500 is constructed to be representative of the "large cap" segment of the U.S. equities market, these results do not apply to smaller firms. Small and medium-sized firms are an important topic for further study. One potential benefit of decoupling production management from fabrication and the associated fixed costs may be that smaller-scale enterprises are more viable, thus promoting firm creation. That being said, Kamal, Moulton, and Ribarsky (Chapter 3 of this volume) find that two-thirds of firms reporting the use of MSPs or the provision of contract manufacturing are large—they have 250 or more employees.
12. References to contract manufacturing of components of the final product, purchase of "private label" merchandise, licensing of company designs, and provision by the company of contract manufacturing services to others were not treated as evidence of factoryless manufacturing.
13. The survey forms for the Census of Wholesale Trade are included in Appendix 4B.
14. Specifically, the 2002 question asked whether fabrication was "performed for this establishment by another company," but offshore fabrication by another establish-

ment of the same company would be sufficient to meet the definition of FGP. The 2007 contract manufacturing question is also not a perfect match. With regard to design, to be an FGP, the establishment must own the rights to the design, but it may be independently developed or otherwise acquired.

15. A negative response to both of these questions by an establishment of an FM firm need not be erroneous. For example, a pure sales office for an FM firm would properly be classified in “Wholesale trade.”
16. Kamal, Moulton, and Ribarsky use the Company Organization Survey, conducted by the Census Bureau, and the BEA’s Benchmark Survey of U.S. Direct Investment Abroad as well as its Benchmark Survey of Transactions in Selected Services and Intellectual Property Products with Foreign Persons.
17. For a detailed discussion of FGPs and MSPs in the semiconductor industry, see Byrne, Kovak, and Michaels (2013). To avoid confusion, we do not use the industry-specific term “fabless” for FM firms or the term “foundries” for manufacturing service providers.
18. See Appendix 4A for a description of the sources and matching process.
19. A handful of these single-unit firms have a second establishment in the management sector. These establishments are omitted from the firm structure calculations. Results for the management sector did not meet Census Bureau standards for disclosure.
20. Most firms have no more than one establishment in these wholesale industries, and the results are little changed by treating each establishment separately.
21. Note that our “other” group may contain establishments of FM companies producing products other than semiconductors. We believe this would lead us to understate the differences between our semiconductor FGPs and true wholesale establishments.
22. We focus on value-added for now because of issues involved in double-counting gross output if an FGP purchases contract manufacturing services from a domestic establishment already in the scope of manufacturing. The value-added approach has limitations as well. We calculate value-added in the wholesale sector as sales minus the cost of merchandise and change in inventory. These results will be biased downwards if the reported cost of merchandise reflects the value of product design or of the management of the fabrication process performed at the FGP—for example, if its valuation on import includes the FGP’s value-added.
23. For each question, we predict the probability that each nonresponding establishment would answer “yes” based on observable characteristics. We then add the value-added of the establishment, weighted by the predicted probability, to the manufacturing sector, in addition to the full value-added for the respondents in our baseline estimates. In unreported results, we also use the weighting scheme developed by Fort (2011) to develop predicted probabilities of answering a question conditional on observables. We then multiply value-added for an establishment that answered both questions by the inverse of the predicted probability. This methodology yields estimates that differ by only a few percentage points from the

results reported. Our estimates of the magnitude of the proportional increment to manufacturing gross output are similar as well.

24. Because very little MSP activity for the semiconductor industry was located domestically in 2007, the magnitude of double-counting when using gross output is unlikely to be significant.
25. At the time of this writing, it has not been determined whether such detail will be made available in U.S. economic statistics.
26. On the importance of prices for imported intermediates for productivity measurement, see Houseman et al. (2011).
27. Levinson (2013) notes the relevance for policymakers of the question of whether manufacturing is becoming “hollowed out”—that is, whether a greater share of value-added is taking place offshore.
28. Helper, Krueger, and Wial (2012) note the dwindling role of the manufacturing sector as a source of “high-wage jobs, especially for workers who would otherwise earn the lowest wages.”
29. Byrne, Oliner, and Sichel (2013) note that the contribution from factoryless goods production is an important area for extension of the contribution of IT in productivity.
30. On “trade in tasks,” see Grossman and Rossi-Hansberg (2008). On developments in the measurement of value-added trade, see Ahmad (Chapter 6 of this volume), Timmer et al. (2013), and Yao, Ma, and Pei (Chapter 7 of this volume).

Appendix 4A

Data Construction

For the case study of the semiconductor industry, we linked company directory entries to the Census Business Register.[1] The Business Register is a database of U.S. business establishments and companies that serves as a sampling frame for Census Bureau firm and establishment surveys.[2] For each establishment in the Business Register there are identifiers that allow the establishment to be linked to corresponding records in Census Bureau economic surveys. In addition, the Business Register contains a firm identifier for each establishment, which enables us to locate other establishments within the same firm.

To generate our list of census firm identifiers corresponding to FGP companies, we began with a list of 1,579 FGP semiconductor companies created from a directory published by Gartner, a high-tech consultancy, and a directory published by the Global Semiconductor Alliance (GSA), a trade association representing a wide variety of companies involved in semiconductor design and fabrication. Gartner provided a worldwide directory of semiconductor FGP companies active in 2001. The GSA provided a worldwide directory of all semiconductor FGP companies active as of 2012 and a supplemental list of mergers and acquisitions between 2005 and 2012.[3] The supplemental list proved critical because of the high frequency of firm birth and firm death in the industry. We reviewed public records for these companies to amend incomplete records. Eliminating companies that we believed were not operational in either 2002 or 2007 based on a review of public records left us with a list of 1,475 companies (Table 4A.1). The list contains the name, headquarters address, and year of occurrence for major events (establishment, dissolution, merger, acquisition) for each company.

Table 4A.1 Match Statistics

Company list	1,475
Matched to business register	1,050
Total Firm IDs	1,125
Matched to 2002 EC establishments	525
Matched to 2007 EC establishments	525
Matched to either 2002 or 2007	750

NOTE: Rounded to nearest 25.
SOURCE: Company data matched to Economic Census (EC) data for 2002 and 2007. See Appendix 4A.

First, for 2002 and 2007, we matched all companies in operation in either census year to a three-year window of the Business Register ending in the census year. For this first stage, we only exploit the company name, by finding the name or names in the Business Register that match the greatest number of leading characters for the FGP company name. We then reviewed a randomly selected set of 1,000 of the approximately 40,000 potential matches generated, and we judged whether the entries were a match when considering both full-name information and address variables. This set of matches was used to estimate the importance of all available match-quality variables using a probit. Variables included an indicator of state match, number of leading digits of the zip code in common, company name-spelling distance, address-spelling distance, and whether the establishment operated in a high-tech industry. The estimated index function was then used to rank possible matches for each company on our list from most to least probable. Then we reviewed by hand the matches for each company in descending order until we judged that we had either found a match or there was no match for the company.

Using this name-matching procedure, we located 71 percent of these FGP companies in the Census Business Register files (Table 4.6).[4] Sometimes, however, we could not find in the Economic Census firm identifiers that had appeared in the Business Register. In the end, we were able to locate establishments for about 50 percent of the companies on our list of FGP firms in the Economic Census microdata for 2002 and 2007. Once we link firms from the GSA and Gartner directories to the census data, we identify all establishments connected to those firms and include them in our final data set.

Appendix Notes

1. For more detail on the matching process, see Smith (2013).
2. See Jarmin and Miranda (2002).
3. Both the GSA and Gartner directories contained companies from around the world. We attempted to find matches for both foreign and domestically headquartered companies because we assumed many of the foreign companies would have a U.S. presence. For the foreign companies we were forced to rely on only name-matching characteristics.
4. It is important to note that our list contains many firms headquartered abroad that may have no U.S. presence.

Appendix 4B

Census of Wholesale Trade Forms

Form WH-42103

28 ESTABLISHMENT ACTIVITIES

A. Indicate activities that were performed by this establishment or were performed for this establishment by another company during 2002.
(Mark "X" ALL that apply.)

	This activity was performed by this establishment	This activity was performed for this establishment by another company	This activity was not provided by this establishment
1. Product Development			
a. Product design/engineering	0921 ☐	0941 ☐	0961 ☐
b. Materials fabrication/processing/assembly/blending	0922 ☐	0942 ☐	0962 ☐
2. Order Fulfillment			
a. Bundling or kitting (combining multiple items into a prepackaged product)	0923 ☐	0943 ☐	0963 ☐
b. Pick and pack (taking goods from inventory and packaging them to fill orders)	0924 ☐	0944 ☐	0964 ☐
c. Warehousing	0925 ☐	0945 ☐	0965 ☐
d. Breaking bulk (reducing large shipments into smaller portions for customers)	0926 ☐	0946 ☐	0966 ☐
e. Local delivery (within a city, town, or other local area, including adjoining towns and suburban areas)	0927 ☐	0947 ☐	0967 ☐
f. Long distance delivery (beyond local areas and commercial zones)	0928 ☐	0948 ☐	0968 ☐
g. Less than truckload	0929 ☐	0949 ☐	0969 ☐
3. Other Services			
a. Customs brokerage (providing the services of a licensed customs broker)	0930 ☐	0950 ☐	0970 ☐
b. Logistics consulting (providing advice and expertise)	0931 ☐	0951 ☐	0971 ☐
c. Processing of returned merchandise	0932 ☐	0952 ☐	0972 ☐

B. During 2002 did this establishment:

1. Manage inventory owned by this establishment AND held at this location?	0936 ☐ Yes	0937 ☐ No
2. Manage inventory owned by this establishment BUT held at a customer's location?	0956 ☐ Yes	0957 ☐ No
3. Manage inventory owned by another company BUT held at this location?	0976 ☐ Yes	0977 ☐ No
4. Manage inventory owned by another company AND held somewhere other than at this location?	0994 ☐ Yes	0995 ☐ No

Form WH-42311 (12/04/2006)

If not shown, please enter your 11-digit Census File Number (CFN) from the mailing address.

26 SPECIAL INQUIRIES - Continued

C. OTHER ESTABLISHMENT ACTIVITIES

1. Did this establishment design, engineer, or formulate the manufactured products that it sold, produced, or shipped?

0318 ☐ Yes

0319 ☐ No

2. Which of the following best describes this establishment's primary activity? *(Mark "X" only ONE box.)*

0362 ☐ Providing contract manufacturing services for others

0363 ☐ Transforming raw materials or components into new products that this establishment owns or controls

0364 ☐ Reselling goods manufactured by others (with or without minor final assembly)

0365 ☐ Other - *Specify*

0366 ____________________

3. Did this establishment purchase contract manufacturing services from other companies or other establishments of your company to process materials or components that this establishment owns or controls?

0496 ☐ Yes, primarily with establishments WITHIN the 50 States and the District of Columbia

0497 ☐ Yes, primarily with establishments OUTSIDE of the 50 States and the District of Columbia

0498 ☐ No

27–**29** Not Applicable.

REMARKS *(Please use this space for any explanations that may be essential in understanding your reported data.)*

30 CERTIFICATION - This report is substantially accurate and was prepared in accordance with the instructions.

Is the time period covered by this report a calendar year?

☐ Yes ☐ No - Enter time period covered →

	Month	Year		Month	Year
FROM			TO		

Name of person to contact regarding this report	Title

	Area code	Number	Extension		Area code	Number
Telephone		-		Fax		-

Internet e-mail address		Month	Day	Year
	Date completed			

Thank you for completing your 2007 ECONOMIC CENSUS form.

PLEASE PHOTOCOPY THIS FORM FOR YOUR RECORDS AND RETURN THE ORIGINAL.

Form **WH-42311** (02-02-2012)

26 SPECIAL INQUIRIES - Continued

C. PURCHASE OF CONTRACT MANUFACTURING

1. Did this establishment **purchase** contract manufacturing services from other companies or foreign plants of your company in 2012?

Include:

- *Products for which the manufacturing (i.e., transforming or otherwise processing materials or components based on specifications provided by your company) was outsourced to other companies.*
- *Products for which the manufacturing was performed by your company's foreign plants.*

Exclude:

- *Services for packaging and assembling.*
- *Purchases of merchandise for resale (sale of products bought and sold without further processing or transformation).*

1011 ☐ Yes - *Go to line 2*

1012 ☐ No - *Go to* **30**

	2012 $ Bil.	Mil.	Thou.
2. Report the costs incurred by this establishment for contract manufacturing purchased in 2012 1013			
3. Report the value of sales, shipments, receipts, or revenue generated in 2012 from products whose purchases were reported as contract manufacturing costs in line 2 1015			

27–29 Not Applicable.

REMARKS *(Please use this space for any explanations that may be essential in understanding your reported data.)*

30 CERTIFICATION - This report is substantially accurate and was prepared in accordance with the instructions.

Is the time period covered by this report a calendar year?

☐ Yes ☐ No - Enter time period covered → FROM Month Year TO Month Year

Name of person to contact regarding this report	Title

Telephone: Area code	Number	Extension	Fax: Area code	Number

E-mail address	Date completed: Month	Day	Year

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Part 2

Global Supply Chains

5
Incomes and Jobs in Global Production of Manufactures

New Measures of Competitiveness Based on the World Input-Output Database

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OVERVIEW

It is frequently argued that globalization has entered a second phase. In the early twentieth century, rapidly falling transport costs ended the need for colocation of production and consumption. Competitiveness of countries in the first phase was determined by domestic clusters of firms, mainly competing sector to sector. More recently, fostered by rapidly falling communication and coordination costs, the production process itself was unbundled, as the various stages of production need not be performed near each other anymore. In this new phase, international competition increasingly plays itself out at the level of tasks within firms, rather than at the level of products. And trade in goods is increasingly replaced by trade in tasks (Baldwin 2006). This creates new challenges for the way in which the competitiveness of nations is analyzed.

Traditional measures indicate that China and other emerging countries have rapidly improved in competitiveness since the late 1990s, both in quantity and in quality, as attested to by booming exports of technologically sophisticated products. But recent product case studies suggest that European, Japanese, and U.S. firms still capture major parts of these value chains, as they specialize in high-value-added activities such as software, design, branding, and system integration. China and other emerging countries are mainly involved in the assembling, testing, and packaging activities, which are poorly compensated. A typical finding is that China keeps less than 4 percent of a product's export value as income for its labor and capital employed in the production process of electronic goods (Ali-Yrkkö et al. 2011; Dedrick, Kraemer, and Linden 2010). To reflect this new reality, a new measure of competitiveness is needed that is based on the value added in production by a country, rather than the gross output value of its exports. Or, as put by Grossman and Rossi-Hansberg (2006, pp. 66–67), "Such measures are inadequate to the task of measuring the extent of a country's international integration in a world with global supply chains. . . . We would like to know the sources of the value-added embodied in goods and the uses to which the goods are eventually put."

Recently, Timmer et al. (2013) introduced a new concept that allows one to analyze the value that is added in various stages of regionally dispersed production processes. It is defined as the income generated in a country by participating in global manufacturing production, abbreviated by the term "GVC income" (for global value chain income). Compared to traditional competitiveness indicators such as a country's share in world exports, this new metric has three advantages. First, it indicates to what extent a country can compete with other nations in terms of *activities* related to global manufacturing, rather than by competing in manufacturing *products* as measured by exports. These activities take place in manufacturing industries but also in services industries. Second, it is a reflection of an economy's strength to compete in both domestic and global markets. Third, income and employment effects of trade in tasks for separate groups of workers (such as low- and high-skilled) can also be determined in the same unified framework, referring to the concept of "GVC jobs."[1]

The main aim of this chapter is to establish a series of stylized facts on GVC incomes and jobs that can serve as a starting point for deeper analysis of the causes of global manufacturing production. Whereas Timmer et al. (2013) focused their analysis on trends in European competitiveness, this chapter takes a more global view and provides analyses for 20 major countries in the world, including the United States, Japan, major economies in Europe, Brazil, China, India, and Russia.

In the remainder of this chapter, we first outline our methodology for slicing up global value chains (in the next section, Section Two—"GVC Incomes and Jobs: Methodology") and introduce the concepts of GVC income and GVC jobs. We identify GVCs by tracing the flow of goods and services across industries and countries as described in a world input-output table. Using a decomposition technique that is built upon the original insights by Leontief (1949), we slice up the value of manufacturing expenditure into incomes for labor and capital in various countries. These are the incomes of factors that are directly and indirectly needed for the production of the final manufacturing goods. The empirical analysis is based on a new database, called the World Input-Output Database (WIOD), which combines national input-output tables, bilateral international trade statistics, and data on production factor requirements. A crucial characteristic of this database is the explicit measurement of national and international trade in intermediates. In Section Three, "The World Input-Output Database (WIOD)," we discuss the major features of this database.

Section Four, "Trends in Manufactures' GVC Incomes," provides trends in GVC income shares across regions and major countries in the world. The analysis is based on demand for final manufacturing products, and we show the dependency of countries on domestic and foreign sources of demand. We also show that only about half of the GVC income originates in the manufacturing sector itself, which indicates the importance of interindustry linkages in the production of manufacturing goods. In Section Five, "Manufactures' GVC Income by Production Factor," we focus more in-depth on the role of different factors of production. We show how in advanced countries GVC income generated by capital and high-skilled labor is increasing, while incomes for medium- and low-skilled workers in manufactures production are declining. In Section Six, "Manufactures' GVC Jobs," we study the number of jobs involved in GVC production of manufactures and find a strong difference between Europe and the United States. Low- and medium-skilled jobs are on the decline in all advanced countries, but whereas in Europe and Japan high-skilled job opportunities have increased, they have declined in the United States since 1995.

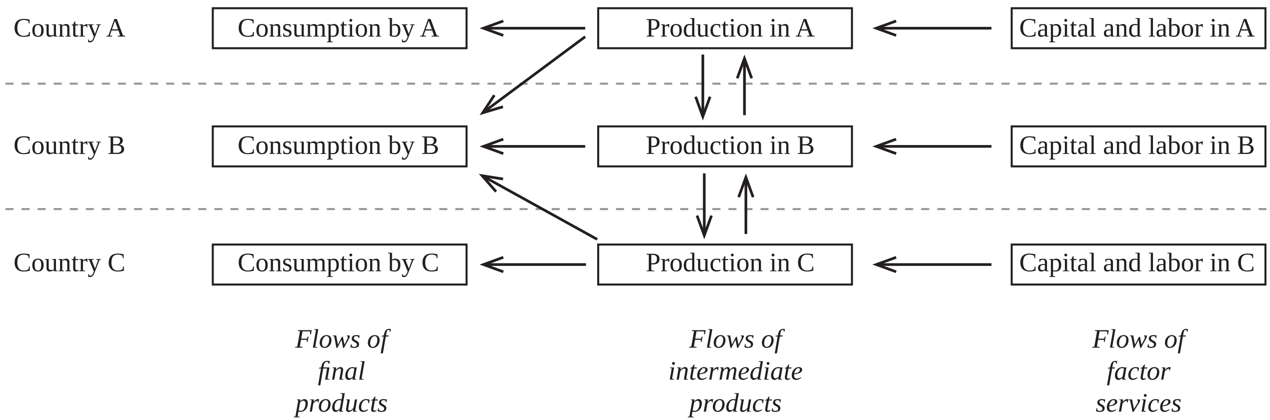
GVC INCOMES AND JOBS: METHODOLOGY

In this section we outline the method to slice up GVCs, as introduced by Timmer et al. (2013). The basic aim of this empirical analysis is to decompose expenditure on a final product into a stream of factor incomes around the world. By modeling the world economy as an input-output model in the tradition of Leontief, we can use his famous insight, which links up changes in consumption to changes in the distribution of factor income both within and across countries. Basically, we will provide the macroeconomic equivalent of famous product case studies that suggest a new division of labor and value in electronics, such as Dedrick, Kraemer, and Linden (2010) for iPods and electronic notebooks and Ali-Yrkkö et al. (2011) for a study of mobile phones. These studies suggest a division of activities between mature and emerging economies where the former concentrate on activities that require skilled labor and capital (in particular, intangibles), while the latter mainly contribute through unskilled labor.

The GVC income metric provides a macroeconomic complement to the product case studies described above. It covers a wide set of products and analyzes not only the first-tier suppliers but also second-tier and higher-order suppliers. The method provides a full decomposition of the value of consumption in a country and traces the associated income flows for labor and capital in various regions in the world. We model the global production system through input-output tables and international trade statistics. The approach follows the seminal insight from Leontief (1949) and traces the amount of factor inputs needed to produce a certain amount of final demand. Value is added at various stages of production through the utilization of production factors such as labor and capital. These links between expenditure and income are illustrated in Figure 5.1.

The arrows in Figure 5.1 indicate flows of products and factor services, which are mirrored by payments that flow in the opposite direction. The central link between income and consumption is the production process, in which value is added through the deployment of labor and capital in the various stages of production. This production process can be highly fragmented, as the case study of the iPod illustrates. Through international trade, consumption in Country B will lead to income for

Figure 5.1 Links between Expenditure, Production, and Income



SOURCE: Authors' construction.

production factors in other countries, either through importing final goods, or through the use of imported intermediates in the production process of Country B. Through these indirect linkages, consumption in Country A will generate income in Country C even though Country C does not trade directly with Country A. These indirect effects are sizable, as international trade in intermediate goods is high.

To model the international production linkages, we use a world input-output model that obeys the identity that at the global level consumption is equal to all value-added generated.[2] Below we will outline how this identity can be used to consistently decompose the value of consumption by a country into income in any country in the world. To do this we rely on the fundamental input-output identity introduced by Leontief (1949), which states that $Q = BQ + C$, where Q denotes outputs, C is consumption, and B is an input-output matrix with intermediate input coefficients. B describes how a given product in a country is produced with different combinations of intermediate inputs. The identity states that a good produced is either used as an intermediate input in another production process or is consumed. It can be rewritten as $Q = (I - B)^{-1}C$, with I being an identity matrix.[3] $(I - B)^{-1}$ is famously known as the Leontief inverse. It represents the total production value in all stages of production that is generated in the production process of one unit of consumption.

To see this, let Z be a vector column, with the first element representing the global consumption of iPods produced in China, which is equal to the output of the Chinese iPod industry, and the rest zeros. Then BZ is the vector of intermediate inputs, both Chinese and foreign, needed to assemble the iPods in China, such as the hard-disc drive, battery, and processors. But these intermediates need to be produced as well. B^2Z indicates the intermediate inputs directly needed to produce BZ, and so on. Thus

$$\sum_{n=1}^{\infty} B^n Z$$

represents all intermediate inputs needed for the iPod production. Then the total gross output value related to the production of Z is given by

$$Z + \sum_{n=1}^{\infty} B^n Z = (I - B)^{-1} Z\,.$$

Using this insight, we can derive production factor requirements for any vector Z. Let F be the direct factor inputs per unit of gross output. An element in this matrix indicates the share in the value of gross output of a production factor used directly by the country to produce a given product. These are country- and industry-specific—one example would be the value of low-skilled labor used in the Chinese electronics industry to produce one dollar of output and to add up to value-added by construction in our data. The elements in F are direct factor inputs in the industry, because they do not account for value embodied in intermediate inputs used by this industry. To include the latter as well, we multiply F by the total gross output value in all stages of production that is generated in the production process defined above, so that

$$K = F(I-B)^{-1}C, \quad (5.1)$$

in which C indicates the levels of consumption[4] and K is the matrix of amounts of factor inputs attributed to each consumption level. A typical element in K indicates the amount of a production factor f from country i, embodied in consumption of product g in country j. By the logic of Leontief's insight, the sum of all elements in a column of K will be equal to the consumption of this product. Thus we have completed our decomposition of the value of consumption into the value-added by various production factors around the world.[5]

For the purpose of this chapter, we are also interested in the effects of foreign versus domestic final demand for growth in GVC income and jobs. For a particular country i, we define foreign final demand (C^{FOR}) and domestic final demand (C^{DOM}) so that $C^{FOR} + C^{DOM} = C$. Substituting this in the linear system given above, one can now derive the gross output generated because of final demand from home country i, and that generated because of final demand from other countries, so that

$$K = F(I-B)^{-1}C^{DOM} + F(I-B)^{-1}C^{FOR} = K^{DOM} + K^{FOR}. \quad (5.2)$$

In this equation, we have decomposed the amount of factors used in each sector of the home economy as given by K into the amount used to satisfy domestic final demand (K^{DOM}) and the amount used to satisfy foreign demand (K^{FOR}). The latter measures *value-added exports*, defined by Johnson and Noguera (2012) as the amount of value-added produced in a given source country that is ultimately embodied in final products absorbed abroad.

In Table 5.1 we provide an example of a GVC decomposition for final expenditures in the United States on electrical machinery in 1995 and 2008. The expenditure value is given at the basic price concept. A key distinction in the System of National Accounts is between a value at basic prices and at purchasers' prices. The latter is the price paid by the final consumer and consists of the basic price plus trade and transport margins in the handling of the product and any (net) product taxes. The basic price can thus be considered as the price received by the producer of the good. In 1995, the share of the value added in the United States was over 50 percent, but this swiftly dropped in the period following that year. Instead, value was increasingly added in other parts in the world, both within NAFTA and outside. China in particular benefited from U.S. demand for electrical machinery and captured more than 20 percent of the value in 2008. Partly this was by exporting final goods to the United States that had been produced in China (direct contribution), but also it was accomplished indirectly through the production of intermediates (such as parts and components) that are used in the United States and elsewhere to produce final goods destined for the U.S. mar-

Table 5.1 Value-Added in Final Expenditure on Electrical Products in United States (billions of 1995 US$)

	1995	2008	Change
Total expenditure in US$, of which	217	253	36
Domestic value-added	119	106	−13
Foreign value-added, of which	98	147	49
Canada and Mexico	10	15	5
China	7	53	46
East Asia	37	24	−13
EU 27	19	28	9
Other	25	27	2

NOTE: Table shows breakdown of final expenditure by households, firms, and government in the United States on electrical machinery products (ISIC Rev. 3 industries 30 to 33) into value-added in regions at basic prices, excluding domestic trade and transport margins, and in billions of U.S. dollars, deflated to 1995 prices with the overall U.S. CPI. "East Asia" includes Japan, South Korea, and Taiwan. "EU 27" includes all countries of the European Union.

SOURCE: Authors' calculations based on World Input-Output Database, April 2012.

ket. The decline in value-added in Japan, South Korea, and Taiwan is illustrative of the major shifts that occurred in production stages across Asia as China was increasingly used as a production location by East Asian multinationals (Fukao, Ishido, and Ito 2003), an issue we will return to later.

THE WORLD INPUT-OUTPUT DATABASE (WIOD)

To implement the new GVC metrics, one needs to have a database with linked consumption, production, and income flows within and between countries. For individual countries, this type of information can be found in input-output tables. However, national tables do not provide any information on bilateral flows of goods and services between countries. For this type of information, researchers have to rely on data sets constructed on the basis of national input-output tables in combination with international trade data. Various alternative data sets have been built in the past, of which the Global Trade Analysis Project (GTAP) database is the most widely known and used (Narayanan and Walmsley 2008). Other data sets are constructed by the Organisation for Economic Co-operation and Development (OECD; see Ahmad, Chapter 6 of this volume; IDE-JETRO (2006); and Yamano and Ahmad [2006]). However, all these databases provide only one or a limited number of benchmark year input-output tables, which preclude an analysis of developments over time. And although they provide separate import matrices, there is no detailed breakdown of imports by trade partner.

For this chapter, we use a new database, called the World Input-Output Database (WIOD), that aims to fill this gap. The WIOD provides a time series of world input-output tables from 1995 onwards, distinguishing between 35 industries and 59 product groups. The construction of the world input-output tables will be discussed in the following subsection. Another crucial element for this type of analysis comes from detailed value-added accounts that provide information on the use of various types of labor (distinguished by educational attainment level) and capital in production. This is discussed in the subsection titled “Factor Input Requirements.”

World Input-Output Tables: Concepts and Construction

In this subsection we outline the basic concepts and construction of our world input-output tables. Basically, a world input-output table (WIOT) is a combination of national input-output tables in which the use of products is broken down according to their origin. In contrast to the national input-output tables, this information is made explicit in the WIOT. For each country, flows of products both for intermediate and final use are split into domestically produced or imported. In addition, for imports, the WIOT shows which foreign *industry* produced the product. This is illustrated by the schematic outline for a WIOT in Table 5.2. It illustrates the simple case of three regions: 1) Country A, 2) Country B, and 3) the rest of the world. In the World Input-Output Database we will distinguish between 40 individual countries and the rest of the world, but the basic outline remains the same.

The rows in the WIOT indicate the use of output from a particular industry in a country. This can be intermediate use either in the country itself (use of domestic output) or by other countries (in which case it is exported). Output can also be for final use,[6] either by the country itself (final use of domestic output) or by other countries (in which case it is exported). Final use is indicated on the right side of the table, and this information can be used to measure the *C* matrix defined in Section Two, "GVC Incomes and Jobs: Methodology." The sum of all of the uses is equal to the output of an industry, denoted by *Q* in Section Two.

A fundamental accounting identity is that total use of output in a row equals total output of the same industry, as indicated in the respective column in the left-hand part of the table. The columns convey information on the technology of production, as they indicate the amounts of intermediate and factor inputs needed for production. The intermediates can be sourced from domestic industries or imported. This is the *B* matrix from Section Two. The residual between total output and total intermediate inputs is value-added. This is made up by compensation for production factors. It is the direct contribution of domestic factors to output. We prepare the *F* matrix from Section Two on this information after breaking out the compensation of various factor inputs as described in the next subsection, "Factor Input Requirements."

As building blocks for the WIOT, national supply-and-use tables (SUTs) were used; these are the core statistical sources from which

Table 5.2 Schematic Outline of World Input-Output Table (WIOT), Three Regions

	Intermediate industry			Final domestic			
	Country A	Country B	Rest of world	Country A	Country B	Rest of world	Total
Country A industry	Intermediate use of domestic output	Intermediate use by B of exports from A	Intermediate use by RoW of exports from A	Final use of domestic output	Final use by B of exports from A	Final use by RoW of exports from A	Output in A
Country B industry	Intermediate use by A of exports from B	Intermediate use of domestic output	Intermediate use by RoW of exports from B	Final use by A of exports from B	Final use of domestic output	Final use by RoW of exports from B	Output in B
Rest of world (RoW) industry	Intermediate use by A of exports from RoW	Intermediate use by B of exports from RoW	Intermediate use of domestic output	Final use by A of exports from RoW	Final use by B of exports from RoW	Final use of domestic output	Output in RoW
	Value-added	Value-added	Value-added				
	Output in A	Output in B	Output in RoW				

SOURCE: Authors' compilation.

national statistical institutes (NSIs) derive national input-output tables. In short, we derive time series from national SUTs. Benchmark national SUTs are linked over time through the use of the most recent National Accounts statistics on final demand categories, as well as through the use of gross output and value-added by detailed industry. This ensures both intercountry and intertemporal consistency of the tables. As such, the WIOT is built according to the conventions of the System of National Accounts and obeys various important accounting identities. National SUTs are linked across countries through detailed international trade statistics to create so-called international SUTs. This is based on a classification of bilateral import flows by end-use category (intermediate, consumer, or investment), in which intermediate inputs are split by country of origin. These international SUTs are used to construct the symmetric world input-output of the industry-by-industry type. See Timmer (2012) for a more elaborate discussion of construction methods, practical implementation, and detailed sources of the WIOT. Dietzenbacher et al. (2013) provide an in-depth technical discussion.

The construction of the WIOT has a number of distinct characteristics. First, we rely on national supply-and-use tables rather than input-output tables as our basic building blocks. SUTs are a natural starting point for this type of analysis, as they provide information on both products and industries. A supply table provides information on products produced by each domestic industry, and a use table indicates the use of each product by an industry or final user. The linking with international trade data, which is product-based, and with factor use, which is industry-based, can be naturally made in an SUT framework.[7]

Ideally, we would like to use official data on the destination of imported goods and services. However, in most countries these flows are not tracked by statistical agencies. Nevertheless, for imports, most do publish an input-output table constructed with the import proportionality assumption, applying a product's economy-wide import share for all use categories. For the United States, researchers have found that this assumption can be rather misleading, in particular at the industry level (Feenstra and Jensen 2012; Strassner, Yuskavage, and Lee 2009). Therefore, we are not using the official import matrices but instead use detailed trade data to make a split. Our basic data are the bilateral import flows of all countries covered in WIOD from all partners in the world at the HS6-digit product level, taken from the UN Comtrade database.

Based on the detailed description, products are allocated to three use categories: 1) intermediates, 2) final consumption, and 3) investment, effectively extending the UN Broad Economic Categories (BEC) classification. We find that import proportions differ widely across use categories and, importantly, also across country of origin. For example, imports by the Czech car industry from Germany contain a much higher share of intermediates than imports from Japan. This type of information is reflected in our WIOT by using detailed bilateral trade data. The domestic use matrix is derived as total use minus imports.

Another novel element in the WIOT is the use of data on trade in services. As yet, no standardized database on bilateral service flows exists. These flows have been collected from various sources—including the OECD, Eurostat, the International Monetary Fund (IMF), and the World Trade Organization (WTO)—checked for consistency, and integrated into a bilateral service trade database.

Clearly, the validity of the findings in this chapter relies heavily on the quality of the databases used. The WIOD has been constructed with the aim of making maximum use of the publicly available data on national input-output tables, international trade statistics, and production factor incomes. In the process of consolidating these separate databases, inconsistencies have been found and compromises made to arrive at an internally consistent world input-output table. For example, the well-known inconsistency between mirror trade flows in the UN Comtrade data was resolved by focusing on import flows only. Other issues relate to reexports of goods and trade in services that are not very well reflected in today's trade statistics. It is clear that present-day statistical systems are lagging behind the developments in today's world. In particular, trade in services and intangibles such as royalties and licences are still poorly reflected (see, e.g., Feenstra et al. [2010]; Houseman and Ryder [2010]). This should have priority in the future development of international trade statistics.

Factor Input Requirements

For factor input requirements, we collected country-specific data on detailed labor and capital inputs. This includes data on hours worked and on compensation for three labor types, as well as data on capital stocks and compensation. Labor types are distinguished on the basis of educational attainment levels, as defined in the International Standard Classification of Education (ISCED) (low-skilled: ISCED 1 + 2; medium-skilled: ISCED 3 + 4; and high-skilled: ISCED 5 + 6). These series are not part of the core set of national accounts statistics reported by NSIs, and additional material has been collected from employment and labor force statistics. For each country covered, we chose what we considered the best statistical source for consistent wage and employment data at the industry level. In most countries, this was the labor force survey (LFS). In most cases this needed to be combined with an earnings survey, as information on wages is often not included in the LFS. In other instances, an establishment survey or social security database was used. Care has been taken to arrive at series that are time-consistent, as most employment surveys are not designed to track developments over time, and breaks in methodology or coverage frequently occur.

Labor compensation of self-employed persons is not registered in the National Accounts, which, as emphasised by Krueger (1999), leads to an understatement of labor's share. This is particularly important for less advanced economies, which typically feature a large share of self-employed workers in industries like agriculture, trade, business, and personal services. We make an imputation by assuming that the compensation per hour of self-employment is equal to the compensation per hour of employees. For most advanced countries, labor data is constructed by extending and updating the EU KLEMS database (www.euklems.net) using the methodologies, data sources, and concepts described in O'Mahony and Timmer (2009). For other countries additional data has been collected according to the same principles.

Capital compensation is derived as gross value-added minus labor compensation, as defined above. It is the gross compensation for capital, including profits and depreciation allowances. Being a residual measure, it is the remuneration for capital in the broadest sense, including tangible capital (such as machinery and buildings), intangible (such as research and development [R&D], software, database development, branding, and organizational capital), mineral resources, land, and financial capital.

TRENDS IN GVC INCOMES OF MANUFACTURES

In this section, we explore trends in the distributions of value in global production chains using the decompositions introduced in Section Two. We decompose global expenditure on manufacturing products into compensation for factor services that are directly or indirectly needed in the production of these products. Throughout the chapter we use the phrase “global manufacturing” to indicate the set of all production activities directly or indirectly needed in producing final manufacturing goods. Note that this includes not only activities in the manufacturing sector but also production activities in all other sectors, such as agriculture, utilities, business services, and so on, that provide inputs in any stage of the production process. Next, we define “GVC income” as the income of all production factors that have been directly and indirectly used in the production of final manufacturing goods. World GVC income is the GVC income summed over all countries; it will be equal to world expenditure on manufacturing goods as we model all regions in the world in our empirical analysis. By definition, any dollar spent on final goods must end up as income for production factors somewhere in the world.

The share of a country in world GVC income is a novel indicator of the competitive strength of a nation. Compared to traditional competitiveness indicators like a country’s share in world exports, it has three advantages. First, it indicates to what extent a country can compete with other nations in terms of *activities* related to global manufacturing, rather than competing in manufacturing *products* as measured by exports. Second, it is a reflection of an economy’s strength to compete in both domestic and global markets. Countries might gain income by serving foreign demand, but might at the same time lose income in production for the domestic market. The income share of a country in global manufacturing measures the combined net effect. Third, income and employment effects of trade in tasks for separate groups of workers (such as low- and high-skilled) can also be determined in the same unified framework, as shown later on.

Throughout the chapter we will focus on GVC income in the production of final manufacturing goods. We denote these goods by the term "manufactures." Production systems of manufactures are highly prone to international fragmentation, as activities have a high degree of international contestability: They can be undertaken in any country with little variation in quality. It is important to note that GVCs of manufactures do not coincide with all activities in the manufacturing sector; neither do they coincide with all activities that are internationally contestable. Some activities in the manufacturing sector are geared toward production of intermediates for final nonmanufacturing products and are not part of GVCs of manufactures. On the other hand, GVCs of manufactures also include value-added outside the manufacturing sector (such as business services, transport, and communication and finance) and value-added in raw materials production. These indirect contributions will be explicitly accounted for through the modeling of input-output linkages across sectors.

Ideally, to measure competitiveness one would like to cover value-added in all activities that are internationally contestable, and not only those in the production of manufactures.[8] GVCs of services cannot be analyzed, however, as the level of observation for services in our data is not fine enough to zoom in on those services that are heavily traded, such as consultancy services. The lowest level of detail in the WIOD is "business services," which for the most part contains activities that are not internationally traded, and hence are much less interesting to analyze from a GVC perspective. This is all the more true for other services, such as personal or retail services. They require a physical interaction between the buyer and the provider of the service, and a major part of the value-added in these chains is effectively not internationally contestable. More detailed data on trade in, and production of, services is needed before meaningful GVC analyses of final services can be made.

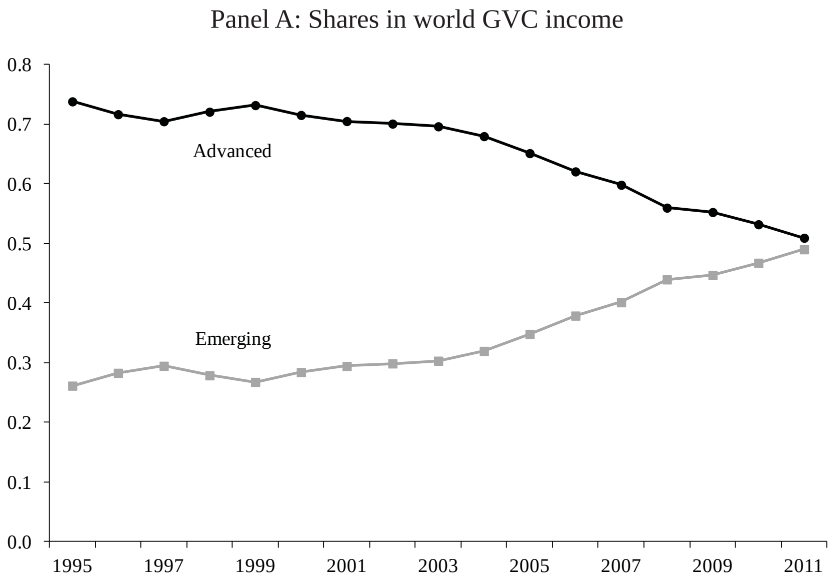
GVC Incomes of Manufactures

Figure 5.2, Panel A, provides a comparison of the GVC incomes in advanced and emerging regions in the production of final manufacturing goods. The GVC income share of advanced countries (East Asia plus the United States, Canada, Australia, and the EU15) has declined from almost three-quarters in 1995 to just above half of world GVC income today. Emerging regions have rapidly increased their shares, and almost all of this increase was realized after 2003. Since 2004 the increase in the GVC income of emerging countries has always been higher than that of advanced countries, reaching a peak in 2008 at a time when advanced countries' GVC income stalled. The drop in the crisis year of 2009 was large for all countries, but recovery occurred much faster in the emerging economies (Figure 5.2, Panel B).

One might hypothesize that shifts in the composition of global manufacturing demand in terms of the type of products being demanded might also be a determinant of the decline of the advanced nations in global manufacturing production. However, the product structure of global demand remained stable over the period 1995 to 2009. Following Engel's law, the expenditure shares of food and other nondurable goods, such as apparel, shoes, furniture, and toys, were on a long-term declining trend. Expenditure on machinery and transport equipment was relatively stable, around 16 percent of the total, as increasing consumer and investment demand from emerging markets was counteracted by declining demand from mature economies. Also, demand for electrical machinery was stagnant in the long run. The only clear upward trend is found for chemical products—including gasoline, cosmetics, and medicines—demand for which has steadily increased around the world, going from 12 percent of global manufacturing expenditures in 1995 to 15 percent in 2008. But these global demand shifts are too small to account for the decline in advanced nations' GVC income. Instead, this decline is due to losses in the amount of value-added in each product's GVC. This will be analyzed in more detail in the remainder of this section.

In Figure 5.3 we show the shares of regions in world GVC income in the production of manufactures for the period from 1995 to 2011. The figure plots measures for five groups of countries: 1) members of the North American Free Trade Agreement (NAFTA) (Canada, Mexico, and the United States); 2) the European Union (EU), consisting of the 27 EU member states; 3) East Asia, consisting of Japan, South Korea, and Taiwan; 4) China; and 5) BRIIAT, which includes Brazil, Russia, India, Indonesia, Australia, and Turkey. In Table 5.3, additional data for 20 major individual economies can be found for 1995 and 2008. It should be kept in mind that international competition is not a zero-sum game, and declining shares in global GVC do not necessarily mean an absolute decline in GVC income in a region. On the contrary, in real

Figure 5.2 GVC Incomes in Advanced and Emerging Countries, All Manufactures, 1995–2011

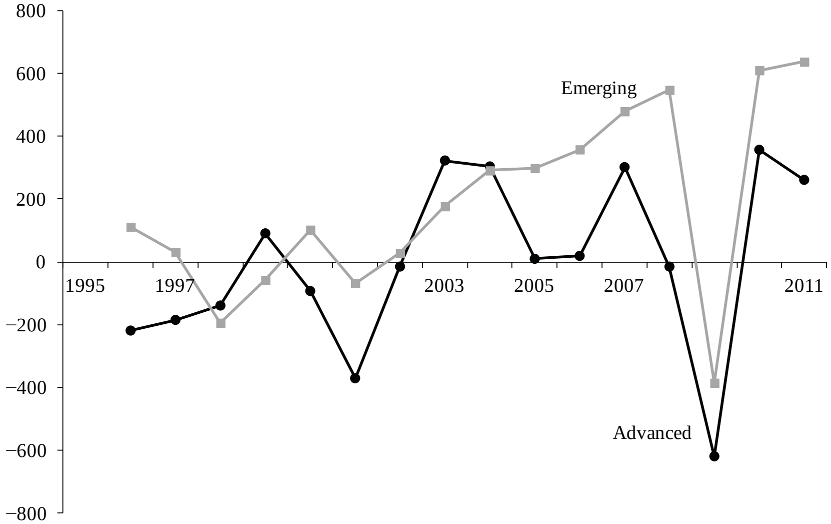


terms, world GVC income on manufactures (deflated by the U.S. Consumer Price Index) rose by about one-third over the period 1995–2008.

Figure 5.3 illustrates that the share of the NAFTA countries in world GVC income increased during the ICT bubble years, climbing as high as 30 percent, at which point their share was even higher than that of the EU. But it rapidly declined after 2001, reaching a low of 20 percent in 2008. The decline of the advanced nations taken as a whole is particularly due to the demise of East Asia, whose share has been dropping rapidly since the mid-1990s. While the shares of South Korea and Taiwan are still increasing, the GVC income share of Japan has been declining precipitously. In contrast, the EU's GVC income share has been relatively stable, only declining slowly over the period from 1995 to 2008. France, Italy, and the United Kingdom slowly lost some shares. The German share dropped rapidly in the latter 1990s but stabilized afterwards. These drops were compensated for by increasing shares for other EU countries, in particular the new member states. As is well known, the aftermath of the global financial crisis hit Europe par-

Figure 5.2 (continued)

Panel B: Annual change (in billions of 1995 US$)

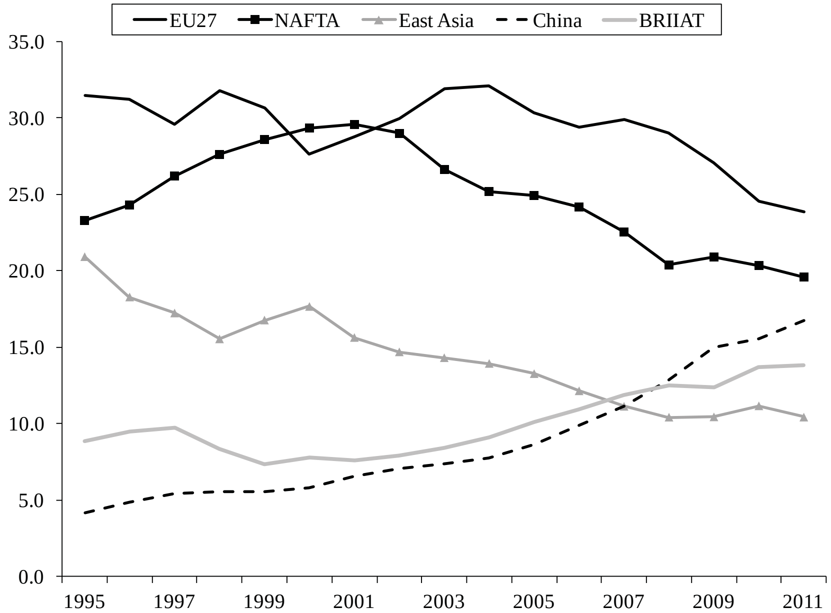


NOTE: "Advanced" nations include the EU15, Japan, Korea, Taiwan, Australia, Canada, and the United States. "Emerging" nations include all other countries in the world. National currencies have been converted to U.S. dollars with official exchange rates, deflated to 1995 prices with the U.S. Consumer Price Index (CPI). World GVC income is equal to world expenditures on manufacturing products at basic prices.
SOURCE: Authors' calculations based on World Input-Output Database. Series updated to 2011 in April 2012.

ticularly hard, and its share dropped sharply, from 32 percent in 2003 to 24 percent in 2011. On the flip side, the share of other regions in the world rapidly increased. China is mainly responsible for the increase of the emerging countries' share, because its share accelerated after its ascension to the WTO in 2000. In 2007 it overtook East Asia in terms of share. In 2009 the Chinese GVC income share overtook that of the combined countries of BRIIAT. And in 2011 its share was almost equal to that of the NAFTA region.[9]

One might argue that these shifts in regional GVC income shares are unsurprising, given the faster growth of China and other emerg-

Figure 5.3 Regional Shares in World GVC Income, All Manufactures, 1995–2011 (%)



NOTE: Figure shows value-added by regions in the production of final manufacturing goods. “East Asia” includes Japan, South Korea, and Taiwan. “BRIIAT” includes Brazil, Russia, India, Indonesia, Australia, and Turkey. “EU27” includes all countries that have joined the European Union. “NAFTA” includes Canada, Mexico, and the United States. Shares do not add up to 100 percent, as the remainder is the share of all other countries in the world.

SOURCE: Authors’ calculations based on World Input-Output Database, April 2012, updated to 2011.

ing economies vis-à-vis advanced regions. Higher consumption in the home economy would naturally lead to higher GVC incomes. But this is only true to the extent that demand for manufactures has a strong home production bias—that is, a bias mainly geared toward goods with a high level of domestic value-added. Given the high tradability of manufacturing goods, this home bias is not obvious, however. Increased Chinese demand for, say, chemicals or electronic equipment can be as easily served by imports as by Chinese domestic production. And in the latter case, a sizable share could still be captured by advanced countries

Table 5.3 Real GVC Income, All Manufactures (in billions of 1995 US$)

Country	1995	2008	Change
Advanced nations			
United States	1,312	1,373	62
Japan	1,154	676	−478
Germany	618	664	46
France	292	330	37
United Kingdom	254	260	6
Italy	289	353	64
Spain	126	171	44
Canada	124	190	66
Australia	68	112	45
South Korea	142	157	15
Netherlands	94	119	25
Other 10 advanced	390	459	69
Total 2l advanced	4,863	4,864	1
Emerging nations			
China	277	1,114	837
Russian Federation	80	246	166
Brazil	164	265	101
India	114	229	115
Mexico	99	208	109
Turkey	73	122	49
Indonesia	83	113	30
Poland	33	86	52
Czech Republic	14	41	27
Rest of world	786	1,396	610
Total emerging countries	1,723	3,820	2,097
World	6,586	8,684	2,098

NOTE: Real GVC indicates the value-added in countries to global output of final manufactures. It includes all manufactures and is in constant 1995 prices using the U.S. Consumer Price Index (CPI) as the deflator. Some numbers in "Change" column may be off by 1 because of rounding.

SOURCE: Authors' calculations based on World Input-Output Database, April 2012.

through the delivery of key intermediate inputs and services. The occurrence of falling shares in global GVC income for advanced regions in Figure 5.2 indicates that these regions failed to capture a large part of the value of the increased market for manufacturing goods in emerging economies. At the same time, the domestic value-added content of their own production declined. Both trends can be interpreted as a loss of competitiveness.

A number of caveats are in order. Shares in world GVC income are expressed in U.S. dollars using current exchange rates. For income changes over time, we deflate incomes in U.S. dollars to the 1995 U.S. dollar value using the U.S. Consumer Price Index (CPI). Exchange rates have fluctuated over the period considered: The dollar-to-euro rate[10] declined sharply over 1995–2001, followed by a steep rise, which by 2007 had returned it to near its 1995 value. The yen-to-dollar rate fluctuated around a long-term constant for this period. The yuan-to-dollar rate was effectively constant over this period, slightly appreciating at the end of the 2000s. The choice of the U.S. dollar as numéraire has no impact on the GVC income measure of a country relative to other countries. For example, expressing GVC income shares in yen or euros would give identical results. But it *will* affect the absolute levels of GVC incomes and hence comparisons over time within a country.

Second, one has to keep in mind that the location where the value is being added is not necessarily identical to where the generated income will eventually end up. The building of global production chains is not only through arms-length trade in intermediate inputs; it also involves sizable flows of investment, and part of the value-added in emerging regions will accrue as income to multinational firms headquartered in advanced regions through the ownership of capital. What is needed is to analyze capital income on a national rather than a domestic basis, as this chapter does in its data on foreign ownership. This type of information is notoriously hard to acquire, not least because of the notional relocation of profits for tax accounting purposes. Hence, further research is needed in this area (Baldwin and Kimura 1998; Lipsey 2010). The decline in East Asian GVC income is likely overestimated, as it is also related to the offshoring of activities to China, which effectively became the assembly place of East Asia. Income earned by East Asian capital is allocated to the place of production (in this case China) and not by ownership, as discussed in Section Two. This difference is probably larger for East Asian countries than for NAFTA or the EU, which have larger FDI flows within the region, so that they net out in regional aggregate numbers.

The Role of Domestic and Foreign Demand

By splitting the final demand vector in the decomposition given in Equation (5.2), we can analyze the importance of domestic versus foreign final demand in the generation of GVC income in a country. The GVC income due to foreign demand is identical to what Johnson and Noguera (2012) refer to as "exports of value-added."[11] Table 5.4 provides the share of GVC income of manufactures due to foreign demand for 20 major economies in the world. The overriding conclusion is that all countries have become increasingly dependent on foreign demand

Table 5.4 Percentage of Real GVC Income Due to Foreign Demand, All Manufactures

Country	1995	2008	Change
Advanced nations			
United States	25.9	33.0	7.1
Japan	24.6	41.8	17.2
Germany	46.3	69.9	23.6
France	53.1	60.0	7.0
United Kingdom	52.6	68.5	15.8
Italy	45.2	52.8	7.6
Spain	39.1	53.3	14.2
Canada	65.8	65.8	0.0
Australia	43.9	55.3	11.3
South Korea	45.2	67.8	22.6
Netherlands	79.3	87.8	8.5
Emerging nations			
China	35.3	48.7	13.5
Russian Federation	42.6	47.3	4.7
Brazil	15.7	26.0	10.3
India	17.7	29.3	11.6
Mexico	32.9	36.5	3.5
Turkey	22.5	35.3	12.8
Indonesia	28.5	38.7	10.2
Poland	42.7	63.0	20.3

NOTE: Numbers represent real GVC income for all manufactures and in constant 1995 prices using the U.S. Consumer Price Index (CPI) as a deflator. Some numbers in the "Change" column may be off by 0.1 because of rounding.

SOURCE: Authors' calculations based on World Input-Output Database, April 2012.

to generate GVC income of manufactures, with the exception of Canada. For all major mature economies, increases in foreign demand have been a necessary spur for slow or even negative growth in their value-added shares in domestic demand. Domestic demand was not a source of growth in the United States, and it contributed strongly to negative growth in Japan, as import substitution took place against a backdrop of stagnating domestic demand. The direction of this trend for advanced countries was to be expected, as the income elasticity of demand for manufactures is low, and in most countries domestic demand is increasingly served through imports with high foreign value-added. But this domestic decline was more than counteracted by a rapid increase in exports of value-added. The most extreme example of this shift toward foreign demand dependence is to be found in Germany, given the large size of its domestic market. In 1995, 46 percent of its GVC income was due to foreign final demand, and by 2008 this had increased to 70 percent. Also, dependence upon foreign demand in Japan, South Korea, Spain, and the United Kingdom rapidly increased over this period.

For emerging economies, changes in foreign demand have been important, but they also have strongly benefited from growth in domestic expenditure on manufacturing. In China, the share of GVC income due to foreign demand increased from 35 percent to 49 percent—which is high, but not outstanding when compared to that of countries of comparable size such as Japan or Germany. The share of foreign demand in Mexico and Russia did barely increase over this period; also, the share for India, while growing, is still at a relatively low level, indicating that the integration of these major emerging economies into world markets is still limited.

Sectoral Origin of GVC Income of Manufactures

The production of manufacturing goods involves a wide variety of activities, which do not take place only in the manufacturing sector. Using the decomposition technique outlined above, one can trace not only the country but also the sector in which value is added during the production process. Typically, the value that is added through activities in the manufacturing sector itself is around half the basic price value of a good, and declines over time. In Table 5.5 we provide for each country the share of a sector in the total value added by the country in

Table 5.5 Sectoral Shares in Total GVC Income, All Manufactures (% of total)

	Natural resources		Manufacturing		Services	
Country	1995	2008	1995	2008	1995	2008
Advanced						
United States	0.06	0.09	0.56	0.52	0.38	0.39
Japan	0.04	0.03	0.65	0.62	0.31	0.35
Germany	0.03	0.02	0.61	0.56	0.36	0.42
France	0.07	0.04	0.48	0.45	0.46	0.51
United Kingdom	0.07	0.07	0.60	0.48	0.34	0.45
Italy	0.05	0.03	0.57	0.52	0.38	0.44
Spain	0.09	0.05	0.54	0.51	0.37	0.43
Canada	0.12	0.19	0.54	0.44	0.34	0.37
Australia	0.20	0.26	0.42	0.34	0.37	0.39
South Korea	0.10	0.04	0.62	0.67	0.28	0.29
Netherlands	0.11	0.12	0.49	0.42	0.40	0.45
Emerging						
China	0.21	0.17	0.58	0.57	0.22	0.26
Russian Federation	0.20	0.21	0.42	0.39	0.38	0.40
Brazil	0.13	0.17	0.55	0.46	0.32	0.37
India	0.22	0.18	0.42	0.41	0.35	0.40
Mexico	0.21	0.22	0.49	0.49	0.30	0.29
Turkey	0.09	0.13	0.64	0.52	0.27	0.36
Indonesia	0.22	0.30	0.61	0.54	0.18	0.16
Poland	0.15	0.10	0.53	0.49	0.32	0.42

NOTE: The numbers represent the share of that sector in total value-added by a country's production of final manufacturing products. "Natural resource" includes the agriculture and mining industries (ISIC Rev. 3 industries A to C), "manufacturing" includes all manufacturing industries (D), and "services" all other industries (E to Q).

SOURCE: Authors' calculations based on World Input-Output Database, April 2012.

global manufacturing expenditure. This is done for 20 major economies in 1995 and 2008, distinguishing between three broad sectors: 1) natural resources, including the agriculture and mining industries (ISIC Rev. 3 industries A to C), 2) manufacturing, including all manufacturing industries (D), and 3) services including all other industries (E to Q). The table shows that the share of manufacturing has declined between 1995 and 2008 in all countries except South Korea and Mexico. The unweighted average share across all 20 countries declined from 54 percent to 50 percent. This partly reflects a shift away from traditional manufacturing activities, such as those carried out by blue-collar production workers, but also the outsourcing of white-collar activities by manufacturing firms to domestic services firms. Contributions from the natural resources sector are high and have increased over the 1995–2008 period in countries such as Australia, Canada, Indonesia, Mexico, Russia,[12] and Turkey. This pattern of value-added suggests that for resource-abundant countries, activities within manufacturing production networks are reinforcing their comparative advantage. Given India's low level of development, services contribute relatively much in that country, reflecting its well-developed business services sector, which delivers intermediate services to both domestic and foreign manufacturing firms. In China, the share of natural resources is declining, and activities in the services sector are starting to contribute more, but the level is still well below the contributions of services in Europe and the United States.

GVC INCOME OF MANUFACTURES BY PRODUCTION FACTOR

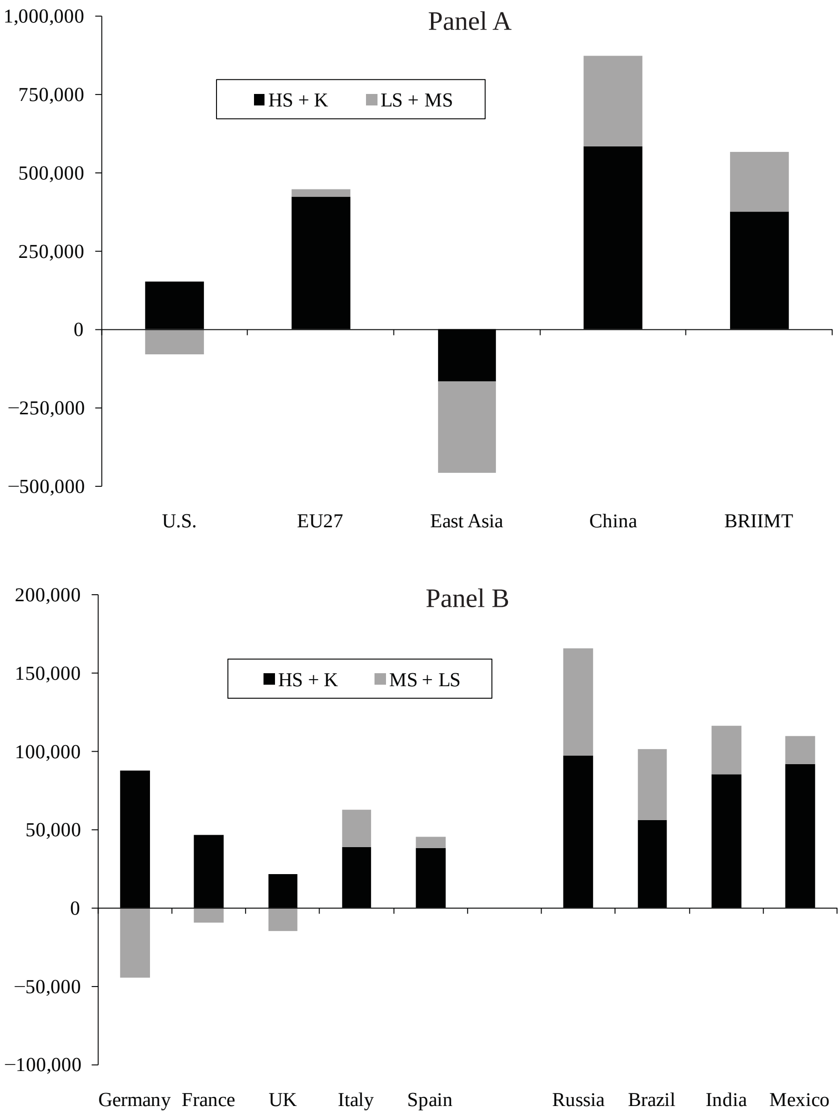
Our income data on labor and capital allow us to study which production factors have benefited from the changes in the regional distribution of global value-added. Increasing trade and integration of world markets have been related to increasing unemployment and stagnating relative wages of low- and medium-skilled workers in developed regions. On the other hand, those factors have offered new opportunities in developing regions for countries to employ their large supply of low-skilled workers. To study these trends, we decomposed value-added into four parts: 1) income for capital and income for labor, further split into 2) low-, 3) medium- and 4) high-skilled labor. High-skilled labor is defined as workers with a college degree or above. Medium-skilled workers have secondary schooling or above, including professional qualifications but below a college degree, and low-skilled have below secondary schooling. An estimate for the income of self-employed workers is included in labor compensation. The income for capital is the amount of value-added that remains after subtracting labor compensation. It is the gross compensation for capital, including profits and depreciation allowances. As a residual measure, it is the remuneration for capital in the broadest sense, including tangible, intangible, mineral resources, land, and financial capital.

In Figure 5.4 and Table 5.6 we provide a breakdown of GVC income by labor and capital for major regions. This is a breakdown of the GVC income discussed in the previous section, “Trends in Manufactures’ GVC Incomes.” At the global level, the share of GVC income that goes to labor is coming down, while the share of capital is increasing. In all regions, the compensation for capital is increasing relative to labor. Particularly in emerging regions, this increase is important and occurs faster than the labor income increase. This might be related to the low wage/rental ratios in these regions, which are still characterized by an abundant surplus of low-skilled workers from agricultural and informal urban sectors. In advanced regions, the increasing importance of capital might be a reflection of the increased investment in so-called intangible assets, which are becoming increasingly important for growth in advanced nations (Corrado and Hulten 2010).

It is important to note that the share captured by capital in emerging markets is known to be overestimated. Our approach is based on domestic production accounting for the location of the production factor and is silent on the ownership, as discussed before. In the case of labor income, this is unproblematic, since for most countries cross-border labor migration is relatively minor. Hence, labor income paid out in a particular country mostly benefits the workers of the country in which production takes place.

Worldwide, medium- and low-skilled workers are losing out to high-skilled workers, as the latter’s share of GVC income is increasing. As expected, GVC income for low-skilled workers has increased strongly in China and in other emerging economies while declining in the advanced regions. In the United States and East Asia, the decline was particularly pronounced for medium-skilled workers. Within Europe, medium-skilled workers in Germany lost the biggest share, and in other European countries the income share going to low-skilled workers also declined. Income for high-skilled workers related to global manufacturing went up in most EU countries. This is not simply the result of a strong supply of higher-skilled labor replacing medium-skilled workers

Figure 5.4 GVC Income by Production Factor (in millions of 1995 US$), Change between 1995 and 2008



NOTE: Figure shows factor income earned by high-skilled labor and capital (HS + K) and by medium- and low-skilled labor (MS + LS). "EU27" includes all countries in the European Union. "BRIIMT" includes Brazil, Russia, India, Indonesia, Mexico, and Turkey.
SOURCE: Authors' calculations based on World Input-Output Database, April 2012, updated to 2011.

Table 5.6 GVC Income by Production Factor and Region (shares in world GVC income)

	Value-added by labor		Value-added by capital		Value-added total	
	1995	2008	1995	2008	1995	2008
EU27	21.5	18.9	9.7	9.8	31.2	28.7
United States	12.8	9.5	7.4	6.7	20.2	16.2
East Asia	12.9	6.1	8.1	4.6	21.0	10.7
China	2.0	5.2	2.1	7.8	4.2	13.0
BRIIMT	4.1	6.1	5.1	7.4	9.3	13.5
Other	6.4	7.3	7.9	10.6	14.3	17.9
World	59.7	53.1	40.3	46.9	100.0	100.0
Advanced	47.1	34.4	25.5	21.2	72.6	55.5
Emerging	12.6	18.8	14.9	25.7	27.4	44.5

	Value-added by high-skilled		Value-added by medium-skilled		Value-added by low-skilled	
	1995	2008	1995	2008	1995	2008
EU27	4.8	6.0	10.0	8.9	6.6	4.0
United States	4.3	4.1	7.4	4.9	1.1	0.5
East Asia	3.2	2.1	7.2	3.3	2.5	0.6
China	0.1	0.4	0.7	1.8	1.3	3.0
BRIIMT	0.8	1.4	1.7	3.0	1.7	1.7
Other	0.8	1.5	2.3	2.9	3.4	3.0
World	14.0	15.5	29.1	24.8	16.6	12.8
Advanced	12.4	12.2	24.8	17.2	10.0	5.0
Emerging	1.6	3.3	4.3	7.6	6.6	7.8

NOTE: "East Asia" includes Japan, South Korea, and Taiwan. "EU27" designates the countries that had joined the EU as of January 1, 2013. "BRIIMT" includes Brazil, Russia, India, Indonesia, Mexico, and Turkey. "Other" is the rest of the world. Skill categories classify workers by their educational attainment levels. World income is equal to world expenditures on manufacturing products at basic prices. Some numbers may not sum to total because of rounding.

SOURCE: Authors' calculations based on World Input-Output Database, April 2012.

but essentially carrying out the same activities; if this were the case, the wages for high-skilled workers should have dropped and the increase in GVC income for high-skilled workers would be limited. However, relative wages for high-skilled workers did not show this pattern (see Timmer et al. 2013).

GVC JOBS IN MANUFACTURES

Many policy concerns surrounding globalization issues are ultimately about jobs—good jobs in particular. The disappearance of manufacturing jobs in advanced nations is occasionally linked to production fragmentation and the associated offshoring of activities; see Bardhan, Jaffee, and Kroll (2013) for an overview. It is thus useful to look at the structure of employment in global value chains and analyze the changes in the characteristics of workers directly and indirectly involved in the production of manufacturing goods—in short, GVC jobs in manufactures.[13] For each country, we will measure the number of workers involved in the domestic territory. As the mobility of labor is much lower than that of capital, GVC jobs will be closer to a national concept than GVC income. We will characterize GVC workers by sector of employment and level of skills. In the next subsection, "The Shift toward Service Jobs in GVCs of Manufactures," we show that only about half of the workers in manufacturing GVCs are actually employed in the manufacturing sector. The other half are employed in nonmanufacturing industries delivering intermediates, and this share is growing. In most countries, GVC job increase in services is even higher than job loss in manufacturing. In the subsection titled "Specialization in High-Skilled Activities in Advanced Countries," on p. 154, we analyze the skill structure of GVC workers and find that there has been a shift away from low-skilled toward high-skilled workers for advanced nations. This increase is faster than the trend in the overall economy, suggesting increased specialization of advanced countries in GVC activities performed by high-skilled workers. This is in line with broad Heckscher-Ohlin predictions of which countries will see a comparative advantage when possibilities for international production fragmentation increase.

The Shift Toward Service Jobs in GVCs of Manufactures

By using the number of workers rather than value-added per unit of output in each industry-country as the requirement vector in Equation (5.1), we can trace the number of workers directly and indirectly involved in the production of manufacturing goods, and their sector of employment. Developments in the 20 main countries over the period from 1995 to 2008 are shown in Table 5.7. The first two columns indicate the share of manufacturing GVC workers as a percentage of the overall workforce in the economy. In the next columns the sectoral structure of employment of these workers is shown. Three sectors are considered—1) agriculture, 2) manufacturing and 3) services (which also include mining, construction, and utilities)—followed by a fourth column for "All sectors." The first set of four columns refers to the absolute number of GVC workers by sector in 2008, while the latter set of four columns refers to the change over the period 1995–2008. Two main facts clearly stand out:

1) The declining importance of global production of manufactures for overall employment in most advanced nations
2) The strong shift in the sector of employment of these workers away from the manufacturing sector toward the services sector

The first two columns of Table 5.7 show the decline in importance of GVCs of manufactures in providing jobs in the economies of all countries except China and Turkey. The job losses in Japan and the United States are major, around 2.9 and 4.6 million, respectively. Also, job loss in the United Kingdom stands out, as more than 1.6 million GVC jobs disappeared in that country alone. The only exception to this trend in advanced countries is Germany: In 2008, 26 percent of German employment was involved in the global production of manufactures, which is the highest share across all advanced countries.

Another important finding on the basis of Table 5.7 is the strong shift toward service jobs in the global production of manufactures since 1995. Faster growth (or slower declines) in service jobs than in manufacturing can be seen in all major advanced countries. As a result, in 2008, the manufacturing sector accounted for about half of the total number of GVC jobs in manufactures in advanced countries. The other

Table 5.7 GVC Workers in Manufactures, 1995 and 2008

	GVC workers in manufactures, as share of all workers in the economy (%)		GVC workers in manufactures in 2008 (in thousands), employed in				Change in GVC workers in manufactures between 1995 and 2008 (in thousands), employed in			
	1995	2008	Agriculture	Manufacturing	Services	All sectors	Agriculture	Manufacturing	Services	All sectors
Advanced										
United States	16.0	11.1	1,143	8,837	6,892	16,872	−331	−3,144	−1,138	−4,612
Japan	22.6	19.4	1,298	6,491	4,417	12,207	−794	−2,225	148	−2,871
Germany	26.8	26.4	400	5,481	4,766	10,647	−161	−666	1,388	561
France	22.0	18.7	303	2,195	2,355	4,853	−96	−423	368	−151
United Kingdom	20.1	12.6	115	1,946	1,931	3,992	−128	−1,148	−347	−1,624
Italy	29.1	25.5	333	3,553	2,559	6,444	−192	−234	517	91
Spain	23.2	17.5	271	1,827	1,494	3,592	−97	185	353	440
Canada	20.8	16.0	157	1,138	1,482	2,777	−102	−136	193	−45
Australia	18.2	14.5	165	641	855	1,661	−48	3	196	150
South Korea	29.7	22.8	655	2,646	2,077	5,378	−468	−735	524	−679
Netherlands	22.8	19.0	89	643	929	1,661	−42	−87	158	29
Emerging										
China	31.7	33.3	121,342	87,568	49,468	258,378	9,963	20,508	11,965	42,436
Russian Federation	24.7	21.9	4,259	6,749	6,228	17,237	−1,403	−2,120	2,198	−1,325
Brazil	29.6	28.7	8,347	9,490	9,823	27,660	−705	2,450	4,118	5,863
India	27.9	27.3	57,926	41,933	26,483	126,343	2,118	10,896	7,025	20,039
Mexico	30.3	24.4	2,817	6,128	3,205	12,150	−400	1,403	1,121	2,124

Turkey	27.1	30.4	1,778	3,115	1,554	6,446	−341	620	584	863
Indonesia	32.1	25.6	13,921	7,427	5,725	27,073	−1,899	−425	1,380	−944
Poland	31.0	28.8	917	2,278	1,347	4,542	−468	81	368	−19
Czech Republic	30.8	30.9	93	990	553	1,636	−59	74	35	50

NOTE: GVC workers are workers directly or indirectly involved in the production of manufacturing goods. Columns 3 through 6 indicate the total number of GVC workers by sector in 2008; columns 7 through 10 indicate the change in the number of GVC workers by sector between 1995 and 2008. The last column shows the change in the total number of workers in the economy for that period. Some numbers in the "All sectors" columns may be off by 1 because of rounding.

SOURCE: Authors' calculations based on World Input-Output Database, April 2012.

half of those jobs are found in agriculture and even more so in services—workers who are involved in the production of intermediate goods and services used in the manufacturing process. These findings testify to the increasing intertwining of manufacturing and service activities.

Following Baumol's cost disease hypothesis, one might argue that this shift in the sectoral distribution of the GVC jobs might be interpreted as the result of differential productivity growth in manufacturing and services. But while there is clear evidence that productivity growth in manufacturing is higher than in services overall, this does not necessarily hold for the service activities in GVCs of manufactures. These only form a subset of the services sector, and they involve in particular intermediate services such as wholesaling, transportation, finance, and several business services.[14] These activities are generally open for international competition and likely to have much higher rates of innovation and productivity growth than service activities for domestic demand, which are dominated by personal services, education, health, and public administration. Hence, it seems more likely that our findings are indicative of a fundamental shift in the type of activities carried out by advanced countries in the global production of manufactures—a shift away from blue-collar manufacturing to white-collar service activities. This hypothesis is confirmed when one analyzes the skill content of GVC jobs, as is done in the next subsection.

In the major emerging economies, most of the jobs are still added in the manufacturing sector, as is to be expected. For China, India, Mexico, and Turkey, job increases in manufacturing outnumber those in the services sector. In Brazil, however, services job growth appears to be more important. Even more strongly, in Indonesia and Russia the number of jobs in the production of manufactures has declined. These countries actually lost jobs overall for the period 1995–2008 and seem to have entered a premature deindustrialization phase.

Specialization in High-Skilled Activities in Advanced Countries

In a world with international production fragmentation, the broad Heckscher-Ohlin predictions will still hold: Countries will carry out activities for which local value-added content is relatively intensive amongst their abundant factors. In fact, increased opportunities for international production fragmentation may have the tendency to magnify the comparative advantage of countries, as suggested by Baldwin and Evenett (2012). A simple example will illustrate. Assume two goods, A and B, which are both produced with two activities: a low-skilled (LS) and a high-skilled (HS) activity. Before unbundling, Goods A and B are bundles of production activities with different skill intensities. Assume that Good A is on average more skill-intensive than Good B, as the HS activity is more important in the production of A than of B. A relatively skill-abundant country would specialize in the production of A, and a skill-scarce country in the production of B. After unbundling, each nation specializes in specific production activities. The skill-abundant country will specialize in the HS activities in the production of both goods, and the skill-scarce country in the LS activities for those goods. As a result, the potential range of comparative advantages across countries in activities will be greater than in the final products (see, e.g., Deardorff [2001]).[15]

To test this prediction, we analyze the number of workers by skill type needed in GVCs of manufactures using Equation (5.1) in combination with a skill requirement vector. This vector is based on a characterization of workers in each industry and country by their observable educational attainment levels, as described in Section Three, "The World Input-Output Database (WIOD)." This delivers the number of low- (LS), medium- (MS) and high-skilled (HS) GVC workers for a particular year. Results are given in Table 5.8. We find that during 1995–2008, in all advanced countries combined, the increase in high-skilled jobs was 4.6 million. Medium-skilled jobs declined by nearly 3.8 million, and the drop in low-skilled jobs was even bigger—9.7 million. This pattern of high-skilled jobs growing faster (or declining slower) than medium- and low-skilled jobs can be found for most countries. But there are some regional differences. In the United States, employment in global production of manufactures dropped for all workers, in particular the medium-skilled. This is a well-known phenomenon that characterizes a broader segment of the U.S. economy and has been extensively studied (see, e.g., Autor [2010]). More surprising is the finding that the number of high-skilled jobs has also declined. This is in stark contrast to Japan and the major EU countries: There, less-skilled jobs also dwindled, but this was at least in part compensated for by increasing opportunities for high-skilled jobs.

Table 5.8 Change in Number of Workers in Global Production of Final Manufactures by Skill Type, 1995 and 2008 (in thousands)

Country	Low	Medium	High	Total
United States	−1,125	−3,286	−201	−4,612
Japan	−1,834	−1,399	361	−2,871
Germany	−168	115	614	561
France	−768	52	566	−151
United Kingdom	−1,236	−560	172	−1,624
Italy	−1,201	853	439	91
Spain	−507	391	556	440
Canada	−118	−105	177	−45
Australia	−84	141	94	150
South Korea	−1,110	−335	766	−679
Netherlands	−119	−54	202	29
Other 10 advanced	−1,441	425	840	−176
Total 21 advanced	−9,711	−3,762	4,587	−8,886
All other countries	56,214	64,370	19,393	139,977
World	46,503	60,607	23,981	131,091

NOTE: Figures represent changes in the number of workers (including both employees and self-employed) involved in global production of final manufactures between 1995 and 2008, split into the number of low-skilled, medium-skilled, and high-skilled workers based on educational attainment. Some numbers may be off by 1 because of rounding.

SOURCE: Authors' calculations based on World Input-Output Database, April 2012.

CONCLUSION

A global-value-chain perspective has profound implications for how one thinks of competitiveness and growth. It highlights the importance of global production networks and the increasing interrelation of consumption, production, and income across national boundaries through the trade of goods and services. Enhancing competitiveness and growth is increasingly about capturing a larger share of global value chains—in particular, of products for which global demand is growing (Porter 1990). This rise of global value chains (GVCs) is also posing new challenges to analyses of international trade and measures of countries' competitiveness.

In this chapter, we take a macro perspective and analyze the value-added of production for a wide set of manufacturing product groups. This is done through a newly developed accounting method in which we build upon an input-output modeling of the world economy in the tradition of Leontief (1949). The novelty of our approach is that we trace the value added by all labor and capital that is directly and indirectly used for the production of final manufactures. We call this “GVC income.” We also introduce the related concept of “GVC jobs,” which connotes the number of jobs directly and indirectly needed in the production of final goods. To measure GVC incomes and jobs for a wide set of countries in the world, we use the global input-output tables and supplementary labor accounts from the World Input-Output Database, available at www.wiod.org and described in Timmer (2012).

The chapter presents new evidence on the main changes in GVC income and jobs across both mature and developing countries. Taken together, the results show that international fragmentation in the production of manufactures has been accompanied by a rapid shift toward higher-skilled activities in advanced nations. These activities are increasingly carried out in the services sector and no longer in the manufacturing sector itself. As such, the shift contributes to the so-called job polarization in advanced economies, as the displaced manufacturing workers are likely to be absorbed into personal and distributional services, where low-skilled employment opportunities are still growing (Goos, Manning, and Salomons 2011). Emerging economies are taking up increasing shares in global GVC income; much of this increase has been driven by rapid growth in China after its accession to the WTO in 2001. We also find increasing intertwining of manufacturing and services activities, which argues against a myopic view of manufacturing jobs in discussions on GVC issues. Rather than focusing on the particular sector in which jobs are lost or created, the discussion should be led by a view toward the activities that are carried out in GVCs, irrespective of the sector in which they are ultimately classified. Thinking in terms of sectors is basically a relic of a world where fragmentation of production, both domestically and internationally, had not progressed far.

Although the model to measure GVC income and jobs is relatively straightforward, it is clear that the validity of the findings relies heavily on the quality of the database used. The WIOD is a prototype database developed mainly to provide a proof-of-concept, and it is up to the statistical community to bring international input-output tables into the realm of official statistics. The development work done by the OECD (Ahmad, Chapter 6 of this volume) is certainly a step in the right direction. Various weak areas in data remain, particularly in the measurement of trade in services and intangibles. In addition, because of the lack of firm-level data matching national input-output tables, one currently has to rely on the assumption that all firms in an industry have a similar production structure. If various types of firms, in particular exporters, have a different production technology and input sourcing structure (i.e., they import larger shares), more detailed data might reveal a bias in the results presented here. More information on the ownership of capital income, which is currently measured on a domestic basis rather than on a national basis, is also desirable. This is far from easy, though, and in pursuing this line of investigation one needs to trace not only the nationality of the firms involved but also the nationality of the ultimate claimants of residual profits.

Arguably the most important area where more study is needed is in tracing where in the value chain the profits from lead firms are realized, as well as how these are recorded in the current statistical system. For example, the product case studies by Dedrick, Kraemer, and Linden (2010), among others, suggest that the profits made by the lead firms in the chains can only be inferred by comparing the final purchase and exfactory prices of the product, which include the trade margins (see also Gereffi 1999). The use of brand names, software, knowledge systems, and other intangibles of the lead firm by other firms in the chain is typically not compensated for by a direct money flow from the users. Rather, the compensation is realized indirectly through the ability of the lead firm to have the exclusive right to sell the particular product with a premium through its own (or through other tightly controlled) sales channels. This indirect compensation takes place in value chains that are completely within a multinational enterprise, but it also arises in chains that are to a large extent organized through arm's-length transactions. When the residual profits are realized—in other words, when manufacturing firms sell to final consumers—this is picked up in our GVC income measure. But alternative value-chain arrangements are feasible.

One particular example is the existence of so-called factoryless goods producers (FGPs), which are proliferating in the United States.

These are firms that are manufacturer-like in that they perform many of the tasks and activities found in manufacturing establishments themselves, except for the actual manufacturing production process. In the current U.S. statistical system they are classified in wholesaling, and their output is recorded as a wholesale margin rather than as manufacturing sales. The value-added of these firms should clearly be part of GVC incomes of manufactures but are currently not picked up, since GVC income is measured at basic prices, which means that trade and transport margins associated with final consumption are not included in GVC incomes. This might bias downwards the total GVC income for the United States compared to other countries to the extent that FGP production is more prominent in this country than in other countries. The scope for this bias is not particularly large, however. Bernard and Fort (2013) suggest that reclassifying the FGPs to the manufacturing sector would increase reported U.S. manufacturing output in 2007 by about 5 percent in a conservative estimate and by a maximum of 17 percent using a more liberal set of assumptions. A deeper understanding of the workings of global value chains is clearly needed before our measurement systems will adequately reflect all of their intricacies.

Notes

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1. Additional applications of the GVC income concept and analysis of fragmentation can be found in Timmer et al. (2014) and Los, Timmer, and de Vries (2014).
2. This identity does not hold true at the country level, as countries can have current account imbalances driving a wedge between value-added produced and final consumption value.
3. See Miller and Blair (2009) for an introduction to input-output analysis.
4. Throughout the paper, we analyze final expenditure, including private and government consumption, and investment.

5. Variations of this approach are also used in the burgeoning literature on trade in value-added, and our approach is related to the work by Koopman, Wang, and Wei (2014) and in particular the work by Johnson and Noguera (2012). But rather than using Leontief's insight to analyze factor content of trade flows, we focus on analyses of global value distributions.
6. Final use includes consumption by households, government and nonprofit organizations, and gross capital formation.
7. Because industries also have secondary production, a simple mapping of industries and products is not feasible.
8. When considering all goods and services produced, the GVC income of a country is equal to gross domestic product when final demand for all goods and services in the world economy are taken into account. Hence, for a meaningful analysis, one has to limit the group of products, and we focus on those products for which production processes are most fragmented and which can be analyzed with the data at hand.
9. We do not show the value-added by the "Rest of the World," consisting of all countries not covered individually in the world input-output database but for which an estimate has been made as a group (see Section Three, "The World Input-Output Database [WIOD]"). Its share in global GVC income rose from 14 percent in 1995 to 17 percent in 2008.
10. The euro was introduced in 2001. For the period before 2001, we are referring to the Deutsche Mark.
11. Johnson and Noguera (2012) focused on foreign final demand for all goods and services, not only on final manufactures as we do here.
12. The share of the natural resource sector in Russia is severely underestimated, since part of the oil and gas production is classified under wholesale services rather than under mining in the Russian national accounts. Adding the wholesale sector would almost double the natural resource share in 2008.
13. We will use the term "jobs" instead of "number of workers" as shorthand. But the underlying data pertains to number of workers rather than jobs. Ideally, one would like to measure hours worked.
14. It should be noted that these numbers exclude any jobs involved in the retailing of manufacturing goods, as we analyze final demand at the basic price concept.
15. Following this traditional international trade theory, having a greater range of comparative advantages across countries would generate higher welfare improvements from trade. These models are essentially comparative, static of nature, and they disregard any dynamic effects. In the innovation and business literature, it has been recently argued that the separation of high-skilled, innovative activities in advanced countries from production in emerging economies will in the long run lead to a decline of innovation activity. In this literature, the spillovers from manufacturing and innovation activities are central (see, e.g., Pisano and Shih [2012]).

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6
Measuring Trade in Value-Added and Beyond

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Global value chains (GVCs) have become a dominant feature of today's global economy. This growing process of international fragmentation of production, driven by technological progress, cost, trade policy reforms, and access to resources and markets, has challenged the conventional wisdom on how we look at and interpret trade and, in particular, the policies that we develop around it. Indeed, taken by themselves, traditional measures of trade, which record gross flows of goods and services each and every time they cross borders, may lead policymakers to make misguided decisions.

In practice, two main approaches (micro and macro) have been used to shed light on this issue. The former is perhaps best characterized by the well-known Apple iPod example (Dedrick, Kraemer, and Linden 2010), which showed that of the $144 factory-gate price of an iPod dispatched from China, less than 10 percent represented Chinese value-added, with the bulk of the components (costing about $100) being imported from Japan and much of the rest coming from the United States and Korea.

But this stylized approach can generally only be conducted for specific products and, even then, only reveals part of the story related to who benefits from trade and how GVCs work, as it is typically unable to reveal how the intermediate parts are created. For example, the message would be significantly different if, for sake of argument, the imported parts from Japan used to make the iPod required significant Chinese content. To deal with the bigger picture and also to capture all of the upstream effects, a number of studies have adopted a macro approach based on the construction of intercountry or world input-output tables (Daudin, Rifflart, and Schweisguth 2009; Hummels, Ishii, and Yi 2001;

Johnson and Noguera 2012; Koopman et al. 2011). And a number of pioneering initiatives, such as those of the Global Trade Analysis Project (GTAP), collaborative efforts between the World Trade Organization (WTO) and the Institute of Developing Economies–Japan External Trade Organization (IDE-JETRO), and the World Input-Output Database (WIOD), have helped accelerate improvements in the underlying statistics used to construct the results.

But these studies and initiatives have generally been one-off in nature and often require the use of nonofficial statistical data. What has been lacking thus far has been a systematic attempt to mainstream the development of statistics in this area. In response to this need, on March 15, 2012, the Organisation for Economic Co-operation and Development (OECD) and WTO joined forces to develop a database of Trade in Value-Added (TiVA) indicators and to mainstream their production within the international statistics system. The first preliminary results from this intiative were released on January 16, 2013, and some highlights from this first release are presented in the following sections of this chapter. But, as described below, further work is needed (and can be done) in order to improve the quality of the estimates produced under the “trade in value-added” umbrella.

Ultimately this chapter acts, in some ways, as a clarion call to statistical agencies to alert them that the world is increasingly interconnected and that conventional approaches used to understand how economies work can no longer rely solely on national statistics. Increasingly, it is necessary to see the whole in order to understand how economies work and, for example, how to target and create industrial policies focusing on competitiveness (notwithstanding trade policies and the implications and importance of trade). National statistics build pictures based on interrelationships between producers and consumers and the rest of the world. But these relationships, particularly those with the rest of the world, have become increasingly more complex, and, as such, there is an increasing need to consider global production within a global accounting framework. This implies a departure from the traditional role of international organizations as compilers of internationally comparable national statistics, such as national input-output or supply-use tables. Instead, it requires that they bring together these national tables to create a global table.

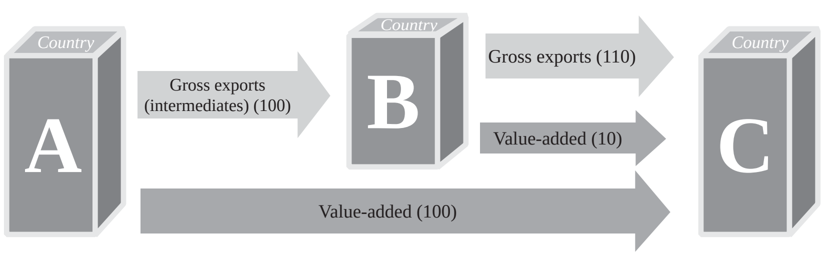
The remainder of this chapter describes the policy drivers and needs for such a framework, as well as the underlying methodology and assumptions used to estimate trade in value-added, before assessing the implications for statistics offices, data collection, and national input-output tables in particular. It ends by describing longer-term future avenues of research.

WHAT IS TRADE IN VALUE-ADDED?

The "trade in value-added" initiative addresses the double counting implicit in current gross flows of trade. Instead of using that method, it measures flows related to the value that is added (labor compensation, other taxes on production, and operating surplus, or profits) by a country in the production of any good or service that is exported.

The simple example shown in Figure 6.1, below, illustrates this. Country A exports $100 of goods, produced entirely within A, to Country B, which further processes them before exporting them to Country C, where they are consumed. Country B adds value of $10 to the goods and so exports $110 to C. Conventional measures of trade show total global exports and imports of $210, but only $110 of value-added has been generated in their production. Conventional measures also show that C has a trade deficit of $110 with B, and no trade at all with A, despite the fact that A is the chief beneficiary of C's consumption.

Figure 6.1 Exports: Gross and Value-Added Flows, in US$



SOURCE: Author's composition.

If instead we track flows in value-added, one can recalculate C's trade deficit with B on the basis of the value-added it "purchases" from B as final demand, which reduces its deficit on this basis to $10, and apply the same approach to A's value-added to show C running a deficit of $100 with A. Note that C's overall trade deficit with the world remains at $110. All that has changed is its bilateral positions. This simple illustration reveals how output in one country can be affected by consumers in another, and by how much. (An example of this is C's consumers driving A's output.) However, it can also reveal many other important insights into global value chains. For example, it shows that B's exports depend significantly on intermediate imports from A, and so reveals that protectionist measures on imports from A could harm its own exporters and hence competitiveness. Indeed, by providing information at the level of specific industries, it is possible to provide insights in other areas, too, such as the contribution of the service sector to international trade.

HOW CAN MEASURES OF TRADE IN VALUE-ADDED INFORM POLICYMAKING?

Even though the literature on trade in value-added is quite technical, it has attracted a lot of attention from policymakers. What initially seemed a concern for trade statisticians is now understood as a key issue for the policy debate. For example, Pascal Lamy, the director-general of the World Trade Organization (WTO), noted that "the statistical bias created by attributing commercial value to the last country of origin perverts the true economic dimension of the bilateral trade imbalances. This affects the political debate, and leads to misguided perceptions" (Lamy 2011). Recently, the French Senate devoted a special seminar to the related statistical and policy issues (WTO and Sénat 2011). There are a number of areas where measuring trade in value-added terms brings a new perspective and is likely to have an impact on policies. Seven key areas are described below:

1) **Trade, growth, and competitiveness.** A better understanding of how much domestic value-added is generated by the export of a good or service in a country is crucial for devel-

opment strategies and industrial policies. Some countries have capitalized on GVCs by developing comparative advantages in specific parts of the value chain. For example, in China, many of its exports involve assembly work, where the foreign content is high. Access to efficient imports therefore matters as much in a world of international fragmentation as access to markets. Conventional gross trade statistics, however, are not able to reveal the foreign content of exports, and so there is a risk that policies to protect industries where gross statistics reveal a comparative advantage may decrease the competitiveness of those very same domestic industries. Because of this, mercantilist-style "beggar thy neighbor" strategies can turn out to be "beggar thyself" miscalculations.

2) **Domestic value-added in imports**. Domestic value-added is found not only in exports but also in imports: Goods and services produced in one domestic industry are intermediates shipped abroad whose value comes back to the domestic economy embodied in the imports of other, and often the same, industries. As a consequence, tariffs, nontariff barriers, and trade measures—such as antidumping rights—can also affect the competitiveness of domestic upstream producers (as well as the competitiveness of downstream producers, as mentioned above), in addition to foreign producers. For example, a study on the European shoe industry undertaken by the Swedish National Board of Trade highlights that shoes "manufactured in Asia" incorporate between 50 and 80 percent of European Union (EU) value-added. In 2006, antidumping rights were introduced by the European Commission on shoes imported from China and Vietnam. An analysis in value-added terms would have revealed that EU value-added was in fact subject to the antidumping rights (Isakson and Verrips 2012).

3) **Improving competitiveness in upstream domestic industries can boost exports**. Looking at trade from a value-added perspective is also a way to better reveal how upstream domestic industries contribute to exports, even if those same industries have little direct international exposure. Gross trade statistics, for example, reveal that less than one-quarter of total global

trade is in services. But in value-added terms the share is significantly higher. Goods industries require significant intermediate inputs of services, both from foreign and also from domestic suppliers. Looking at trade in value-added terms therefore can reveal that policies to encourage services trade liberalization and more foreign direct investment (and so policies designed to improve access to more efficient services) can improve the export competitiveness of goods industries.

4) **Global imbalances**. Accounting for trade in value-added (specifically accounting for trade in intermediate parts and components), and taking into account “trade in tasks,” does not change the overall trade balance of a country with the rest of the world—rather, it redistributes the surpluses and deficits across partner countries. When bilateral trade balances are measured in gross terms, the deficit with final goods producers (or the surplus of exporters of final products) is exaggerated because it incorporates the value of foreign inputs. The underlying imbalance is in fact with the countries who supplied inputs to the final producer. As pressure for rebalancing increases in the context of persistent deficits, there is a risk of protectionist responses that target countries at the end of global value chains on the basis of an inaccurate perception of the origin of trade imbalances. As shown in the section starting on p. 172, the preliminary results from the OECD-WTO database point to significant changes.

5) **The impact of macroeconomic shocks**. The 2008–2009 financial crisis was characterized by a synchronized trade collapse in all economies. Authors have discussed the role of global supply chains in the transmission of what was initially a shock on demand in markets affected by a credit shortage. In particular, the literature has emphasized the “bullwhip effect” of GVCs (Escaith, Lindenberg, and Miroudot 2010; Lee, Padmanabhan, and Whang 1997). When there is a sudden drop in demand, firms delay orders and run down inventories, with the consequence that the fall in demand is amplified along the supply chain and can translate into a standstill for companies located upstream. A better understanding of value-added trade flows would provide tools for policymakers to anticipate the impact

of macroeconomic shocks and adopt the right policy responses. Any analysis of the impact of trade on short-term demand is likely to be biased when looking only at gross trade flows. This was recently demonstrated in the aftermath of the natural disaster that hit Japan in March 2011.[1]

6) **Trade and employment**. Several studies on the impact of trade liberalization on labor markets try to estimate the "job content" of trade. Such analysis is only relevant if one looks at the value-added of trade. What the value-added figures can tell us is where exactly jobs are created. Decomposing the value of imports into the contribution of each economy (including the domestic one) can give an idea of who benefits from trade. The EU shoe industry example given above can be interpreted in terms of jobs. Traditional thinking in gross terms would regard imports of shoes manufactured in China and Vietnam by EU shoe retailers as EU jobs lost and transferred to these countries. But in value-added terms, one would have to account for the EU value-added, and while workers may have indeed lost their jobs in the EU at the assembly stage, value-added-based measures would have highlighted the important contribution made by those working in the research, development, design, and marketing activities that exist because of trade (and the fact that this fragmented production process keeps costs low and EU companies competitive). When comparative advantages apply to "tasks" rather than to "final products," the skill composition of labor embedded in the domestic content of exports reflects the relative development level of participating countries. Industrialized countries tend to specialize in high-skilled tasks, which are better paid and capture a larger share of the total value added. A WTO and IDE-JETRO study on global value chains in East Asia shows that China specializes in low-skilled types of jobs. Japan, on the other hand, has been focusing on export activities intensive in medium- and high-skilled labor while importing goods produced by low-skilled workers. The study also shows that in 2006 the Republic of Korea was adopt-

ing a middle-ground position but was also moving closer to the pattern found in Japan (WTO and IDE-JETRO 2011).

7) **Trade and the environment.** Another area where the measurement of trade flows in value-added terms would support policymaking is in the assessment of the environmental impact of trade. For example, concerns over greenhouse gas emissions and their potential role in climate change have triggered research on how trade openness affects CO_2 emissions. The unbundling of production and consumption and the international fragmentation of production require a value-added view of trade to understand where imported goods are produced (and hence where CO_2 is produced as a consequence of trade). Various OECD studies note that the relocation of industrial activities can have a significant impact on differences in consumption-based and production-based measures of CO_2 emissions (Ahmad and Wyckoff 2003; Nakano et al. 2009).

EARLY EVIDENCE FROM THE OECD-WTO DATABASE

Currently, the database is based on a global input-output table that brings together national input-output tables for 57 economies, combined with bilateral trade data on goods and services broken down into 37 industries aggregated from a 48-industry list (see Table 6.1). The following provides an overview of the key messages provided by the data.[2]

Exports Require Imports

The data reveal that the import content of exports—the share of value added by the export of a given product that originates abroad—is significant in all countries for which data are presented (40 at the time of this writing: all 34 OECD countries, Brazil, China, India, Indonesia, the Russian Federation, and South Africa—see Figure 6.2).

Typically, the larger a country, the lower the overall foreign content; this reflects, in part, scale and cost. But a number of smaller economies also have relatively low foreign content in their exports, such as Aus-

Table 6.1 OECD Input-Output Industry Classification and Concordance with ISIC

ISIC Rev. 3 code		Description
1 + 2 + 5	1	Agriculture, hunting, forestry, and fishing
10 + 11 + 12	2	Mining and quarrying (energy)
13 + 14	3	Mining and quarrying (nonenergy)
15 + 16	4	Food products, beverages, and tobacco
17 + 18 + 19	5	Textiles, textile products, leather, and footwear
20	6	Wood and products of wood and cork
21 + 22	7	Pulp, paper, paper products, printing, and publishing
23	8	Coke, refined petroleum products, and nuclear fuel
24ex2423	9	Chemicals, excluding pharmaceuticals
2423	10	Pharmaceuticals
25	11	Rubber and plastics products
26	12	Other nonmetallic mineral products
271 + 2731	13	Iron and steel
272 + 2732	14	Nonferrous metals
28	15	Fabricated metal products, except machinery and equip.
29	16	Machinery and equipment, n.e.c.
30	17	Office, accounting and computing machinery
31	18	Electrical machinery and apparatus, n.e.c.
32	19	Radio, television, and communication equipment
33	20	Medical, precision, and optical instruments
34	21	Motor vehicles, trailers, and semitrailers
351	22	Building and repairing of ships and boats
353	23	Aircraft and spacecraft
352 + 359	24	Railroad equipment and transport equipment, n.e.c.
36 + 37	25	Manufacturing, n.e.c.; recycling (including furniture)
401	26	Production, collection, and distribution of electricity
402	27	Manufacture of gas; distribution of gaseous fuels through mains
403	28	Steam and hot water supply
41	29	Collection, purification, and distribution of water
45	30	Construction
50 + 51 + 52	31	Wholesale and retail trade; repairs
55	32	Hotels and restaurants
60	33	Land transport; transport via pipelines
61	34	Water transport

(continued)

Table 6.1 (continued)

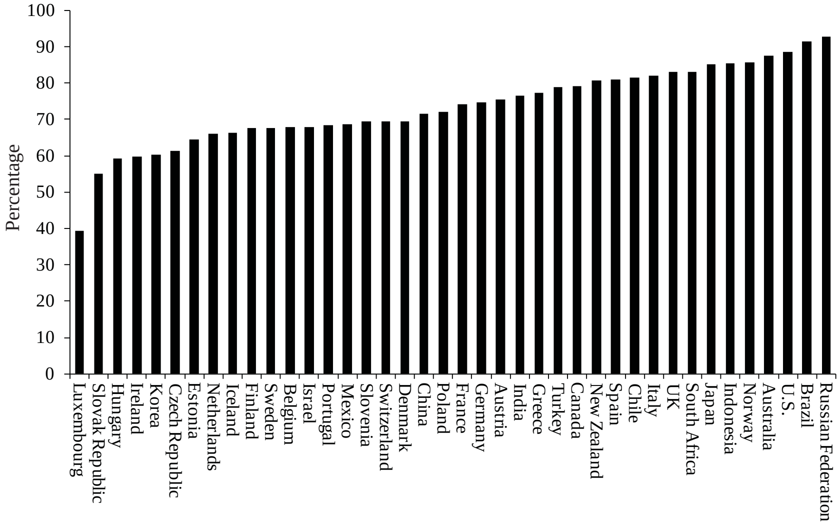
ISIC Rev. 3 code		Description
62	35	Air transport
63	36	Supporting and auxiliary transport activities; activities of travel agencies
64	37	Post and telecommunications
65 + 66 + 67	38	Finance and insurance
70	39	Real estate activities
71	40	Renting of machinery and equipment
72	41	Computer and related activities
73	42	Research and development
74	43	Other business activities
75	44	Public administration and defense; compulsory social security
80	45	Education
85	46	Health and social work
90–93	47	Other community, social, and personal services
95 + 99	48	Private households and extraterritorial organizations

NOTE: "n.e.c." stands for "not elsewhere classified."
SOURCE: Author's compilation.

tralia, Chile, and Norway. This can be explained by their high share of exports of natural resource goods, such as ores, oil, and copper, which have, not surprisingly, a low foreign content. Geography also plays a role; this helps to explain New Zealand's relatively low ratio, as well as its relatively high dependency on agricultural exports, which also have a low foreign content. For midsize economies, however, particularly those in Eastern Europe, the norm is that around one-third of the value of exports reflects foreign content.

Notwithstanding some of the interpretative caveats above, the ratio is perhaps the single most digestible indicator of the propensity of a country to engage in global value chains. It reveals the existence of European, Asian, and North American production hubs and also the significant dependency many countries have on imports to generate exports. In Mexico, with its maquiladoras, and in China, with its processors/assemblers, about one-third of overall exports reflect foreign content (and, as described below, these are considered to be conservative estimates).

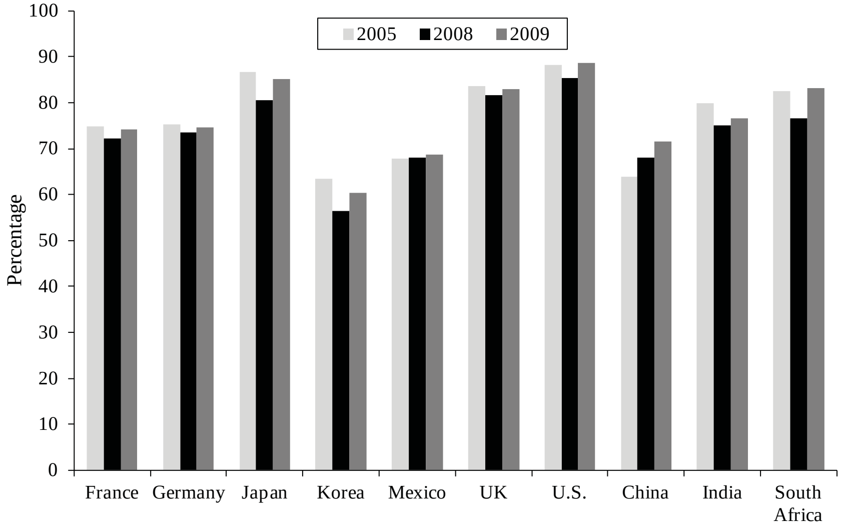
Figure 6.2 Domestic Content of Exports: Percentage of Total Gross Exports Represented by Domestic Value-Added Exports, 2009



SOURCE: OECD-WTO Trade in Value-Added (TiVA) indicators, preliminary results from OECD, January 2013, http://stats.oecd.org.

Some care is needed in interpreting the results, however: 2009 was an exceptional year, the year that signified perhaps the nadir of the recent financial crisis. As such, it was partly characterized by an unprecedented slowdown in global trade. Although the database only provides data as far back as 2005, illustrative data going back to 1995 suggest that international fragmentation of production (in other words, the import content of exports) had been steadily rising in most countries over recent decades, which continued over the period 2005–2008 (Figure 6.3), despite the slowdown that began in many countries in 2008. But 2009 saw drops in the import content of exports, an indication that the greater the fragmentation of a good or service, the more likely it was to be affected by the synchronized slowdown in trade. In most countries, therefore, the import content of overall exports in 2009 returned to around the ratios seen in 2005, but in China the data point to a steady rise over the period, suggesting developments that saw China begin to move up the value-added chain.

Figure 6.3 Domestic Content of Exports: Percentage of Total Gross Exports Represented by Domestic Value-Added Exports, 2005, 2008, and 2009

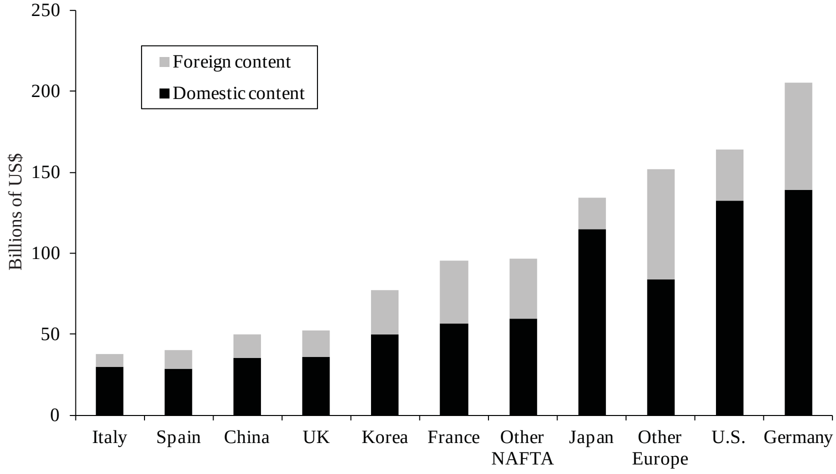


SOURCE: OECD-WTO Trade in Value-Added (TiVA) indicators, preliminary results, OECD, January 2013.

Tangible evidence of the scale of global value chains emerges more clearly when considering specific sectors. For example, between one-third and one-half of the total value of exports of transport parts and equipment by most major producers originated abroad in 2009 (Figure 6.4), driven by regional production hubs. In the United States and Japan, the shares were only about one-fifth, reflecting the larger scope in those countries of source inputs from domestic providers. However, this was also the case for Italy, and there it may have reflected efficient upstream domestic networks of small and medium enterprises. Interestingly, in 2009, Germany exported 25 percent more transport parts and equipment output than the United States in gross terms but only 5 percent more in value-added terms.

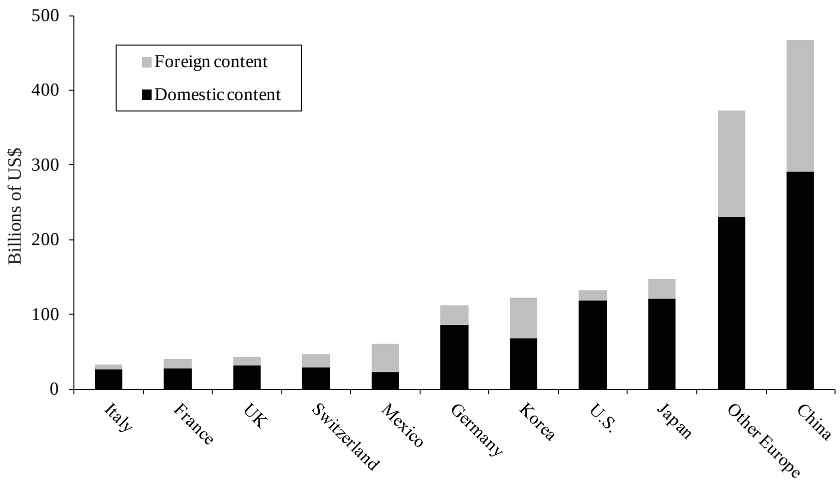
Similar patterns emerge in other sectors with a high degree of international fragmentation. For example, in China and Korea, in 2009, the

Figure 6.4 Transport Equipment, Gross Exports Decomposed by Source, 2009 (billions of US$)



SOURCE: OECD-WTO TiVA indicators, preliminary results, OECD, January 2013.

Figure 6.5 Electronic Equipment, Gross Exports Decomposed by Source, 2009 (billions of US$)



SOURCE: OECD-WTO TiVA indicators, preliminary results, OECD, January 2013.

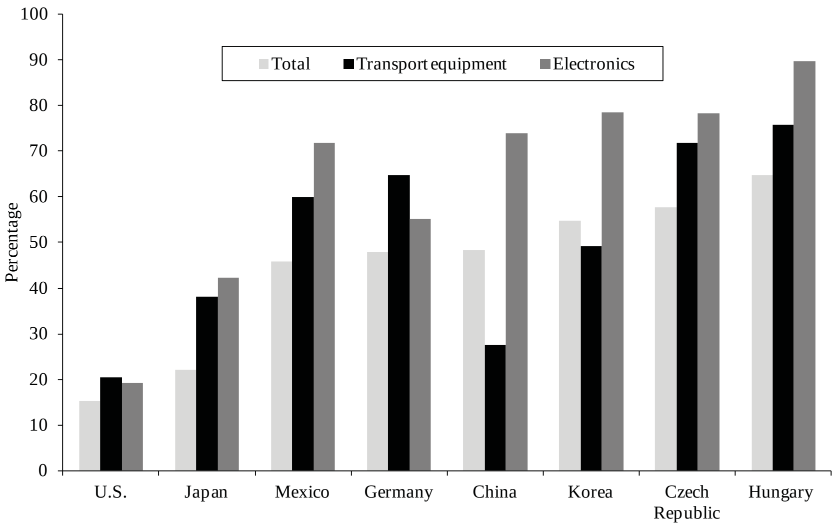
foreign content of exports of electronic products was about 40 percent, and in Mexico, the share was over 60 percent (Figure 6.5).

High Shares of Intermediate Imports Are Used to Serve Export Markets

The figures above reveal that exporting firms require access to efficient imports in order to be competitive, and so highlight the potential counterproductive effects of protectionist measures. But an alternative way of indicating the adverse effects of such policies can be seen when looking at the overall share of intermediate imports that are used to serve export markets.

In most economies, around one-third of intermediate imports are destined for the export market. Not surprisingly, typically, the smaller the economy the higher the share, but even in the United States and Japan these shares are 15 and 20 percent, respectively, at the total economy level, with a higher incidence of intermediate imports in some

Figure 6.6 Intermediate Imports Embodied in Exports: Percentage of Total Intermediate Imports, 2009



SOURCE: OECD-WTO TiVA indicators, preliminary results, OECD, January 2013.

highly integrated industries (Figure 6.6). In Japan, for example, nearly 40 percent of all intermediate imports of transport equipment end up in exports.

In many other countries, the share of intermediate imports embodied in exports is significantly higher. In Hungary, two-thirds of all intermediate imports are destined for the export market after further processing, and the share reaches 90 percent for electronic intermediate imports. In China, Korea, and Mexico, around three-quarters of all intermediate imports of electronics are embodied in exports. The database also shows that close to 85 percent of China's intermediate imports of textile products end up in exports.

Open and Efficient Service Markets Matter

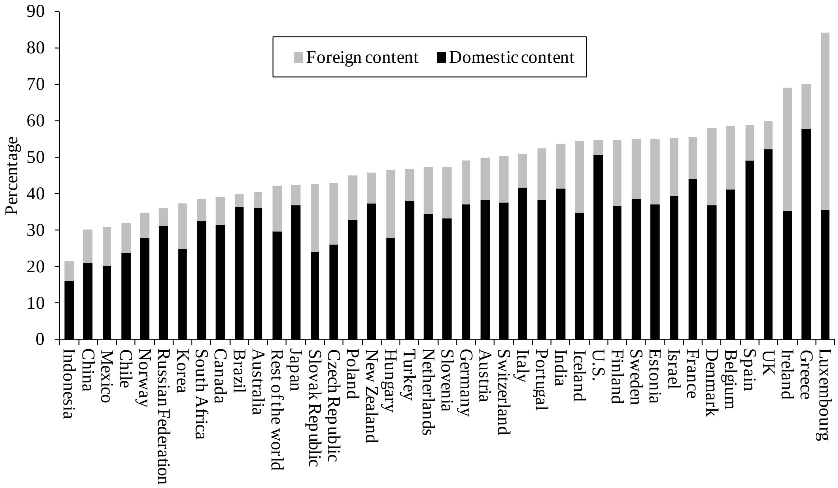
Services make up about two-thirds of gross domestic product (GDP) in most developed economies, but in gross terms, trade in services typically accounts for less than one-quarter of their exports This partly reflects the fact that significant shares of services output are generally not tradable—e.g., government services, many personal services, and imputations such as those made in GDP calculations to reflect the rent homeowners are assumed to pay themselves (between 6 and 10 percent of GDP in most developed economies). But it also reflects the fact that the service sector provides significant intermediate inputs to domestic goods manufacturers.

Accounting for the value-added produced by the service sector in the production of goods shows that the service content of total gross exports is over 50 percent in many OECD economies, and it approaches two-thirds of the total in the United Kingdom (Figure 6.7). Canada, because of its significant exports of natural resources, which typically have low service content, has the lowest service content of its exports in the G7—but even here the share is close to 40 percent.

Typically, emerging economies and other large exporters of natural assets, such as Norway, Chile, and Australia, have the lowest shares of services. But in India, over half of the value of its gross exports originates in the service sector. Indonesia has the lowest share of the 40 countries in the database at around 20 percent.

Part of the explanation for the difference between OECD countries and emerging economies can be found in the relatively higher degree of

Figure 6.7 Services Value-Added: Percentage of Total Exports, 2009

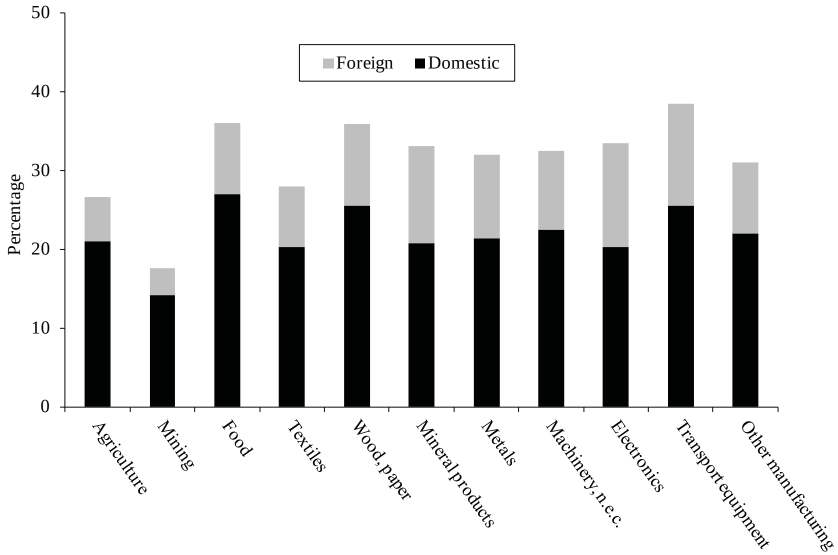


SOURCE: OECD-WTO Trade in Value-Added (TiVA) indicators, preliminary results, OECD, January 2013.

(largely domestic) outsourcing of services by manufacturers in OECD countries in recent decades, suggesting that a similar process could lead to improvements in the competitiveness of emerging economy manufacturers. Figure 6.7 also reveals a not insignificant contribution to exports coming from foreign service providers.

Another, perhaps clearer way of illustrating the importance of services to exports is to consider the services content of specific exports in goods-producing sectors. Figure 6.8 takes an average of all 40 countries in the database and shows that services make a significant contribution (typically one-third) across all manufacturing sectors, with significant shares provided by both foreign and domestic service providers. For individual sectors in specific countries the importance of the service sector is often starker. In France, for example, the data reveal that over half of the domestic value-added generated in producing transport equipment originates in the French service sector.

Figure 6.8 Services Value-Added: Percentage of Total Exports of Goods, 2009

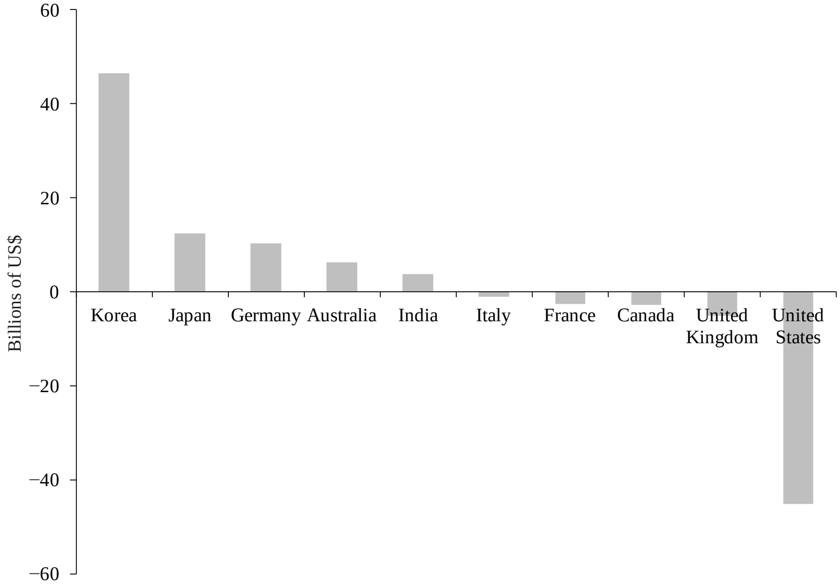


NOTE: "n.e.c." stands for "not elsewhere classified."
SOURCE: OECD-WTO Trade in Value-Added (TiVA) indicators, preliminary results, OECD, January 2013.

Intermediate Imports Often Embody a Country's Own (Returned) Domestic Value-Added

Imports can also contain "returned" value-added, which is value-added that originated in the importing country. The preliminary—and, one should stress, conservative—estimates in the OECD-WTO database show that in the United States, for example, nearly 5 percent of the total value of imported intermediate goods reflects U.S. value-added, and in China the equivalent shares are close to 7 percent. For electronic goods, Chinese intermediate imports contain over 12 percent of returned Chinese domestic value-added, and Korean intermediate imports contain close to 5 percent of returned Korean domestic value-added.

Figure 6.9 Difference between China's Value-Added and Gross Trade Balances, 2009 (billions of US$)



SOURCE: OECD-WTO TiVA indicators, preliminary results, OECD, January 2013.

What You See Is Not What You Get: Trade Patterns Change

Bilateral trade balance positions can change significantly when measured in value-added terms, even though the total trade balance is unaffected. Figure 6.9 shows that China's bilateral trade surplus with the United States was over US$40 billion (25 percent) smaller in value-added terms in 2009. (It was 30 percent smaller in 2005.) This partly reflects the higher share of U.S. value-added imports in Chinese final demand but also the fact that a significant share (one-third) of China's exports reflects foreign content—the "Factory Asia" phenomenon. The data illustrate that significant exports of value-added from Korea and Japan pass through China on their way to final consumers, resulting in significantly smaller Chinese trade deficits with these countries but also typically higher Japanese and Korean trade surpluses with other countries. Similarly, the database shows that Korea's significant trade deficit with Japan in gross terms almost disappears when measured in value-added terms.

ESTIMATING TRADE IN VALUE-ADDED

Creating a Multiregional Input-Output Table

As mentioned above, several initiatives have tried to address the issue of the measurement of trade flows in the context of the fragmentation of world production.[3] The most commonly used approach to develop a macro picture is based on global input-output tables, using simple standard Leontief inverses. More detail can be found in a joint report by the OECD and WTO (2012) and in an online appendix to this chapter, "Appendix 6A: Indicator Descriptions and Definitions," which can be found at http://www.upjohn.org/MEG/ahmad-appendix.pdf.

Constructing a global table is a data-intensive process and presents numerous challenges. The key challenge is to identify and create links between exports in one country and the purchasing industries (as intermediate consumers) or final-demand consumers in the importing country. In this respect, it is important to note that the data issues faced by the OECD are similar to those confronted by other initiatives, such as IDE-JETRO (which has produced intercountry input-output tables for Asia) or the World Input-Output Database project, with whom (along with the U.S. International Trade Commission) the OECD and WTO have been actively coordinating in order to share experiences and derive a set of best practices.

The data sources at OECD are harmonized input-output tables and bilateral trade coefficients in goods and services, derived from official sources.[4] The model specification and estimation procedures can be summarized as follows:

- Preparation of input-output (I-O) tables for reference years, using the latest published data sources—e.g., supply-and-use tables, national accounts, and trade statistics.
- Preparation of bilateral merchandise data by end-use categories for reference years. The published trade statistics are adjusted

for analytical purposes (such as confidential flows, reexports, waste and scrap products, and valuables). Trade coefficients of utility services are estimated based on cross-border energy transfers. Other trade coefficients of service sectors are based on the OECD Statistics on International Trade in Services and the United Nations (UN) Service Trade statistics. However, many missing flows are currently estimated using econometric model estimates.

- Conversion of "cost, insurance, and freight" (CIF) price-based import figures to "free on board" (FOB) price-based imports to reduce the inconsistency issues of mirror trade. (Because of asymmetry in reporting exports and imports in national trade statistics, imports of Country A from Country B often differ significantly from the exports reported from Country B to Country A). In an international I-O system, trade flows need to be perfectly symmetrical (i.e., the bilateral trade flows should be consistent at the highest relevant level of disaggregation) and consistent with the supply-utilization tables' trade data.
- Creation of import matrices.
- Total adjustment (missing sectors, trade with rest of the world, and other factors) and minimization of discrepancy columns using biproportional methods.

The OECD has been updating and maintaining harmonized I-O tables—that is, splitting intermediate flows into tables of domestic origin and imports—since the mid-1990s. Usually this process follows the rhythm of national releases of benchmark I-O tables. The first edition of the OECD Input-Output Database came out in 1995. It covered 10 OECD countries, and its I-O tables spanned the period from the early 1970s to the early 1990s. The first updated edition of this database, released in 2002, increased the country coverage to 18 OECD countries, China, and Brazil, and introduced harmonized tables for the mid-1990s. The database now includes national I-O tables for 34 OECD member countries and 18 non-OECD countries.[5]

The I-O tables show transactions between domestic industries but, as a complement, also include supplementary tables, which break down total imports by user (industry and category of final demand). Some countries provide these import tables in conjunction with their I-O tables, but in other cases they are derived from calculations by the OECD.

The OECD's input-output tables are based on an industry-by-industry basis, reflecting the fact that the underlying source data measure both the activities and production of industries. This means that the relationships between value-added and industrial output are unaffected by the statistical manipulations that will be required to build product-by-product-based input-output tables. The industry classification used in the current version of OECD's I-O database is based on the International Standard Industrial Classification of All Economic Activities, Revision 3 (ISIC Rev. 3) (Table 6.1), meaning that it is compatible with other industry-based analytical data sets, and in particular with the OECD bilateral trade in goods by industry data set (derived from merchandise trade statistics through the standard Harmonized System to ISIC conversion keys). The system, by necessity (in other words, to maximize cross-country comparability), is relatively aggregated. Differentiating between types of companies within a given sector is essential, however, to improve the quality of trade in value-added results (particularly in the context of exporting and nonexporting companies), and so part of future work will be to explore ways to do this, using microdata that could improve the quality of results (which is discussed in more detail in the following section).

In essence, a global I-O table is little different from a national I-O table except that while the matrix of flows of intermediate goods and services in a national table can be industry × industry, in a global I-O table, the rows and columns are country-industry combinations. In addition, in a global I-O table there are separate columns for each country's final demand. For illustration, Table 6.2 shows a two-country, two-sector representation.

Most of the components intuitively follow from the row and column headings, but by way of explanation, Z_{12}^{AB} = intermediate purchase by Sector 2 of Country B from Sector 1 of Country A; F_1^{AB} = final demand of consumers in Country B of output of Sector 1 in Country A.

Typically in the above matrix, statistics offices are able to provide most of the blocks required (recalling that supply-use tables can be readily converted to the above format and, moreover, that the above format can be initially constructed as a global supply-use table, which

Table 6.2 A Simplified ICIO System

	Country A		Country B		Final demand	
	Sector 1	Sector 2	Sector 1	Sector 2	Country A	Country B
Country A						
Sector 1: Goods	Z_{11}^{AA}	Z_{12}^{AA}	Z_{11}^{AB}	Z_{12}^{AB}	F_1^{AA}	F_1^{AB}
Sector 2: Services	Z_{21}^{AA}	Z_{22}^{AA}	Z_{21}^{AB}	Z_{22}^{AB}	F_2^{AA}	F_{2AB}
Country B						
Sector 1: Goods	Z_{11}^{BA}	Z_{12}^{BA}	Z_{11}^{BB}	Z_{12}^{BB}	F_1^{BA}	F_1^{BB}
Sector 2: Services	Z_{21}^{BA}	Z_{22}^{BA}	Z_{21}^{BB}	Z_{22}^{BB}	F_{2BA}	F_2^{BB}
Tax less subsidy on products	NTZ_1^A	NTZ_2^A	NTZ^{1B}	NTZ_2^B	NTF^A	NTF^B
International trade margin and insurance	TIZ_1^A	TIZ_2^A	TIZ_1^B	TIZ_2^B	TIF^A	TIF^B
Value-added						
Labor compensation	VL_1^A	VL_2^A	VL_1^B	VL_2^B		
Operating surplus	VO_1^A	VO_2^A	VO_1^B	VO_2^B		
Tax less subsidy on production	VT_1^A	VT_2^A	VT_1^B	VT_2^B		
Output	X_1^A	X_2^A	X_1^B	X_2^B		

SOURCE: Author's compilation.

will form the long-term approach to be used by the OECD). But even though some countries are able to estimate the overall import of a given product used by a particular industry, many are not, and none are able to show, systematically, the source of that import (by originating country and industry) by the using industry (or “final demand” category).

Central to the construction of a global input-output table, therefore, is the estimation of trade flows between industries and consumers across countries. Indeed, these trade flows in intermediate goods and services are the glue that binds together the national individual input-output tables. A positive spin-off of the work is worth mentioning in this context. National estimates of trade (exports and imports) are not coherent across countries, even after adjusting for price differences, CIF, and FOB. The process of constructing a global I-O table confronts this issue head-on. The spin-off to the work is therefore a mechanism to reveal where global imbalances lie. The results and policy implications of the work highlight the importance that should be attached to reconciling these flows at the national level. Over the coming years, this will form an important part of the OECD’s work program, through its Working Party on Trade in Goods and Services.

Bilateral trade in goods and services and I-O balancing

Given the fact that many imports enter countries through intermediaries (wholesalers), it is highly unlikely that countries will ever be able to collect statistics that systematically show the country source of all imports consumed by all industries, nor does it seem likely that countries will be able to show which foreign industries consume their products. But, as shown below, it is possible, at least in the medium term, for countries to do more in this field by capitalizing on microdata and links between trade and business registers.

In the short term, however, more can be—and is being—done to improve how imports are allocated to using industries. Most countries are able to produce estimates of bilateral trade in goods and services showing the export of a given good or service to a given partner country. And indeed, most countries are able to further reveal whether any particular import or export of a good (at least, for most imports and exports) was intermediate, an investment, or a consumer good.

In constructing the import (and export) flows of its global I-O table, the OECD necessarily uses a number of assumptions. The main assumption used in creating these import matrices is the “proportionality” assumption, which assumes that the country-of-origin share of a given import consumed by a given industry in a given country is the same for all industries in that country. For countries that are not able to provide any “import-flow” matrices at all—i.e., the intermediate consumption of imports by origin and destination industries—the OECD necessarily assumes that the share of intermediate imports in total intermediate consumption for a given imported product is the same for all using industries. Furthermore, the OECD assumes that this share is equivalent to the overall share of intermediate imports to total intermediates supplied for that product. In all cases, the OECD has been able to significantly improve the quality of the assumptions it necessarily uses by creating a new database of bilateral trade (for goods) that breaks down imports (and exports) on the basis of the nature of the traded product (intermediate, household, investment, other). This database is called the Bilateral Trade Database by Industry and End-Use category (BTDIxE), and is derived from the United Nations Statistics Division (UNSD) UN Comtrade database, where values and quantities of imports and exports are compiled according to product classifications and by partner.[6]

UN Comtrade data are classified by declaring country (the country supplying the information), by partner country (the origin of imports or destination of exports), and by product (according to Harmonized System, or HS). Trade flows are stored according to the product classification used by the declaring country at the time of data collection. In general, source data are held according to Standard International Trade Classification (SITC) Revision 2 (Rev. 2) for the time period 1978–1987, the Harmonized System (1988) for 1988–1995, HS Rev. 1 (1996) for 1996–2001, HS Rev. 2 (2002) for 2002–2006, and HS Rev. 3 (2007) from 2007 onwards.

To generate estimates of trade in goods by industry and by end-use category, six-digit product codes from each version of HS from UN Comtrade are assigned to a unique ISIC Rev. 3 industry and a unique end-use category—and hence, assigned to a basic class of goods as specified in the System of National Accounts (SNA) (European Commission et al. 2009; see Table 6.3).

Notwithstanding the known problems relating to the asymmetries that exist within bilateral trade statistics (i.e., global exports do not equal global imports), these bilateral statistics form the basis for populating the international flows in goods used in the OECD's global input-output tables, before balancing.

The approach used for bilateral trade in services statistics is in essence similar: Estimates based on official bilateral statistics form the basis for the original estimates of exports and imports by country. However, the quality of bilateral trade in services statistics is notoriously poor, and so the original partner-share coefficients used to populate I-O cells of international trade in services are based on gravity model techniques (see Miroudot, Lanz, and Ragoussis 2009), which are subsequently balanced within the overall system.

Only very few countries have a consistency between bilateral trade flows (imports and exports) by partner country and the corresponding flows shown in their supply-use tables (the basis for the creation of national I-O tables), reflecting the fact that, for goods at least, bilateral trade flows follow merchandise trade accounting standards. As such, there are a number of recommendations that follow for official statisticians:

Coherent bilateral trade and national accounts data. Producing bilateral trade flows that are consistent with underlying supply-use tables should form a high priority of national statistics offices.

Confidential trade. In some countries, disclosure rules suppress six-digit HS components in UN Comtrade and also higher two-digit HS chapter levels. This should be avoided where possible by adopting other forms of preserving confidentiality, such as suppressing another six-digit category.

Reexports. Adjustments are required for reexports—and, for major continental trading hubs, these adjustments can be significant. Sufficient data are available to adjust for reported trade between China and the rest of the world via Hong Kong, but not currently for other major hubs such as Belgium, the Netherlands, and Singapore.

Identifying used capital goods. HS codes, and thus reported trade in UN Comtrade, cannot differentiate between new and old capital goods (such as secondhand aircraft and ships). Estimating international

Table 6.3 Current BEC and SNA Classes of Goods

	End-use			
		Final-demand goods		
Product characteristics	Intermediate	Household consumption	Industrial capital goods	Other
Primary products	Food and beverages (111)	Food and beverages (112)		
	Industrial supplies (21)			
	Fuels and lubricants (31)			
Processed unfinished	Fuels and lubricants (32)	Fuels and lubricants (32)		
	Industrial supplies (22)	Food and beverages (122)		
	Parts and components of transport equipment (53)			
	Parts and components of capital goods (42)			
Processed finished	Packed medicaments (part of 63)	Packed medicaments (part of 63)	Capital goods (41)	
		Nonindustrial transport equipment (522)	Industrial transport equipment (521)	
		Nondurable consumer goods (63)		
		Semidurable consumer goods (62)		
		Durable consumer goods for households (61)		
		Durable personal consumer goods, e.g., personal computers (part of 61)	Durable personal consumer goods, e.g., personal computers (part of 61)	
		Mobile phones (part of 41)	Mobile phones (part of 41)	

	Passenger motor cars (51)	Passenger motor cars (51)	
	Fixed-line phones (part of 62)	Fixed-line phones (part of 62)	
Other			Goods n.e.c. (7)

NOTE: Numbers are in Broad Economic Categories (BEC) codes. “SNA” stands for “System of National Accounts.” “n.e.c.” stands for “not elsewhere classified.”
SOURCE: United Nations Statistics Division (2013).

trade in these flows in a value-added context requires an elaboration on the input-output framework that allows these flows to be recorded in a way that aligns with total global value-added produced in a given period.

Unidentified scrap and waste. Certain types of waste and scrap do not have separate six-digit HS codes—e.g., PCs and other electrical equipment exported (often to developing countries) for recycling.

Better services data. Moreover, for services, countries are encouraged to provide more detail on partner countries and also on the type of products (following EBOPS 2010).[7]

Coherent international trade data. Greater efforts are needed to reconcile asymmetries in international trade flows.

Without the issues outlined above being resolved, the OECD's global input-output table must necessarily balance global discrepancies in trade using a quasi automatic (RAS) balancing procedure. This process constrains each country's exports and imports to published national accounts totals, while also constraining estimates of national GDP. Resolving these asymmetries in bilateral trade statistics is a work in progress, and efforts to improve the nature of the balancing process are ongoing (Ahmad, Wang, and Yamano 2013).

Given the assumptions and balancing adjustments necessarily used, it is important to stress that the indicators shown in the database are *estimates*. Official gross statistics on international trade produced by national statistics institutions result in inconsistent figures for total global exports and total global imports, inconsistencies that are magnified when bilateral partner country positions are considered. The global input-output tables from which trade in value-added indicators are derived necessarily eliminate these inconsistencies, such as those that reflect different national treatments of reexports and transit trade (e.g., going through hubs such as the Netherlands), to achieve a coherent picture of global trade. For the countries for which data are presented, total exports and imports are consistent with official national accounts estimates.

Level of detail in national supply-use and input-output (I-O) tables—future improvements

Indicators created by input-output techniques are limited by the degree of industry disaggregation that the tables provide. The national input-output tables used by the OECD are based on a harmonized set of 37 industries. In simple terms, therefore, any given indicator for a particular industry assumes that all consumers of that industry's output purchase exactly the same shares of products produced by all of the firms allocated to that industry.

In practice, this boils down to (but is not the same thing as) assuming that there exists only one single production technique for all of the firms (and all of the products) in the industry grouping. We know that this is not true and that different firms, even those producing the same products, will have different production techniques (and so technical I-O coefficients), and we also know that different firms produce different products and that these products will be destined for different types of consumers and markets.

Of chief concern in this respect is the evidence that points to exports having very different coefficients from the coefficients of goods and services produced for domestic markets, particularly when the exports (typically intermediate) are produced by foreign-owned affiliates in a global value chain. Because exporting firms are generally more integrated into value-added chains, they will typically have higher foreign content ratios, particularly when they are foreign-owned. Generally, therefore, an ability to account for this heterogeneity in producing trade in value-added estimates will result in lower shares of foreign content than might be recorded if more detailed input-output tables were available.

It is important to note, however, that more detail does not necessarily translate into more disaggregated industries. What matters for developing indicators on GVCs is more detail on firms trading internationally. In this sense, given a choice between doubling the number of industries available within current national I-O or supply-and-use tables or providing a split of existing industries into one group of exporting firms and another of nonexporting firms, the latter may, arguably, be preferable.

Ideally, therefore, countries should attempt to construct supply-use or input-output tables that better respond to the challenges presented by GVCs. In a project coordinated by the OECD and the Chinese Ministry of Commerce (the latter in collaboration with the Chinese National Bureau of Statistics), an input-output table for China was created that split all of its industrial sectors into three categories: 1) processing firms, 2) other exporting firms, and 3) all other firms (Cuihong et al 2013).

Ideally, countries could adopt similar approaches in constructing their I-O or supply-and-use tables, using splits based on national circumstances. Processing firms form a significant part of China's exporters, so such a classification made sense in the case of China, but this may not be optimal for all countries. For most countries, achieving changes to national I-O or supply-and-use tables may take some time.

Other, potentially simpler, approaches, however, could be used to significantly improve the quality of the information I-O tables are able to produce for analyzing GVCs.

In October 2012, the OECD and Eurostat launched one such approach by building on the OECD-Eurostat Trade by Enterprise Characteristics (TEC) data collection. The TEC exercise collects information on the turnover generated through exports broken down by size class, industry, and partner country. For imports, similar information is provided but with a more limited breakdown on the importing industry. But these indicators only begin to scratch the surface of the potential, if researchers can make links to structural business statistics (Ahmad et al. 2011). With these further links, they can create information on the direct value-added of exporting firms, as well as information on employment. In addition, they can create indicators broken down by whether the firms are foreign or domestically owned, an important additional breakdown required for analyses of "trade in income." (This topic of trade in income is further addressed under the subsection heading of that name, below.) Moreover, information that links the data on importing firms with those on exporting firms can provide vital insights into the nature of global production chains. Importantly, for those countries that already produce TEC statistics, researchers could develop this information without necessarily using links to structural business statistics, although they would have to do so on the basis of turnover flows. This information could form the basis for disaggregating I-O or supply-and-use industries into characteristics required to better measure GVCs.

The questionnaire that was circulated to test the feasible and practical level of detail that could be collected, bearing in mind disclosure rules, focused only on export intensities (rather than on import intensities, where it was recognized that other steps would need to precede development of a questionnaire on that aspect). The primary purpose of the questionnaire was to categorize firms on the basis of their share of output generated by exports (i.e., export intensities). The form provided for three different levels of breakdown; it asked countries to use the level of breakdown that best suited their disclosure rules and resources:

1) Firms that export (i.e., more than 0 percent of output is made up by exports) and firms that don't (0 percent of output is exported).
2) A breakdown of firms by export-intensity quartiles, with a separate category for nonexporting firms: 0 percent, between >0 and 25 percent, between >25 and 50 percent, between >50 and 75 percent, and greater than 75 percent.
3) A more aggregated breakdown of export intensity into three categories: a) nonexporting firms, b) firms with exports between >0 and 50 percent, and c) firms with exports greater than 50 percent.

Seven variables, described below, were requested in the exercise, and each was broken down by industry, size class, and ownership. However, recognizing that disclosure rules would restrict what could realistically be produced for public consumption, the distributors of the survey asked countries to prioritize their information along the following lines:

- Priority 1: Industries (preferably, ISIC Rev. 4) for two-digit groupings
- Priority 2: Export intensities (exports as a percentage of output)
- Priority 3: Ownership (a breakdown into foreign/domestic ownership)
- Priority 4: Size class (a breakdown preferably done by number of employees)

The seven variables requested were as follows:

1) The number of statistical units, participating or otherwise, in exports, ideally using a concept consistent with that used in preparing supply-use and input-output tables.

2) The value-added generated by firms in national currency units, ideally at basic prices.
3) The value of exports generated by firms in national currency units, ideally at FOB (free on board) prices.
4) The output generated by firms in national currency units, ideally at basic prices.
5) The total employment of firms, ideally on a full-time equivalent basis.
6) The total compensation of employees of firms.
7) Direct imports of firms in national currency units, ideally at CIF (cost, insurance, and freight) prices.

Going beyond Trade in Value-Added

Looking at trade in value-added terms provides a valuable insight into broader notions of competitiveness (in addition to providing insights into trade policies) by illustrating interlinkages between countries and also by illustrating those activities (or tasks) that generate the most value. But additional indicators and insights can be gained by considering extensions to the accounting framework.

Trade in jobs

One immediate area relates to jobs. This requires consistent estimates of employment measures (employment, employees, actual hours worked) using the underlying value-added estimates produced by national statistics offices in their supply-use tables.

Countries have already begun to make improvements in this area, driven by a need to produce coherent productivity estimates by industry, and it is hoped that highlighting the important insights that can be gained by looking at trade in jobs will reinforce and support these national initiatives aimed at improving coherence. Going a step further, we can state that, particularly because international fragmentation has meant industries across countries are less comparable than they used to be (as countries specialize in those stages of the underlying activity where they have a comparative advantage), it is increasingly becoming necessary to link jobs statistics to skills statistics.

The OECD's ANSKILL database (in the process of being updated) provides information on employment and skill composition at the industry level. The database matches industry data at the two-digit level (classified according to the ISIC Rev. 3) to occupations at the two-digit level (classified according to International Standard Classification of Occupations [ISCO]-88). It also includes an additional proxy for skills, in the form of data on the educational attainment of employees (classified on the basis of International Standard Classification of Education [ISCED]-97). The database covers 26 countries, mostly for 1997–2005, although coverage of seven of the countries is much more limited.

For ANSKILL, the ISCO-88 occupation classification corresponds to high-, medium-, and low-skilled levels, as follows:

- Categories 1 (legislators, senior officials, managers), 2 (professionals), and 3 (technicians and associate professionals) are regarded as high-skilled.
- Categories 4 (clerks), 5 (service workers and shop and market sale workers), 6 (skilled agricultural and fishery workers), and 7 (craft and related trade workers) are regarded as medium-skilled.
- Categories 8 (plant and machine operators and assemblers) and 9 (elementary occupations) are regarded as low-skilled.

The ISCED-97 educational classification maps to high, medium, and low skill levels in ANSKILL as follows:

- Categories 1 (primary education) and 2 (lower secondary/second stage of basic education) are regarded as low-skilled.
- Categories 3 (upper secondary education) and 4 (postsecondary nontertiary education) are regarded as medium-skilled.
- Categories 5 (first stage of tertiary education) and 6 (second stage of tertiary education) are regarded as high-skilled.

Trade in income

Conventional trade statistics do not always record transactions between affiliates as sales or purchases of goods and services. This is especially true of intellectual property products (IPPs).

Consider, for example, an affiliate enterprise, recognized in the national accounts of its resident economy as the economic owner of an

IPP that it uses to produce goods, which it sells. The affiliate's value-added would reflect in part the return on this underlying asset, realized as profits (operating surplus). These profits would subsequently be recorded as reinvested earnings, whether or not any actual flows occur between the parent and its affiliate. Ultimately, therefore, it is the parent (often the entity that finances the underlying IPP) that benefits from the use of the IPP. (Indeed, this in itself raises questions about how economic ownership of IPPs should be considered with respect to multinationals—an issue that is currently being tackled by the international statistics community.)

However, the difficulties raised by the current recording of IPPs in the balance of payments and national accounts of countries extend beyond this simple example (which correctly records flows in line with current standards and guidelines). Often, for example, the national accounts in the economy of the parent company will record the asset, but there will not be any flows related to the use the owner makes of its affiliates, which use is frequently driven by tax minimization purposes. Often, as well, the owner may transfer the asset to an affiliate (such as a special purpose enterprise, or SPE), with the parent and other affiliates making explicit payments to the SPE, again driven to do so by tax minimization purposes.

What is clear from the above, therefore, is that flows related to IPPs require an extension of accounting systems beyond looking merely at value-added flows in order to fully understand who benefits from trade and indeed trade liberalization (and investment). Sometimes these flows will increase value-added, sometimes they will not. But in both cases the beneficiary is arguably the same (the parent company).

But the flows merely illustrate a wider issue, notwithstanding the obvious implications they raise for multifactor productivity calculations. First, they illustrate the potential distortions that may arise when one factors in the scope for transfer pricing manipulations. Second, such interpretations extend beyond looking only at the conventional set of assets recognized as such in the 2008 SNA. Other knowledge-based assets, such as brands and organizational capital, can also increase an affiliate's value-added, and even though these assets are not recognized in the SNA, the profits recorded by the affiliate compensate for their use, and these still flow back to the parent, eventually, as reinvested earnings flows in the accounts. But these flows are typically not available on a bilateral partner country basis, let alone a partner country–industry basis, which is what is needed to analyze trade in income analogously with trade in value-added.

Recording these flows, therefore, is crucial. Part of the solution lies in producing supply-use tables (or indicators) that capture foreign ownership. Clearly, it is unlikely that it will be feasible to produce supply-use tables that capture foreign ownership by country for all of the owners of the affiliates. But a separate breakdown of activities in a supply-use table that differentiates between foreign- and domestic-owned firms should be feasible, as it relates to confidentiality rules and burdens.

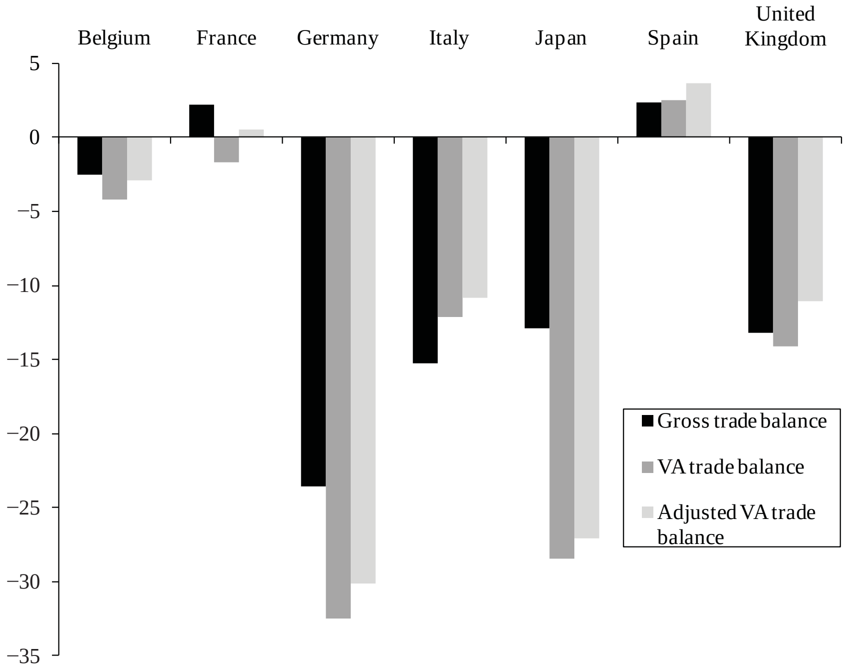
By supplementing this with bilateral trade in primary income statistics (a from-whom-to-whom framework) broken down by type of income (in particular, reinvested earnings and interest), it should be possible to create extensions to the trade-in-value-added accounting framework by treating the primary income flows (and components) as if they were services produced by artificial industries in the host country of the parent company.

Some of the tools to do this already exist. Foreign affiliate trade statistics (FATS) can be combined, for example, with information in supply-use tables that shows breakdowns based on ownership. And there is also scope to link this further to balance-of-payment (BoP) data flows. The OECD is looking at developing a more detailed accounting framework and set of recommendations in this area, which could form the basis for estimating flows of trade in income.

Figure 6.10 provides an illustration of the potential impact this may have on our understanding of trade relationships. For illustrative purposes only, the operating surplus generated by U.S.-owned affiliates in the "Chemicals and electronics" sector in Ireland (available from FATS) is considered to be equivalent to value-added generated by U.S. firms. These flows can then be treated as exports from the United States to those countries consuming the U.S. affiliate exports from Ireland, revealing not insignificant changes in bilateral trade positions. For example, for France the trade deficit in value-added terms becomes a trade surplus again, which is what gross flows show.

To further illustrate the potential impact of accounting for these flows between multinationals, about 70 percent of China's gross high-tech exports were made by foreign affiliates in 2009, according to data

Figure 6.10 U.S. Trade Balance, Adjusted for U.S. Affiliates' Exports from Ireland, $US Billions, 2009



NOTE: "VA" stands for "value-added."
SOURCE: OECD calculations, based on the OECD-WTO Trade in Value-Added (TiVA) database and the OECD Activity of Multinational Enterprises (AMNE) database.

supplied by the Chinese Ministry of Commerce. Furthermore, between 1995 and 2007, Japanese foreign affiliates increased their employment in China eightfold, from just over one hundred thousand employees to more than one million, and in Thailand fourfold, from over one hundred thousand to over four hundred thousand; the pattern was similar in other Association of Southeast Asian Nations (ASEAN) countries, such as the Philippines, Malaysia, and Indonesia. And from 1995 to 2009, Japan's primary income trade surplus increased by around $100 billion, more than offsetting the $50 billion reduction in its gross trade surplus over the same period.

Trade in CO_2 (and other emissions)

One additional extension that follows from the accounting framework for trade in value-added (and trade in jobs) is carbon footprints. Carbon footprint calculations are typically estimated using I-O tables (Ahmad and Wyckoff 2003).

Incorporating capital flows

Other areas where extensions to the accounting framework would be desirable include the contribution made by capital more generally. Because of the way capital (gross fixed capital formation) is recorded in the accounting system, analyses that look at trade in value-added do not fully capture how production across countries is linked and how capital goods (and services) produced in one country contribute to the value-added in another. For example, all the value-added exported by Japan in producing machinery for manufacturers in China will be recorded as Chinese imports from Japan. But, arguably, the capital service values embodied in the goods produced and exported by China should show Japan as the beneficiary. This requires high-quality capital flow (and capital stock) matrices.

Distribution sectors and trade

One final area of work that merits attention concerns the value added by distributors through sales of final imported goods. The estimates of trade in value-added do not reveal how cheap imports are also important to retailers, who are able to generate domestic value-added through sales to consumers. Tariff measures will necessarily impose additional costs on these goods which, all other things being equal, could suppress demand and so in turn lead to lower value-added in the distribution sectors. The OECD is also considering how these estimates could be incorporated within its accounting framework, using margin rates for all products in national supply-use tables, and through this usage motivating the further development of such data.

Notes

1. See an application of international I-O in Escaith et al. (2011).
2. For more information on the database, see OECD (2013).
3. An OECD–World Bank workshop on "New Metrics for Global Value Chains" was held on September 21, 2010. WTO hosted a "Global Forum on Trade Statistics" on February 2–4, 2011, in collaboration with Eurostat, the United Nations Statistics Division (UNSD), and the United Nations Conference on Trade and Development (UNCTAD).
4. Some research-oriented initiatives have been using the GTAP database for international input-output data. This database is not, however, based on official sources of statistics.
5. For more details, see OECD (2012b). The list of countries includes Australia, Austria, Belgium, Canada, Chile, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States, Argentina, Brazil, China, Chinese Taipei, Cyprus, India, Indonesia, Latvia, Lithuania, Malaysia, Malta, Romania, the Russian Federation, Singapore, South Africa, Thailand, and Vietnam.
6. For more details, see OECD (2012a).
7. EBOPS stands for Extended Balance of Payments Services Classification; see the service list of EBOPS items at http://unstats.un.org/unsd/servicetrade/mr/rfCommoditiesList.aspx.

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7
Import Uses and Domestic Value-Added in Chinese Exports

What Can We Learn from Chinese Microdata?

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Estimating the economy-wide and sectoral domestic value-added in exports requires an input-output (I-O) table with good information on import uses. Normally, statistical agencies do not compile this information at the sectoral level. The I-O experts either break down the data on total import uses or make an inference from available but limited microdata. In so doing, they often explicitly rely on the proportionality assumption to assign imported inputs to different sectors, or else they implicitly resort to the proportionality assumption when making generalizations about the import use patterns by a sample of firms. However, this assumption is hardly valid in reality, because individual sectors normally do not have the same patterns of import use as the overall economy, and also because firms are heterogeneous and they often behave differently in international trade (Bernard et al. 2007). As a result, these approaches tend to lead to biased estimates, as shown by the microdata work at the U.S. Census Bureau (Feenstra and Jensen 2012) and the microdata work for Germany (Winkler and Milberg 2009). Meanwhile, I-O-based trade-related estimates are sensitive to the structure of the import matrix, such as for emission estimation, as shown in Dietzenbacher, Pei, and Yang (2012), and for vertical specialization (VS) estimation, as in Yang et al. (2013).[1]

Therefore, when the World Trade Organization (WTO) and the Organisation for Economic Co-operation and Development (OECD) launched the “Made in the World Initiative” in 2011 to promote worldwide research on domestic value-added share (DVS) estimation and to enhance understanding of the global value chain, they pointed out that “the key challenges in the immediate future concern the quality of trade statistics and the assumptions made to allocate imports to users” and that linking traders to the manufacturers would form an important part of the work (Ahmad et al. 2011). In addition to the Trade by Enterprise Characteristics (TEC) joint project with Eurostat, the OECD’s exercise with Turkish microdata is another attempt to reveal the patterns of firm heterogeneity in trade and production and, based on that, to improve trade in value-added measures (Ahmad and Araujo 2011).

There are two threads of methodologies with which to estimate China’s DVS in exports under an I-O framework: one relies on assumptions or optimization programming to derive key coefficients, and the other employs real data to obtain these coefficients. The former approach includes the work of Dean, Fung, and Wang (2011) and of Koopman, Wang, and Wei (2012). Koopman, Wang, and Wei split the officially published Chinese 2007 I-O tables into two parts—1) processing and 2) normal trade—in their modified Chinese I-O tables. Ma, Wang, and Zhu (2013) take the modified I-O table that Koopman, Wang, and Wei developed and further split it by producers’ ownership. In doing so, Ma, Wang, and Zhu also incorporate micro firm-level data and other real data. Even though their approach contains real data, it falls into the former category, given the complexity of the I-O tables’ structure after two rounds of splitting and the lack of import-use information in the microdata, as will be shown in this chapter.

On the other hand, the Chinese National Bureau of Statistics (NBS) follows the latter approach. When compiling China’s 2007 input-output table, NBS researchers for the first time used a survey of firms to prepare the import-use coefficients. Recently, in updating the I-O tables and also as China’s response to the WTO/OECD Made in the World Initiative, the NBS decided to employ import-use matrices from two sources. While the NBS will keep the previous 2007 matrix, the Chinese General Administration of Customs has started its own independent firm survey on import uses. The approaches by the two agencies are quite different. The NBS has jurisdiction over enterprise production data collection, and its survey is an added module to its existing annual survey on above-scale industrial production enterprises, called the Annual Survey of Industrial Production (ASIP). On the other hand, Customs is responsible for managing the customs clearance documents provided by firms doing international trade. These firm-level trade data form the basis on which Customs conducts the survey.

The two agencies are trying to reach the same goal from different starting points and by taking different routes. The two microdata sets have rich information on firms' production, financial positions, and trade. Combined, they would be able to provide much-needed information on firms' import uses. However, the two threads of similar work are independent of each other. Therefore, among various sampling problems, the biggest problem with the two approaches is that neither of them is based on prior knowledge of both production and trade distribution patterns in the population.[2] Although this chapter does not include them, surveys on import uses by the two agencies serve as background for our analysis of the combined production and trade microdata sets on import uses.

Surveys are costly. Unless existing microdata are exhausted, surveys would not be efficient and, even worse, could lead to aggregation bias if they were not based on samples representative of Chinese firms' trade and production patterns, as the proportionality assumption would be implicitly applied.

Needless to say, the ideal approach is to make the best use of existing microdata on trade and production. Upward, Wang, and Zheng (2013) made the first attempt to do so in estimating China's DVS in exports. However, their work suffers from several flaws. These include

- proportionality assumption on import uses between domestic and export production,
- no differentiation regarding the proprietary rights between the two submodes of processing trade—1) processing with imported materials (PWIM) and 2) processing and assembly with provided imported materials (P&A),
- ignoring trading agency issues,
- treating the import and export data in the firm-level trade data set as having been used or produced by the same firms, and

- giving no consideration of the imported inputs embodied in domestic inputs.

Despite the above problems, Upward, Wang, and Zheng (2013) represent the right direction in which to move to pursue the microdata work in order to estimate the Chinese DVS in exports. This chapter follows this direction. Specifically, like Upward, Wang, and Zheng, we combine the two microdata sets used respectively and independently by the NBS and Customs. We identify the production enterprises that also do international trade by linking the two data sets. This enables us to reveal the patterns of Chinese firm heterogeneity in trade and production, which justify further exploration of the microdata in import uses and DVS estimation. After appropriately treating the problems in Upward, Wang, and Zheng, identified above, this chapter provides various estimates of DVS boundaries.

The chapter has five sections, counting this one. The next section, "Chinese I-O Table Development: Backgrounding the Microdata Work," introduces the recent development of Chinese I-O tables as background for our microdata work. Section Three, "Chinese Microdata and Firm Heterogeneity," explores the merged microdata and reports various measures of firm exposure to international trade to illustrate not only the within-sample but also the between-sample firm heterogeneity. Section Four, "Estimating DVS: Boundaries and Confidence," estimates Chinese DVS in exports based not only on various samples pulled from the microdata population but also on the aggregate commodity-level trade data. It provides lower and upper boundaries for DVS and the associated confidence levels. Section Five concludes with our speculation on how a firm survey project might improve the VS/DVS estimation.

CHINESE I-O TABLE DEVELOPMENT: BACKGROUNDING THE MICRODATA WORK

Recent Chinese I-O Table Development

As a tool of central planning, Chinese I-O tables traditionally had a domestic focus when the country was closed to the outside world, before 1978. The treatment of international trade in the I-O tables was minimal, assuming as it did that domestic and imported goods were identical. But with China increasingly opening up to foreign trade and investment, this assumption was later relaxed so that domestic and imported goods were treated as differentiated products. Pioneered by Chen et al. (2001) and continued in Chen et al. (2012), the structure of Chinese I-O tables has undergone dramatic change in the past decade to reflect the unique feature of Chinese foreign trade: About half of the country's foreign trade is administered under the processing trade regime. The separation of processing trade, normal trade, and domestic production in the Chinese I-O tables is justified by the theory of firm heterogeneity (Melitz 2003). The new I-O table has a rich trade structure and requires more information to fill in the coefficients, including the import-use matrices, which are crucial to estimating DVS in exports.

DVS Estimation without Import-Use Information

What can we know about the Chinese DVS in exports if we do not know the information on import uses? Table 7.1 shows several estimates based on public data. When talking about DVS in exports, one may be quick to think of it as a country's net exports in goods and services, or its current account balances. This is true only if imports used for final domestic consumption replace the same amount of domestic resources, which would otherwise be used for the same domestic production but instead are allocated to export production. This is a strong assumption. More often than not, imports for final domestic use are not perfect substitutes for goods or services in the export sector. This proxy overestimates the foreign content in exports or underestimates the DVS in exports. The proxy could be treated as the lower bound of the real DVS in exports. As shown in Table 7.1, this measure of lower-bound DVS (Total DVS1_lower) ranges between 8.2 and 25.3 percent over the period 2001–2010, reaching its high of 25.3 percent in 2007.

Furthermore, by breaking down Chinese foreign trade into normal and processing trade, the numbers for which are readily available from major Chinese government Web sites, we could treat processing imports as the only imported intermediates used for exports. This allows us to obtain an estimate of lower-bound vertical specialization, or VS, ranging from 26.4 to 37.5 percent over 2001–2010 and measuring 30.3 percent for 2007, which translates into an upper bound of DVS in exports of 69.7 percent for that year (Total DVS2_upper in Table 7.1).

Table 7.1 Estimates of Domestic Value-Added Shares in Exports without Import-Use Information (%)

	CA balances/ total exports	Total			L&M firms		
Year	Total DVS1_lower	Processing imports/ processing exports	Processing imports/ total exports	Total DVS2_upper	Processing imports/ processing exports	Processing imports/ total exports	Total DVS3_upper
2001	10.6	63.7	35.3	64.7	64.9	49.2	50.8
2002	11.5	67.9	37.5	62.5	67.9	51.0	49.0
2003	8.2	67.4	37.2	62.8	67.3	51.1	48.9
2004	8.3	67.6	37.4	62.6	69.9	50.6	49.4
2005	16.4	65.8	36.0	64.0	67.9	49.6	50.4
2006	21.6	63.0	33.2	66.8	62.4	44.8	55.2
2007	25.3	59.6	30.3	69.7	57.6	40.5	59.5
2008	24.4	56.0	26.4	73.6	—	—	—
2009	18.3	54.9	26.8	73.2	—	—	—
2010	14.7	56.4	26.5	73.5	—	—	—

NOTE: "CA" stands for "current account." "L&M" stands for "large and medium-sized firms." "DVS" stand for "domestic value-added share." — = data not available.

SOURCE: Authors' calculations based on data from National Bureau of Statistics of China Web site and China Customs Statistics (CCS).

In short, with the data on current account balances and the Chinese trade statistics alone, we can at best estimate only a range of Chinese DVS in exports, which for 2007 is 25.3 to 69.7 percent. To narrow down the lower and upper boundaries, we need to explore other data sources, which is the focus of the remaining part of the chapter.

Microdata Approach: What Can We Do, and What Can't We Do?

At the firm level, the Customs statistics have the same variables as those in the commodity-level trade statistics. Together with the firm production data, they raise the hope of estimating firm-level I-O tables. However, the following three problems hamper our efforts to do so:

1) The production enterprise data contain only total input use, but not its breakdown into domestic or foreign sources, or into different sectors.
2) The production enterprise data, normally without an import-use module, do not have import information and only have total exports. There is detailed import and export information in the firm trade data set, but the trading companies may resell the imports to other production firms and may also help export products made by other firms.
3) Neither of the two data sets has interfirm transaction information in either inputs or final products.

As a result, with the current Chinese firm-level data, it is difficult to give a precise DVS estimate. However, with rich information, it could be used to reveal the stylized patterns of firms' trade and production and serve as the basis for sensible assumptions and for efficient and unbiased survey design.

CHINESE MICRODATA AND FIRM HETEROGENEITY

Chinese Microdata Sets and Their Matching

We use two sets of 2007 Chinese firm-level data. First, the Customs data has product-level transaction information for 236,505 trading companies, which is the entire population of firm-level trade statistics. Second, ASIP data has 336,768 enterprises—all state-owned enterprises and other enterprises with annual sales of more than 5 million yuan—and covers 95 percent of industrial output and 98 percent of industrial exports, approximately the whole population of the Chinese industrial enterprises.

To merge the two data sets by firm name and other identifying information produces the linked data set, which is a subset of each of the two data sets. This is a standard exercise for researchers working on Chinese microdata. They may differ in specific matching criteria, but they use a similar strategy and therefore produce similar overall results. In this chapter, the matching exercise includes only trade data with nonzero exports and excludes those with zero exports but nonzero imports. This is a shortcoming for research on import uses. In terms of firm size, firms in the matched data set do both production and direct trade and tend to be large and medium (L&M), while firms in the nonmatched data set are generally small. Key summary statistics of the matching exercise for this chapter are presented in Table 7.2.

Among the 336,768 firms in the ASIP data set and the 236,505 firms in the trade data set, only 65,545 firms are successfully matched, accounting for 19.5 and 27.7 percent of the two data sets, respectively. The shares are small, but they account for 82.9 percent of the total of 79,103 exporting ASIP firms. In terms of trade volume, the matched firms handle 35.1 and 27.8 percent of the total exports for the two data sets, respectively. The ASIP data set does not have the import variable, and this data set accounts for only 16.9 percent of the total imports for the trade data set, lower than the same export share. The output and sales variables only appear in the ASIP data set, and they are almost the same in value, roughly 40–41 trillion yuan in total and 21–22 trillion yuan for exporting ASIP. Therefore, the L&M firms produce and sell about 18.5 percent of all ASIP firms' sales/output and 34.5 percent of exporting ASIP firms' sales/output.

There are several reasons that a large number of firms in the two data sets are not matched, in addition to the lack of accurate identification information. For the 80.5 percent of the total ASIP firms and the 17.1 percent of the exporting ASIP firms that are not matched, they either do not export at all or do not export directly, and therefore their names do not show up in the Customs registry. As for the 72.3 percent

Table 7.2 Summary Statistics of the 2007 Enterprise and Trade Data

Data Set	Firm numbers	Exports	Imports	Output	Sales
ASIP	336,768	7.34		40.50	40.00
Exporting ASIP	79,103	7.34		21.90	21.30
Trade data	236,505	9.27	7.27		
L&M (matched)	65,545	2.58	1.23	7.54	7.34
L&M ASIP exp > 0	50,277	2.31	1.05	5.95	5.81
L&M imp > 0	37,536	2.17	1.23	5.48	5.38

NOTE: Values for "Exports," "Imports," "Output," and "Sales" columns are in trillions of yuan. "ASIP" stands for "Annual Survey of Industrial Production." "L&M" stands for "large and medium-sized firms." Blank cell = data not applicable.

SOURCE: Authors' calculations based on data from National Bureau of Statistics of China Web site and China Customs Statistics (CCS).

of the firms in the trade data set that are not matched, they could be pure trading companies with no production at all, or they could be production firms that are not included in the ASIP data set.

In the L&M data set, there are two subsets that are used in this chapter. The subset "L&M ASIP exp > 0" represents the firms whose exports in the production data are also positive. The last row in Table 7.2 shows a subset of the matched data with positive imports (L&M imp > 0). This is the data set that Upward, Wang, and Zheng (2013) use in estimating China's DVS in exports. Because it is the smallest sample in terms of number of firms, its representativeness of the whole population is in doubt, and both firm heterogeneity within the data set and firm heterogeneity across samples deserve careful scrutiny if the aggregate DVS is to be derived from it.

Firm Heterogeneity in Trade and Production Patterns

The intermediates include two parts: 1) processing imports are treated as intermediates, and 2) intermediates under normal imports are identified with the "broad economic categories" (BEC) classification developed by the United Nations Statistics Division. Because of the existence of two submodes of processing imports, two different definitions are adopted for imported intermediates under processing imports in estimating DVS. One defines all processing imports as intermediates, and the other includes only processing with imported materials, or PWIM. To be consistent, the second definition is adopted when firms' input and output are used in estimating DVS together with import data, as the P&A (processing and assembly with provided imported materials) imports are not counted as input and not part of the output, either.

Trade intensity by ownership is shown in Table 7.3. The shares of intermediate imports in processing exports are listed in the first two columns. In comparing the shares in the L&M samples with those in the total population of trade statistics, we see that collective enterprises, wholly foreign-funded enterprises, and joint ventures behave similarly, whereas state-owned enterprises and private firms show significant differences. These differences possibly stem from the high concentration of pure trading companies among state-owned trading enterprises and the prevalence of small private firms in China's processing trade sector, since neither of these concentrations is included in the L&M samples. In both the total population and the L&M samples, only wholly foreign-funded enterprises have higher-than-average shares.

In the third and fourth columns in Table 7.3, normal imports of intermediates (defined in the BEC classification as a share of normal exports) are listed, showing large differences between the L&M samples and the population for all types of firms. Therefore, L&M samples are not representative of the population for this indicator either. Foreign firms (wholly foreign-funded firms and joint ventures) and state-owned enterprises have higher-than-average shares in both the total population and the L&M samples.[3]

In terms of the share of processing exports in total exports, shown in the fifth and sixth columns in Table 7.3, foreign firms (wholly foreign-funded firms and joint ventures) have the highest shares, and they are even higher in the L&M samples (85.9 and 65.5 percent, respectively), far ahead of the closest state-owned enterprises (34.2 percent). But the opposite is true for normal export share in total exports, as foreign firms have the lowest shares, shown in the seventh and eighth columns.

Across and within sample variations

Firm heterogeneity can be revealed in many ways. As we report in an earlier version of this chapter, which is available on the Web (Yao, Ma, and Pei 2013), when constructing export intensity (export/output)

Table 7.3 Use of Imported Intermediates and Exports Breakdown by Firm Type, 2007 (%)

	Imported intermediates as share of export value				Share of exports by customs category			
Formula	Processing imports/ processing exports		Normal BEC input imports/normal exports		Processing exports/ total exports		Normal exports/ total exports	
Firm type	Total	L&M firms	Total	L&M firms	Total	L&M firms	Total	L&M firms
Collective enterprises	41.6	41.0	37.8	14.9	24.1	15.4	75.9	84.6
Wholly foreign-funded enterprises	63.1	61.9	78.7	52.4	81.8	85.9	18.2	14.1
Joint ventures	48.3	46.7	73.7	59.2	59.7	65.5	40.3	34.5
Private firms	58.7	47.2	25.6	6.4	9.8	14.9	90.2	85.1
State-owned enterprises	63.4	38.0	104.4	64.3	26.6	34.2	73.4	65.8
All	59.7	57.6	62.7	40.7	50.6	70.4	49.4	29.6

NOTE: “L&M” stands for “large and medium-sized firms.” “BEC” stands for the “broad economic categories” classification.
SOURCE: Authors’ calculations based on data from National Bureau of Statistics of China Web site and China Customs Statistics (CCS).

and intermediates import intensity (imports input/output and imports input/input) indicators, we see considerable firm heterogeneity across and within sectors or samples, as well as evidence of importing agency problems, shown as larger-than-one intermediate import ratios over total output or input. To put things in perspective, Table 7.4 assembles some aggregate measures together with shares of value-added in output, with breakdown by firm ownership (domestic or foreign) and size.

For import intensity, large discrepancies exist between domestic and foreign firms, as foreign firms' import shares are much higher. There are some differences across firm size but more differences within the same size group for the share of imported input in total input, as shown by the difference between the weighted and simple averages, where total input value is used as the weight.

For export intensity, too, domestic and foreign firms behave differently: Again, foreign firms' export shares are higher. Compared to the "L&M ASIP exp > 0" sample, firm size matters more for the "Other exporting ASIP" sample, in which larger firms tend to export a smaller share of total output.

Value-added share in total output (Value-added/output) is a new indicator. While the aggregate measures in the two samples are quite similar, they can differ by as much as 6.3 and 58.6 percent, respectively, for the sectors "Artcrafts and other manufacturing" (China Industrial Classification [CIC] 42) and "Tobacco" (CIC 16), as shown in the tables of an earlier version of this chapter (Yao, Ma, and Pei 2013).

In summary, the existence of firm heterogeneity is extensive, and the issues of proprietary rights in processing imports and trading agency are real. These will complicate the efforts to estimate the DVS in Chinese exports.

ESTIMATING DVS: BOUNDARIES AND CONFIDENCE

Proportionality Assumption on Domestic and Export Production

Proportionality assumption regarding import uses means two things: 1) imports are proportionally allocated among different sectors, and 2) within each sector, they are further proportionally allocated between

Table 7.4 Summary Indicators by Type of Ownership and Firm Size, 2007 (%)

				Type of ownership		Firm size (no. of employees)			
Indicator	Data set	Average	All	Domestic	Foreign	<50	50–200	200–1,000	>1,000
Import input/	L&M	Weighted	22.8	6.3	29.4	28.7	24.6	21.3	23.9
input		across firms	59.0	22.0	71.0	38.0	57.4	69.5	29.7
Import input/	L&M	Weighted	17.3	4.8	22.2	21.6	18.6	16.2	18.2
output		across firms	16.1	5.3	19.6	18.9	15.8	15.4	18.5
Export/output	L&M	Weighted	45.6	37.0	59.5	55.0	50.1	50.8	52.5
	ASIP exp > 0	across firms	62.1	51.1	68.9	58.9	60.9	63.8	62.6
	Other exporting	Weighted	41.5	37.5	55.3	62.3	55.6	43.1	32.9
	ASIP firms	across firms	66.7	64.3	71.4	70.5	69.4	62.8	46.2
Value-added/	L&M	Weighted	25.9	25.8	26.0	25.7	25.4	26.1	26.0
output		across firms	26.7	25.6	27.4	24.4	26.1	27.6	28.4
	Other exporting	Weighted	27.1	26.9	27.6	24.1	26.6	27.1	27.8
	ASIP firms	across firms	28.3	27.5	30.0	23.8	27.5	31.1	31.8

NOTE: For the first indicator, total input value is used as the weight, and for the remaining three indicators, output value is used as the weight. "L&M" stands for "large and medium-sized firms." "ASIP" stands for "Annual Survey of Industrial Production."

SOURCE: Authors' calculations based on data from National Bureau of Statistics of China Web site and China Customs Statistics (CCS).

domestic and export production. If the importing agency problem could be solved so that the import data truly reflected the amount of intermediate imports used in a firm's production, then the L&M data set would be able to remedy the first problem. Thus, the importing agency issue is a focus of this chapter. As for the second problem, unfortunately, firm-level data alone are of little help, as they do not contain information on how firms split intermediate imports between domestic and export production.

When Hummels, Ishii, and Yi (2001) first employ I-O tables to estimate VS, they assume an equal percentage of foreign input in domestic output and exports. Upward, Wang, and Zheng (2013) retain this assumption in estimating China's vertical specialization (VS). Working from a data set similar to L&M, Upward, Wang, and Zheng distinguish between processing and normal trade and apply this assumption to normal trade only. That is, within normal trade, imports are allocated to domestic and export production proportionally to domestic output and normal exports. This assumption is oversimplified but still acceptable. However, when Upward, Wang, and Zheng actually do the calculation, they use the following formula to determine the ratio of intermediate import in domestic output and normal exports:

$$(7.1) \qquad r^{uwz} = \frac{M^{bec}}{Y - X^p} .$$

This is problematic, because imports for processing and assembly ($M^{p\&a}$) in the trade data set are included only in X^p but not in Y. Therefore, the denominator in the above formula gives a lower value for domestic output and normal exports, or a higher share of foreign content in domestic output and normal exports. $M^{p\&a}$ accounts for 17.0 and 24.2 percent of L&M processing imports and total processing imports, respectively, and these are not trivial amounts. As such, the problem associated with $M^{p\&a}$ in the above formula cannot be ignored.

Imports for Processing and Assembly and a Lower VS Boundary

This chapter corrects this problem and modifies the above formula by deducting $M^{p\&a}$ from processing exports when calculating the ratio of normal intermediate imports defined by BEC (M^{bec}):

$$(7.2) \qquad r = \frac{M^{bec}}{Y - (X^p - M^{p\&a})} = \frac{M^{bec}}{DN},$$

where *DN* represents domestic output and normal exports.

Export production often uses more foreign inputs than domestic production. This can be seen from trade intensity measures by ownership breakdown in Tables 7.3 and 7.4, where foreign-funded enterprises (FFEs) have higher shares of intermediate imports in normal exports, total input, and total output. Because FFEs dominate Chinese foreign trade in both imports and exports, a link can be established showing that export production has higher shares of foreign intermediates than domestic production. Also, considering that a domestic content requirement is normally imposed on FFEs for domestic production, a lower bound of *VS* exists as a result of this policy. In fact, the proportionality assumption regarding the import uses among domestic and export production, as reflected in Equation (7.2), can be regarded as the lower bound:

$$(7.3) \qquad VS^{lower} = M^p + \frac{M^{bec}}{Y - (X^p - M^{p\&a})} X^n = M^p + r \times X^n.$$

Trading Agency Problem

Imports and exports in the above equations mean the actual imports used as inputs by the firms and the actual exports produced by the firms. Because of the trading agency problem, trade volume from the trade data set does not meet this requirement at the firm level. However, since the L&M data already screened out the pure trading companies, production firms doing trading agency business are more likely to deal with firms in the same sector. Based on this assumption, we first sum up the variables across firms within a sector and then proceed to estimate sectoral *VS* using that formula. By so doing, we neutralize the trading agency problem among firms within a sector, but we also risk introducing aggregation bias. This can be illustrated by the following equations:

$$(7.4) \qquad VS_i^{lower} = M_i^p + \frac{M_i^{bec}}{DN_i} \times X_i^n,$$

$$(7.5) \qquad VS^{lower} = \sum M_i^p + \frac{\sum M_i^{bec}}{\sum DN_i} \times \sum X_i^n, \text{ and}$$

(7.6) $$VS^{lower} - \sum VS_i^{lower} = \sum\left(\frac{X_i^n}{DN_i} - \frac{\sum X_i^n}{\sum DN_i^n}\right) \times M_i^{bec}.$$

Because both within and between sectors variations could be large, as suggested in the section titled "Chinese Microdata and Firm Heterogeneity," the two approaches may generate different sectoral *VS*, as the right-hand side of Equation (7.6) is not always zero. This potential bias can also occur when estimation is done at the whole manufacturing level. The lower bound of VS thus should be treated with less confidence.[4]

Upper VS Boundary

After determining that the estimation of the lower bound of *VS* should be treated with less confidence, we now turn to the upper-bound *VS* estimation. As exports use more intermediate imports than domestic production, the upper limit of *VS* can be achieved by assuming all intermediate imports are used for export production:

(7.7) $$VS^{upper} = M^p + M^{bec} .$$

In contrast to the lower-bound *VS*, the upper-bound *VS* estimate is invariant of the level of analysis, commodity, or sectoral level. It is not subject to the constraint of the domestic content requirement, either. As a result, the confidence level is high for it, as long as we are confident in the BEC definition of intermediates.[5]

Results and Discussions

Sectoral and whole manufacturing shares of *VS* (*VSS*) over two samples, "L&M imp > 0" and "L&M," are reported in Table 7.5.[6] The lower bound of VSS is converted into the upper bound of DVS through the following formula:

(7.8) $$DVS = 1 - \frac{VS}{X} = 1 - VSS .$$

Across all sectors, DVS upper bounds are 61.0 and 67.2 percent for the respective two samples. Among all sectors, DVS's in the CIC sectors "Food manufacturing" and "Beverages" (CIC 14 and 15), "Furni-

Table 7.5 VS Share (VSS) and DVS by Sector, Estimated with Microdata (%)

		L&M imp > 0		L&M	
CIC[a]	Sector description	VSS_ lower	Total DVS4_ upper	VSS_ lower	Total DVS5_ upper
13	Agriculture and food processing	32.2	67.8	20.5	79.5
14	Food manufacturing	11.5	88.5	8.3	91.7
15	Beverages	8.2	91.8	5.5	94.5
16	Tobacco	56.7	43.3	56.7	43.3
17	Textile	23.1	76.9	16.2	83.8
18	Clothing, footwear, and caps	27.9	72.1	22.7	77.3
19	Leather, fur, feather, and products	35.7	64.3	28.1	71.9
20	Timber and wood products	24.6	75.4	16.2	83.8
21	Furniture	12.5	87.5	10.2	89.8
22	Paper and products	56.9	43.1	50.3	49.7
23	Printing and recording	26.9	73.1	24.0	76.0
24	Culture, educ., and sports products	23.7	76.3	20.2	79.8
25	Energy resource processing	16.6	83.4	6.1	93.9
26	Raw chem. materials and products	49.0	51.0	39.2	60.8
27	Medicines	19.7	80.3	14.3	85.7
28	Chemical fibers	51.8	48.2	48.8	51.2
29	Rubber	39.2	60.8	35.2	64.8
30	Plastics	55.1	44.9	47.2	52.8
31	Nonmetallic mineral products	17.8	82.2	11.7	88.3
32	Ferrous metals processing	72.8	27.2	37.9	62.1
33	Nonferrous metals processing	50.9	49.1	36.8	63.2
34	Metal products	23.6	76.4	18.9	81.1
35	General purpose machinery	22.7	77.3	18.3	81.7
36	Special purpose machinery	29.0	71.0	25.7	74.3
37	Transport equipment	30.0	70.0	26.2	73.8
39	Electrical machinery & equipment	35.6	64.4	30.8	69.2
40	Electronics	66.6	33.4	64.9	35.1
41	Measuring, cultural, office machine	42.0	58.0	39.2	60.8
42	Artcrafts and other manufacturing	30.9	69.1	21.8	78.2
43	Waste recycling and processing	88.8	11.2	80.7	19.3
All		39.0	61.0	32.8	67.2

NOTE: Gross output (rather than total sales) is adopted in the denominator. "VSS" stands for "vertical specialization share." "DVS" stands for "domestic value-added share." CIC category 38 has been omitted from the table.

[a] "CIC" stands for China Industrial Classification.

SOURCE: Authors' calculations based on data from National Bureau of Statistics of China Web site and China Customs Statistics (CCS).

ture" (CIC 21), "Petroleum and coking processing" (shown as "Energy resource processing," CIC 25), and "Nonmetallic mineral products" (CIC 31) are among the highest, because these domestic sectors are not as much globalized as the sectors with the lowest DVS's, such as "Communication, computer, and other electronic equipment" (shown as "Electronics," CIC 40) and "Waste recycling and disposal" (shown as "Waste recycling and processing," CIC 43). The DVS patterns are consistent with import intensity patterns reported in an earlier version of this chapter (Yao, Ma, and Pei 2013), where sectors with higher DVS's tend to have lower intensity of intermediate imports, and vice versa.

Comparing the two data samples, DVS's in the "L&M" sample are consistently higher than those in the "L&M imp > 0" sample, simply because the former data set has records with zero imports. Firms that do not import intermediates may buy from other production firms that are also in the importing agency business. This is another example of the fact that sampling matters in DVS estimation and the view that the trading agency problem deserves careful treatment.

Table 7.6 reports the aggregate DVS's, both lower and upper bounds, for overall and normal trade estimated with different data sets and intermediate definitions. Some of the numbers are drawn from previous tables. The numbers with superscript "a" are the estimates with

Table 7.6 Estimated DVS Boundaries (%)

	Total DVS		Normal DVS		Shares of
Data scope and imports input	Lower	Upper	Lower	Upper	P&A in PI
CA balances (DVS1)	25.3				
Total PI (DVS2)		69.7			
L&M PI (DVS3)		59.5			
L&M imp > 0 PI BEC (DVS4)	50.7	61.0[a]	66.9	94.5[a]	17.0
L&M PI BEC (DVS5)	58.5	67.2[a]	77.8	96.4[a]	17.0
Total PI BEC	38.9	68.0[a]	37.3	96.3[a]	24.2

NOTE: "DVS" stands for "domestic value-added share." "P&A" stands for "processing and assembly." "PI" stands for "processing imports." "L&M" stands for "large and medium-sized firms." "BEC" stands for the "broad economic categories" classification. Blank cell = data not applicable.

[a] Signifies a number that is an estimate with less confidence.

SOURCE: Authors' calculations based on data from National Bureau of Statistics of China Web site and China Customs Statistics (CCS).

less confidence, in part because of the firm heterogeneity issue, as discussed earlier in regard to Equation (7.6).[7] As a reminder, Table 7.6 also lists the shares of processing and assembly imports in total processing imports for the three data sets affected by the proprietary rights issue. Taking this issue into consideration helps improve the confidence level in the GVC upper bounds for the three data sets.

Clearly, the range of DVS estimates varies, depending on the scope of the data and the associated definitions of intermediates. For overall DVS, both lower and upper bounds are estimated with confidence, and the true value could be anywhere in the range of 38.9 to 69.7 percent. For normal trade, the DVS could be anywhere in a much wider range, from 37.3 to 96.3 percent.

What have we learned from our DVS estimation results? First of all, DVS estimates are sensitive to data samples. Cross-sample variations for lower and upper DVS bounds as well as the ranges of possible DVS are significant, especially when compared to the overall DVS estimates. This suggests that none of the samples appear to be representative of the population.

Second, as reflected by the wide range of possible GVC values, DVS estimates are sensitive to assumptions on import uses. This is intuitive, as the import uses across sectors and across domestic and export production directly allocate the flow of foreign intermediates within a country, and they ultimately determine the sectoral and overall DVS's. It is also in line with previous findings in I-O table literature—e.g., Dietzenbacher, Pei, and Yang (2012) and Yang et al. (2013).

Given the uncertainties surrounding the true DVS numbers, it is natural and logical to speculate about a firm survey project on import uses that aims to obtain additional information for better DVS estimation.

CONCLUSION

This chapter does not estimate the exact true DVS value because we do not make arbitrary assumptions. Instead, we take stock of the possible estimates, and in so doing we clarify several conceptual issues, which helps to improve the methodology in the literature. We leave a wide range for possible DVS estimates and only expect them to be narrowed down by future firm survey work.

Firm-level data have rich information that could be used to correct the bias in the import-use matrix caused by proportionality assumption in I-O table development. To realize the potential of such data, surveys need to overcome the nonrepresentative sampling and trading agency problems. They can do so, among other ways, by taking the following steps:

- First, identify the small production firms from firm-level trade data. This could be done by first screening the nonmatched small trading firms and then tracking them through firms' contact information to verify their production status. By incorporating these small trade and production firms, the L&M data set could be expanded to include large, medium, and small firms (LMS).
- Second, select a sample of firms from LMS to be covered by the survey. The questionnaire should include questions on the amount of imports that are for a firm's own use, the exports produced by customs regime, and the amount split between domestic production and export production, among others.

Of course, various other aspects of the firm distribution should also be considered, such as ownership, sector, location, and trading partners.

Firms are able to answer questions regarding direct import uses, but it is difficult for firms to know the uses of imports embodied in domestic inputs. Probably this is the only area that would require an assumption.

Notes

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1. The term "vertical specialization" is borrowed from Hummels, Ishii, and Yi (2001) and is defined as the value of imported intermediates in exports.

2. Details on the NBS and Customs import use surveys are documented in an earlier version of this chapter (Yao, Ma, and Pei 2013), which is available on the Web.
3. The higher shares for the state-owned companies are either because some of the traditional state trading companies have diversified their operations into production business and therefore are kept in the L&M data set, or because import of primary resources is often conducted by state-owned production enterprises with overseas investment.
4. Less confidence in the lower bound of VS is also due to lack of an exact minimum for domestic content requirement.
5. According to Timmer (2012), 14 percent of BEC codes can be both final goods and intermediates.
6. We do not attempt to compare the numerical results with those from other studies because our methodology is based on a different set of concepts, which makes it uncomparable.
7. VS is first estimated at sector level and then summed up across sectors. For VS estimation with the entirety of commodity trade data, in the last row of Table 7.6, there is no link between production output and trade data, and estimation can only be done with data summed over the whole database.

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Part 3

Trade in Intangibles and Data

8
A Formulary Approach for Attributing Measured Production to Foreign Affiliates of U.S. Parents

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The *Balance of Payments and International Investment Position Manual, Sixth Edition* (BPM), and the *System of National Accounts 2008* (SNA) both recommend attributing production to countries based on the residence of productive entities. The residence of an entity is generally determined to be the country in which a significant amount of production takes place. In cases where an entity has little or no physical presence, residence is determined as the country in which the entity is legally incorporated or registered. In the case of a multinational enterprise (MNE), the residency-based framework of the BPM and the SNA requires that the activities of affiliated entities resident in different countries be measured separately in order to accurately attribute the economic activity of each entity to the country in which it is resident.[1] Likewise, the residency-based framework requires that cross-border transactions between affiliated entities resident in different countries be included in balance of payments statistics.

For practical reasons, statisticians generally measure production and other attributes of MNEs based on accounting data. While the BPM (International Monetary Fund 2009) and the SNA (European Commission et al. 2009) recommend the residency-based framework for attributing measured production, attribution under the framework is not limited to a specific accounting treatment. In this chapter, we focus on formulary apportionment as an alternative treatment to separate accounting, which is the basis for current measures of production. Under separate accounting, accounting records are maintained separately for each entity within an MNE. As a result, accounting measures such as costs and profits are attributed to affiliated entities based on each entity's purpose within the structure of the MNE and not necessarily on the economic activity of the entity. In other words, accounting measures recorded under separate accounting may not accurately reflect the economic activity of the entity. Formulary apportionment is commonly required by U.S. state corporate income tax regulations to determine the income attributable to the state for a corporation that operates in multiple states. Rather than keeping separate accounting records for operations in each state, the corporation keeps consolidated records and attributes income to a state based on prescribed apportionment factors—such as employment, property, and sales—that reflect where income is actually earned.

Residency-based separate accounting may be particularly problematic for statisticians in cases where production is accomplished with inputs that are shared by multiple entities within the same MNE. Shared inputs may include intangible property such as patents, trademarks, formulas, processes, and so forth, or they may include headquarter services such as accounting, finance, and marketing, which do not need to be physically located at an entity in order to provide service (Helpman 1984; Markusen 1984, 1997). If a statistician is able to directly observe the economic activity of the entity in order to determine actual production, residency-based separate accounting may pose no particular problem. However, if the statistician only has accounting data for the entity, then identifying the location of production, which is the essence of the residency-based framework, is particularly difficult when the entity employs relatively few or no local inputs such as labor or property, plant, and equipment (PPE) but reports relatively significant accounting measures related to shared inputs. As shared inputs become more common and as MNE activities increase, challenges encountered under the residency-based framework become more important in the U.S. international transactions accounts (ITAs) and the U.S. National Income and Product Accounts (NIPAs) (Lipsey 2009, 2010; United Nations Economic Commission for Europe 2011).

As is consistent with the residency-based framework, the U.S. Bureau of Economic Analysis (BEA) attributes production to a foreign affiliate of a U.S. parent according to the country in which the affiliate is resident. If the affiliate has little or no physical presence in the country, the BEA follows the BPM and SNA recommendations to attribute production to the affiliate as long as the affiliate is legally incorporated or registered in the country. In addition, the BEA measures production based on accounting measures reported for the affiliate, and the accounting measures are determined under separate accounting according to generally accepted U.S. accounting principles. Thus, if an MNE is structured in a way that attributes accounting measures to an affiliate based on economic activity resulting from shared inputs that are not actually employed by the affiliate, production may be attributed to an affiliate with no economic activity.

In this chapter, we use formulary apportionment, which is also consistent with the residency-based framework, as an alternative for separate accounting to measure value-added at foreign affiliates of U.S. parents. We find that overall reattributions from foreign affiliates to U.S. parents are relatively small—less than 5 percent of total value-added attributed to all majority-owned foreign affiliates and U.S. parents under separate accounting. In contrast, reattributions across global regions including Africa, Asia, Europe, Latin America, and the Middle East are greater than 10 percent of value-added under separate accounting. Moreover, reattributions for foreign affiliates are greater than 10 percent of value-added under separate accounting for all industry sectors except administration, information, and transportation.

In addition to applying formulary apportionment to reattribute value-added, we report preliminary results to reattribute service imports and exports between U.S. parents and their foreign affiliates. We find a relatively large decrease in imports but no meaningful change in exports. The overall effect on gross domestic product (GDP) is only a small increase—approximately 0.1 percent. Based on our preliminary results, we expect to be able to provide a complete picture of the U.S. current account under formulary apportionment in a future paper.

Using factor shares to evaluate the results, we conclude that value-added attributed to foreign affiliates and U.S. parents under formulary apportionment yields a picture of measured production by industry sector and country that is more congruent with economic activity than related measures generated under separate accounting. Thus, formulary apportionment appears to be a viable alternative to separate accounting under the residency-based framework of the BPM and the SNA.

Following this introductory section, the chapter is organized into the five sections that follow. The next section provides an overview of related literature. The third section outlines the BEA's current framework for measuring production based on residency-based separate accounting and outlines the proposed framework for attributing production based on residency-based formulary apportionment. The fourth section describes the BEA's survey data on the operations of MNEs. The fifth section presents the results of the formulary apportionment. The last section offers a conclusion.

RELATED LITERATURE

To provide context for our work, we draw upon four distinct but related lines of literature. First, we borrow features from the industrial-organization (IO) literature on foreign direct investment (FDI) and trade to outline a simple production model for foreign affiliates that underlies our choice of formulary apportionment. Second, we describe the international guidelines that provide a framework for organizing official statistics on FDI and trade. Third, we review the literature that identifies challenges encountered under the residency-based framework and proposes alternative frameworks for organizing official statistics on FDI and trade. Fourth and finally, we discuss the literature on formulary apportionment as it is applied in international taxation and identify features of formulary apportionment as a tool for attributing measured production to entities within an MNE.

Industrial-Organization Literature

The IO literature on FDI and trade focuses on adapting general equilibrium trade models to include endogenous MNEs. Early work explains the origination of MNEs based on the organization of production into one of two types (Caves 1971): 1) vertical integration (Brainard 1993; Helpman 1984) and 2) horizontal integration (Brainard 1997; Markusen 1984). However, Markusen (1997) argues that the outcomes identified by vertical and horizontal models face limitations based on underlying assumptions; he constructs an alternative knowledge-capital model.

Regardless of how production is organized, a useful feature of each of the IO models of FDI and trade is the inclusion of a local input and a firm-specific shared input, which can be used jointly by multiple affiliates. Firm-specific inputs do not need to be physically present for production to take place, but firm-specific inputs cannot generate production without the local input. General equilibrium in each model results under assumptions that include foreign affiliates that produce with constant returns to scale and operate in perfectly competitive markets. The models also assume that production is separable across affiliates and that markets are segmented.

International Guidelines

The international guidelines explain how official FDI and trade statistics should be constructed. In paragraph 4.11 of the BPM, an economy is defined as comprising "all the institutional units that are resident in a particular economic territory."[2] One of the attributes of an institutional unit is the existence of a complete set of accounting records (BPM para. 4.13[d]; SNA para. 4.2[d]), which implies that the possibility of separate accounting is required under the residency-based framework. In addition, the international guidelines consider the possibility that production may be located somewhere other than the economic territory where an entity is legally incorporated or registered. In particular, paragraph 4.134 of the BPM states, "A legal entity is resident in the economic territory under whose laws the entity is incorporated or registered. . . . It must not be combined with entities resident in other economies. If [the entity] has substantial operations in another economy, a branch may be identified there." In this case, the branch is treated as an institutional unit subject to the criterion for accounting records (BPM para. 4.27[a]), and the operations of the branch are to be attributed to the corresponding economic territory (BPM para. 4.26). Thus, as is consistent with the IO literature on FDI and trade, the international guidelines consider the possibility that factors of production may be located somewhere within an MNE other than with an affiliate to which production would be attributed based merely on legal incorporation or registration of the affiliate. Furthermore, the criterion for accounting records does not rule out formulary apportionment as an alternative to separate accounting for either the measurement or the attribution of production at the affiliate. The intent of the guidelines is that production is attributed where it is actually taking place.

Alternative Measurement Frameworks

Challenges in implementing the residency-based framework are widely addressed in international discourse and academic literature. The United Nations recently published a collection of papers that address the impact of globalization on national accounts (United Nations Economic Commission for Europe 2011). An entire chapter is dedicated to identifying and explaining challenges associated with allocating production to national economies under a residency-based framework. Among the challenges are the transfers of intangible property and the attribution of associated income. However, the chapter does not offer any analysis to identify the extent to which allocation of production may be incongruent with actual economic activity. Lipsey (2009, 2010) offers evidence of possible distortions in U.S. outbound FDI and trade flows present in aggregate data published by the BEA for service industries. Lipsey suggests the distortions are a result of global structuring of MNEs and the mobility of productive resources in the service industries. As a result, he suggests but does not develop an alternative location-based framework to accompany the residency-based framework for measuring trade in services.

Early work also suggests supplemental frameworks for organizing FDI and trade statistics based on ownership. Baldwin and Kimura (1998) find that net sales activities of U.S. affiliates of foreign-based MNEs to Americans and of foreign affiliates of U.S.-based MNEs to foreigners are almost as high as measured U.S. imports and exports, respectively. Kimura and Baldwin (1998) find that FDI has an even larger role in the Japanese economy. In each case, the authors use their results to highlight the usefulness of an ownership-based framework. Landefeld, Whichard, and Lowe (1993) explain and evaluate ownership-based trade measures and propose an alternative residency-based trade measure that includes an adjustment for the net effect on the U.S. economy of the operations of U.S.-owned companies abroad and of foreign-owned companies in the United States. As a result of the early work on alternative organizing frameworks, the BEA publishes annual ownership-based measures of the current account of the

ITAs as a supplement to the residency-based framework (Whichard and Lowe 1995). The ownership-based framework is fully consistent with the international standards of the BPM and the SNA and combines with the residency-based measures of U.S. imports and exports the transactions of affiliates that are not captured in the residency-based framework. While the ownership-based framework may address some of the challenges encountered under the residency-based framework, the ownership-based framework is not intended to identify the location of production, which is the centerpiece for national economic accounting purposes.

Formulary Apportionment Literature

While formulary apportionment is historically used in U.S. multistate taxation practice, the treatment of global income under formulary apportionment is also explored in research. In particular, some researchers suggest formulary apportionment as an alternative to the complexities of determining transfer prices and applying the arm's length standard in the determination of international tax obligations of MNEs. Martens-Weiner (2006) discusses the problems related to replacing separate accounting for companies operating in Europe with a system of formulary apportionment for the European Union. The issues span a spectrum including business attitudes toward formulary apportionment, designing an apportionment formula, and tax administration and compliance.

In related work, Fuest, Hemmelgarn, and Ramb (2007) find that smaller European countries that currently attract a relatively large tax base under separate accounting would have a much smaller tax base under formulary apportionment. Avi-Yonah and Clausing (2007) propose a system of formulary apportionment that would include sales as a single apportionment factor. Avi-Yonah and Clausing argue that their proposed method would protect the U.S. tax base by preventing the practice of income-shifting to low-tax countries. Avi-Yonah (2010) proposes a hybrid system in which separate accounting is used to the extent that income can be attributed based on observed determinants and the residual profit is attributed under formulary apportionment. Altshuler and Grubert (2010) simulate firm behavior and U.S. revenue collection and find that different responses to tax incentives yield similar revenue under separate accounting and formulary apportionment. In contrast, Hines (2010) presents evidence that the determination of international tax obligations under formulary apportionment may distort actual income attributable to a given country because of income that is unexplained by apportionment factors; this may lead to inefficient allocation of productive resources because of differences in tax rates across countries.

We are not aware of any previous study that applies formulary apportionment to attribute measured production to entities within an MNE, but the attribution of measured production under formulary apportionment does not invoke the policy concerns described above for international taxation, because MNEs presumably do not make operating decisions based on surveys intended solely for statistical purposes. However, formulary apportionment could affect the picture of global production, which could have policy implications. Given the definitions and concepts underlying the international guidelines for measuring official FDI and trade statistics and the challenges encountered under the resulting residency-based framework when applied to MNEs, we next draw upon the related IO literature to outline a simple production model for foreign affiliates and construct a formulary framework for attributing measured production to foreign affiliates of U.S. parents.

MEASURING PRODUCTION

Before we outline the formulary framework to attribute production to foreign affiliates of U.S. parents, we discuss a production model based in part on Bartelsman and Beetsma (2003), Helpman (1984), and Markusen (1984, 1997). Consider an MNE with one U.S. parent and one or more foreign affiliates. An affiliate engages in actual production, denoted as Q^*, with locally purchased inputs such as labor and PPE, denoted as L, and shared inputs such as intangible property and headquarter services, denoted as H, as follows:[3]

$$Q^* = f(L,H). \quad (8.1)$$

While we do not assume a particular functional form, we do assume that shared inputs cannot be utilized without local inputs (i.e., $L > 0$). In contrast, we assume that local inputs do not necessarily require shared inputs (i.e., $H \geq 0$).

In practice, a statistician does not observe actual production for the affiliate. However, value-added, denoted as Q^{ε}, can be measured for the affiliate with one of two approaches. As one approach, value-added can be measured as the difference between gross sales and intermediate inputs. In this case, a discrepancy exists between actual production and measured production to the extent that gross sales and intermediate inputs include related party transactions that do not reflect market prices. Alternatively, value-added can be measured as the sum of costs incurred (other than costs of intermediate inputs) and profits earned in production. In this case, costs and profits reflect returns to local inputs and shared inputs, and a discrepancy exists between actual production and measured production to the extent that returns accruing to local and shared inputs are over- or underattributed to the affiliate. While we can assume returns accruing to local inputs are properly attributed because they are generally determined from market transactions, we cannot be sure that returns to shared inputs are properly attributed, given the mobility of shared inputs and their related returns as well as the possible lack of associated market transactions. In either case, the discrepancy, denoted as ε, between actual production, Q^{*}, and measured production, Q^{ε}, can be written as follows:

$$(8.2) \quad \varepsilon = Q^{*} - Q^{\varepsilon}.$$

The objective is to choose a measurement approach to minimize ε. Determining the magnitude of ε is difficult, but Lipsey (2009, 2010) provides some evidence of possible distortions in statistics measured for foreign affiliates of U.S. parents.

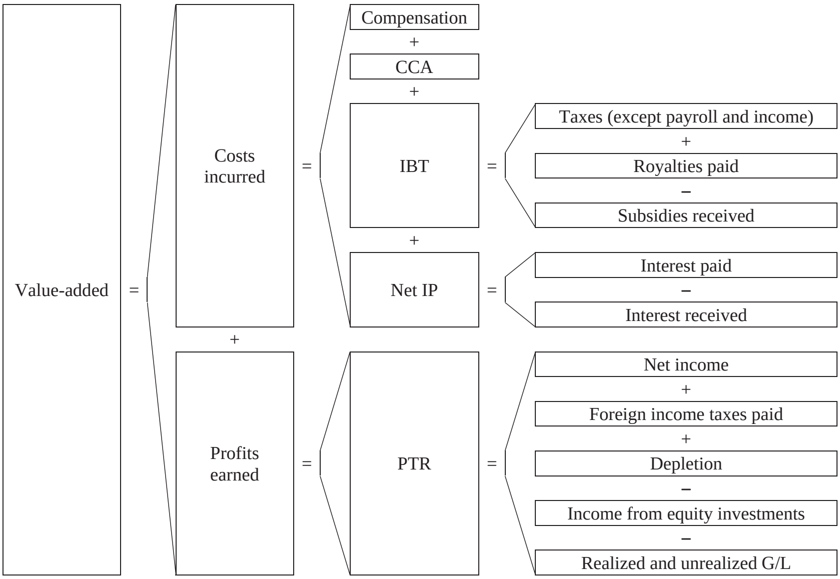
Residency-Based Separate Accounting

As is consistent with the residency-based framework of the BPM and the SNA, the BEA attributes value-added to a foreign affiliate according to the country in which the affiliate is resident. If the affiliate has little or no physical presence in the country, the BEA follows the BPM and SNA recommendations to attribute value-added to the affiliate, as long as the affiliate is legally incorporated or registered in the country. The BEA measures value-added as the sum of costs incurred and profits earned in production. Both costs and profits are determined under separate accounting, according to generally accepted U.S. accounting principles. Under separate accounting, accounting records are maintained separately for each entity within an MNE. As a result, if the MNE is structured in a way that attributes costs and profits to an affiliate based partially or solely on economic activity related to shared inputs, measured value-added may be attributed to an affiliate with relatively few or no local inputs and relatively little or no economic activity. In other words, value-added attributed to the affiliate may be distorted to the extent that costs and profits reflect economic activity related to shared inputs that are not actually employed by the affiliate.[4]

Figure 8.1 depicts each of the components and subcomponents of value-added that are published as part of the BEA's multinational statistics. Costs incurred include four components: 1) compensation, 2) capital consumption allowance (CCA), 3) indirect business taxes (IBT), and 4) net interest paid (IP). Compensation includes payroll taxes. CCA is an accounting rather than an economic measure of depreciation.[5] IBT includes taxes related to business registry and operations other than income taxes and payroll taxes.[6] IBT is adjusted for government subsidies received and production royalty payments to foreign governments for natural resources. Net IP includes interest expensed or capitalized less interest income. The profits component is referred to as profit-type return (PTR) in the BEA's multinational statistics and includes net income adjusted for foreign income taxes paid, depletion, income from equity investments in foreign affiliates, and realized and unrealized gains and losses.

Using the context of our production model, we identify the components of value-added that reflect returns to local inputs and to shared inputs. In particular, we consider compensation and CCA to only reflect returns to local inputs. Compensation and CCA are returns for services provided by labor and PPE, respectively, which need to be physically located at an affiliate in order to provide service. In contrast, IBT reflects payments to the host government for the privilege of existing in a location, such as fees for licenses and registration, in addition to payments for conducting operations in the location, such as sales taxes and property taxes. Licenses and registration do not require a physical location, but we do consider sales taxes for unaffiliated sales and prop-

Figure 8.1 Measurement Framework for Value-Added Attributable to Foreign Affiliates and U.S. Parents



NOTE: "CCA" stands for capital consumption allowance; "IBT" stands for indirect business taxes; "IP" stands for interest paid; "PTR" stands for profit-type return; and "G/L" stands for gain/loss.

SOURCE: Authors' summary based on Table 10 of Mataloni and Goldberg (1994).

erty taxes to require a physical location. Likewise, net IP and PTR can reflect returns to local inputs, shared inputs, or both. However, absent any compensation and CCA (and IBT related to operations), measured value-added that includes only net IP and PTR (and IBT related to registration) under separate accounting cannot be correct, according to our model. According to our assumption for *L* in Equation (8.1), production is impossible without local inputs. In other words, separate accounting may not minimize ε in Equation (8.2). We refer to IBT, net IP, and PTR collectively as the shared input components of value-added. We turn now to formulary apportionment as an alternative to separate accounting for attributing value-added to foreign affiliates.

Residency-Based Formulary Apportionment

While the BPM and the SNA recommend the residency-based framework for attributing measured production to entities within an MNE, attribution under the framework is not limited to separate accounting and may presumably include formulary apportionment. In contrast to separate accounting, formulary apportionment is based on consolidated accounting measures. Formulary apportionment is commonly required by U.S. state corporate income tax regulations to determine the income attributable to the state for a corporation that operates in multiple states. Rather than keeping separate accounting records for operations in each state, the corporation keeps consolidated records and attributes income to states based on prescribed apportionment factors that ideally reflect where income is actually earned based on economic activity. Apportionment factors generally include factors related to employment, property, and sales, which reflect the presence of local inputs and economic activity specific to the entity.

As is consistent with our production model, consider an MNE m with one U.S. parent and one or more foreign affiliates. Let q_n denote measured production under separate accounting for each entity n (i.e., the U.S. parent and its foreign affiliates) belonging to the MNE m. For flexibility, q may include total value-added or simply include the shared-input components of value-added. Likewise, let $x_{j,n}$ denote apportionment factor j for each entity n, and let α_j denote the weight associated with apportionment factor j, where $\sum_j \alpha_j = 1$. Apportionment factor j should reflect economic activity. Under formulary apportionment, measured production (denoted as $\bar{q}_n$) attributable to entity n within MNE m is calculated as follows:

$$\text{(8.3)} \qquad \bar{q}_n = \underbrace{\left(\sum_j \alpha_j \frac{x_{j,n}}{\sum_n x_{j,n}} \right)}_{\substack{\textit{Apportionment} \\ \textit{Weight}}} \underbrace{\left(\sum_n q_n \right)}_{\substack{\textit{MNE} \\ \textit{Production}}} \ \forall\ n \in m.$$

As noted under the horizontal brackets in Equation (8.3), measured production attributable to an entity under formulary apportionment, $\bar{q}_n$, is a weighted average of the consolidated measured production determined for the MNE (i.e., the U.S. parent and its foreign affiliates) under separate accounting. Each apportionment weight is a combination of each apportionment factor and its associated weight.

We apply data to *q* in Equation (8.3) for the shared-input components of value-added (i.e., IBT, net IP, and PTR) for foreign affiliates and their U.S. parents. We then add the shared input components attributed to each entity under formulary apportionment to the local input components of value-added (i.e., compensation and CCA) attributed to each entity under separate accounting in order to obtain a new measure of value-added for each entity under formulary apportionment.[7]

DATA

We use survey data for 2009 that are collected by the BEA from MNEs on direct investment operations and that are used to compile the BEA's published statistics on the activities of MNEs. The data include apportionment factors related to employment, property, and sales. We focus attention on results obtained for foreign affiliates classified in select service-industry sectors because services are a growing component of MNE activities and because of the role shared inputs potentially play in the production attributed to foreign affiliates classified in the select service industry sectors (Lipsey 2010). The select service industry sectors include administration; finance; information; insurance; management of companies; miscellaneous; professional, scientific, and technical (PST); and real estate and leasing.

Data on Operations

We use operations data collected for U.S. parents and their majority-owned foreign affiliates (MOFAs) in the 2009 Benchmark Survey of U.S. Direct Investment Abroad. A foreign affiliate is an enterprise that has more than 10 percent of its voting stock owned by a U.S. parent. A MOFA is a foreign affiliate in which the combined direct and indirect ownership interest of all U.S. interests is more than 50 percent. A U.S. parent is defined as a U.S. person with an investment interest, either directly or indirectly, of 10 percent or more in a foreign business enterprise.

Benchmark-operations survey forms are required to be completed for all U.S. parents (Form BE-10A). In addition, benchmark-operations survey forms are required for each MOFA with more than $80 million in assets, sales, or net income (net loss) (Form BE-10B).[8] Data used in this study for a given U.S. parent pertain only to the activities of the parent. Data for a given foreign affiliate pertain only to the activities of the affiliate. Data collected on the operations survey forms include income statement information and balance sheet information. Income statement information includes sales by type (i.e., goods, services, and investment income), location, and affiliation. In addition, income statement information includes detailed expenses such as compensation, depreciation, interest, and taxes. The BEA uses information from the income statement to measure value-added for each affiliate. Balance sheet information includes details regarding assets, liabilities, and owner's equity. Asset details include PPE.

Apportionment Factors

The choice of apportionment factors and their associated weights influences the results obtained from formulary apportionment. We consider three apportionment factors that are available in the operations data: 1) compensation, 2) net PPE, and 3) unaffiliated sales. Compensation and net PPE reflect local inputs employed in production. Unaffiliated sales may also reflect local inputs that may not be reflected in compensation and net PPE. If an affiliate has no compensation or net PPE, production is still attributed to the affiliate under formulary apportionment if unaffiliated sales are greater than zero. Likewise, if an affiliate has no unaffiliated sales, production is still attributed to the affiliate under formulary apportionment if compensation or net PPE is greater than zero. In other words, production attributed to the affiliate by Equation (8.3) is assumed to be proportional to the economic activity reported for the affiliate.[9]

We report the results from weighting compensation by 60 percent, net PPE by 25 percent, and unaffiliated sales by 15 percent.[10] We determine the factor weights based on each factor's share of the mean value-added, as calculated by using coefficients from a regression of value-added on the apportionment factors. We initially determine factor weights separately for two subsamples of the data: 1) MOFAs and U.S. parents classified in select service industry sectors and 2) MOFAs and U.S. parents classified in all other industry sectors. However, even though the coefficient estimates are statistically different for the two subsamples, the resulting factor weights from each subsample are nearly identical because of differences in the subsample means.[11] Thus, we apply the factor weights obtained from the combined sample of MOFAs and U.S. parents classified in any industry sector. In addition to obtaining reasonable factor weights, the explanatory power of the apportionment factors is high (i.e., adjusted *r*-squared = 0.84).

RESULTS

Our goal is to use formulary apportionment as a substitute for separate accounting to reattribute measured value-added to foreign affiliates of U.S. parents. Our primary approach is to consolidate the shared-input components of value-added (i.e., IBT, net IP, and PTR) measured under separate accounting for a given MNE (i.e., the U.S. parent and its MOFAs) and reattribute to all entities within the MNE (i.e., the U.S. parent and its MOFAs) based on each entity's apportionment weight. In this case, value-added for an entity within the MNE includes compensation and CCA under separate accounting plus the shared-input components reattributed under formulary apportionment.

We divide the discussion of the results into four subsections: 1) reporting value-added and the related reattributions under formulary apportionment, 2) evaluating value-added under formulary apportionment relative to value-added under separate accounting, 3) interpreting the results in the context of our production model, and 4) discussing implications for the U.S. current account.

Value-Added and Reattributions under Formulary Apportionment

Table 8.1 summarizes value-added by industry sector and by global region for MOFAs and U.S. parents. For reference, the first three columns report published value-added determined under separate account-

Table 8.1 Value-Added by Industry Sector and by Global Region (billions of US$)

		Separate accounting			Formulary apportionment		
		MOFAs	U.S. parents	Total	MOFAs	U.S. parents	Total
	Select service industry sectors						
1	Administration	25.1	59.1	84.2	27.2	60.6	87.8
2	Finance	66.9	192.7	259.6	48.7	206.7	255.4
3	Information	51.0	287.6	338.7	50.7	294.6	345.2
4	Insurance	13.8	67.4	81.2	9.9	74.7	84.6
5	Management of companies	−14.5	−1.3	−15.7	3.2	– 0.6	2.7
6	Miscellaneous services	10.3	28.1	38.4	8.4	28.9	37.3
7	Professional, scientific, technical	78.5	177.5	256.1	88.3	176.2	264.5
8	Real estate and rental and leasing	22.7	34.5	57.2	14.1	35.7	49.9
9	Subtotals	254.0	845.6	1,099.6	250.6	876.8	1,127.4
	Other industry sectors						
10	Accommodation and food services	14.3	52.7	67.0	18.2	49.1	67.3
11	Construction	4.9	22.1	27.0	(D)	(D)	(D)
12	Farming, fishing, forestry	0.9	2.2	3.1	(D)	(D)	(D)
13	Health care and social assistance	1.5	31.8	33.3	(D)	(D)	(D)
14	Manufacturing	478.2	1,034.1	1,512.3	411.1	1,147.7	1,558.8
15	Mining	153.7	76.1	229.8	104.4	81.4	185.7
16	Retail trade	57.1	238.6	295.7	50.8	241.0	291.7
17	Transportation and warehousing	18.1	106.1	124.3	17.0	106.9	123.9
18	Utilities	9.5	62.0	71.5	(D)	(D)	(D)

19	Wholesale trade	152.7	124.4	277.1	122.4	128.6	251.1
20	Subtotals	891.0	1,750.1	2,641.1	741.1	1,872.2	2,613.3
21	Totals for industry sectors	1,145.0	2,595.8	3,740.7	991.7	2,749.0	3,740.7
	Global regions						
22	Africa	44.9		44.9	29.7		29.7
23	Asia	241.1		241.1	210.7		210.7
24	Canada	113.7		113.7	111.3		111.3
25	Europe	599.2		599.2	523.7		523.7
26	Latin America	128.4		128.4	102.3		102.3
27	Middle East	17.7		17.7	14.0		14.0
28	United States		2,595.8	2,595.8		2,749.0	2,749.0
29	Totals for global regions	1,145.0	2,595.8	3,740.7	991.7	2,749.0	3,740.7

NOTE: A “(D)” denotes data suppressed to avoid disclosure of data of individual companies. Blank cell = data not applicable. Some totals or subtotals may be slightly off because of rounding.

SOURCE: The first three columns, under the heading "Separate accounting," include statistics published online in the BEA’s financial and operating data on direct investment and multinational companies (http://www.bea.gov/iTable/index_MNC.cfm). The second three columns, under the heading "Formulary apportionment," include the authors’ calculations after value-added is attributed under Equation (8.3).

ing. The second three columns of Table 8.1 present results determined under formulary apportionment in Equation (8.3). Table 8.2 reports the dollar differences and the percentage differences between value-added under formulary apportionment and value-added under separate accounting from Table 8.1. Table 8.2 shows overall reattributions, reattributions by global region, and reattributions by industry sector.

Overall Reattributions

Line 21 of Table 8.2 shows that the overall reattribution of value-added from MOFAs to U.S. parents is $153.3 billion under formulary apportionment. The percentage decrease in value-added attributable to MOFAs is 13.4 percent (column 4), and the percentage increase in value-added attributable to U.S. parents is 5.9 percent (column 5). Overall, reattributions are small relative to total value-added attributed to all MOFAs and U.S. parents under separate accounting—less than 5 percent.

Reattributions by Global Region

In contrast to overall reattributions from MOFAs to U.S. parents, reattributions across some global regions are relatively large. In particular, the percentage decreases in value-added are greater than 10 percent for Africa, Asia, Europe, Latin America, and the Middle East but less than 10 percent for Canada (Table 8.2, column 4). Under both formulary apportionment and separate accounting, more value-added is attributed to MOFAs in Europe than in any other global region (Table 8.1, line 25). However, Canada and Latin America change places under formulary apportionment in the distribution of value-added by global region (Table 8.1, lines 24 and 26). Under formulary apportionment, more production is attributable to MOFAs in Canada than in Latin America. Thus, in addition to less measured production attributable to MOFAs in each of the six global regions, there are interregional changes in the distribution of measured production attributable to MOFAs of U.S. parents as a result of formulary apportionment.

Reattributions by Industry Sector

Reattributions across some industry sectors are also relatively large. The percentage changes in value-added are greater than 10 percent for MOFAs classified in all industry sectors except administration, information, and transportation (Table 8.2, column 4). Reattributions greater than 10 percent also result for U.S. parents classified in insurance, management, and manufacturing (Table 8.2, column 5).

Under both formulary apportionment and separate accounting, more value-added is attributed to MOFAs classified in PST than for any other select service sector (Table 8.1, line 7), and more value-added is attributed to MOFAs classified in manufacturing than for any of the other industry sectors (Table 8.1, line 14). The distribution of value-added under formulary apportionment is also the same for MOFAs classified in all other select service sectors except finance and information (Table 8.1, lines 2 and 3, respectively). However, the distribution of value-added under formulary apportionment changes for MOFAs classified in accommodation, mining, transportation, and wholesale (Table 8.1, lines 10, 15, 17, and 19, respectively). The industry distribution of value-added under formulary apportionment does not change for U.S. parents. Thus, we observe an interindustry change in the distribution of measured production attributable to MOFAs but not to U.S. parents.

As is consistent both with overall reattributions and with reattributions by global region, value-added reported in Table 8.1 for each industry sector is generally higher under formulary apportionment for U.S. parents and lower for MOFAs. While this is not directly observable in Table 8.2, we look at the underlying data to trace reattributions to U.S. parents from MOFAs. Reattributions to U.S. parents classified in manufacturing are due in large part to reattributions from MOFAs classified in manufacturing and mining. Likewise, increases for U.S. parents classified in information and manufacturing are explained in large part by decreases for MOFAs classified in leasing. There are also reattributions from MOFAs classified in finance to U.S. parents classified in insurance. The remaining reattributions are among MOFAs classified in management and MOFAs and U.S. parents classified in finance, insurance, miscellaneous, PST, retail, and wholesale.

Table 8.2 Value-Added Reattributable under Formulary Apportionment

		Billions of US$			Percentage		
		MOFAs	U.S. parents	Total	MOFAs	U.S. parents	Total
	Select service industry sectors						
1	Administration	2.0	1.5	3.6	8.1	2.6	4.3
2	Finance	−18.2	14.0	−4.2	−27.2	7.3	−1.6
3	Information	−0.4	6.9	6.6	−0.7	2.4	1.9
4	Insurance	−3.9	7.3	3.4	−28.0	10.8	4.2
5	Management of companies	17.7	0.7	18.4	122.5	53.5	116.9
6	Miscellaneous services	−1.9	0.8	−1.0	−18.1	2.9	−2.7
7	Professional, scientific, technical	9.8	−1.3	8.4	12.4	−0.7	3.3
8	Real estate and rental and leasing	−8.6	1.2	−7.3	−37.8	3.6	−12.8
9	Subtotals	−3.4	31.2	27.8	−1.3	3.7	2.5
	Other industry sectors						
10	Accommodation and food services	3.8	−3.5	0.3	26.6	−6.7	0.4
11	Construction	(D)	(D)	(D)	(D)	(D)	(D)
12	Farming, fishing, forestry	(D)	(D)	(D)	(D)	(D)	(D)
13	Health care and social assistance	(D)	(D)	(D)	(D)	(D)	(D)
14	Manufacturing	−67.0	113.5	46.5	−14.0	11.0	3.1
15	Mining	−49.3	5.2	−44.1	−32.1	6.9	−19.2
16	Retail trade	–6.3	2.4	–4.0	−11.1	1.0	−1.3

17	Transportation and warehousing	−1.1	0.8	−0.3	−6.1	0.7	−0.3
18	Utilities	(D)	(D)	(D)	(D)	(D)	(D)
19	Wholesale trade	−30.3	4.2	−26.1	−19.8	3.4	−9.4
20	Subtotals	−149.9	122.1	−27.8	−16.8	7.0	−1.1
21	Totals for industry sectors	−153.3	153.3	0.0	−13.4	5.9	0.0
	Global regions						
22	Africa	−15.2		−15.2	−33.8		−33.8
23	Asia	−30.4		−30.4	−12.6		−12.6
24	Canada	−2.4		−2.4	−2.1		−2.1
25	Europe	−75.5		−75.5	−12.6		−12.6
26	Latin America	−26.2		−26.2	−20.4		−20.4
27	Middle East	−3.6		−3.6	−20.5		−20.5
28	United States		153.3	153.3		5.9	5.9
29	Totals for global regions	−153.3	153.3	0.0	−13.4	5.9	0.0

NOTE: A "(D)" denotes data suppressed to avoid disclosure of data of individual companies. The values for "Billions of US$" (first three columns) are calculated by subtracting value-added under separate accounting from value-added under formulary apportionment. Percentages (second three columns) are calculated by dividing the values for "Billions of US$" by the absolute value of value-added under separate accounting. Some totals or subtotals may be slightly off because of rounding. Blank cell = data not applicable.

SOURCE: Authors' tabulations.

Evaluation of Value-Added under Separate Accounting and Formulary Apportionment

We calculate approximate factor shares of value-added using the local input components and shared input components of value-added. Factor shares are informative because they reveal the relative contributions of local inputs and shared inputs to total measured production. We interpret factor shares using global factor shares as a reference. Published returns to local inputs as a share of published value-added are 52.8 percent for all MOFAs and 75.3 percent for all U.S. parents. Published returns to local inputs for all MOFAs and all U.S. parents combined are 68.4 percent of published value-added for all MOFAs and all U.S. parents combined. Thus, we use 68.4 percent as a reference for factor shares based on local inputs for both separate accounting and formulary apportionment. Likewise, we use 31.6 percent as a reference for factor shares based on shared inputs. In other words, we expect the relative contributions of local inputs and of shared inputs to total measured production to be about 68.4 percent and 31.6 percent, respectively.

Given differences in production functions, we expect some variation in factor shares across MOFAs and U.S. parents, across industry sectors and global regions, and across industries and countries. In addition, the factor shares are affected to the extent that returns to local inputs are included in the shared input components of value-added. However, given our model, in which affiliate production is a function of both local inputs and shared inputs, we consider differences in factor shares between formulary apportionment and separate accounting based on local inputs to be indicative of possible over- or underattributed returns to entities, based on shared inputs under separate accounting.[12]

Table 8.3 reports factor shares based on local input components under separate accounting and under formulary apportionment. Table 8.4 reports factor shares based on shared input components. Overall, the factor shares reflect the net reattribution of value-added from MOFAs to U.S. parents presented in Table 8.2. In particular, the local input shares of value-added increase for MOFAs and decrease for U.S. parents under formulary apportionment (Table 8.3, line 21). In contrast, the shared input shares of value-added decrease for MOFAs and increase for U.S. parents (Table 8.4, line 21). Local input shares are lower for MOFAs than for U.S. parents, and shared input shares are higher for MOFAs than for U.S. parents; however, local input shares and shared input shares for MOFAs and U.S. parents combined are generally closer to the global reference points under formulary apportionment.

Across all industry sectors, local input shares and shared input shares display considerable variation under separate accounting and under formulary apportionment. Local input shares are generally higher for the select service industry sectors than for the other industry sectors. Local input shares for MOFAs classified in finance, information, leasing, management, manufacturing, mining, miscellaneous, transportation, and wholesale increase under formulary apportionment. Conversely, local input shares for MOFAs classified in accommodation, administration, insurance, and PST decrease under formulary apportionment. These results imply that separate accounting may result in over- or underattributed returns to local inputs in some industries.

Across global regions, local input shares increase by more than 10 percentage points for Africa, Latin America, and the Middle East and by less than 10 percentage points for Asia, Canada, and Europe. Increases in Latin America are driven in large part by considerable increases in Barbados, Bermuda, and the UK Caribbean islands. Increases in Asia are explained primarily by increases in Hong Kong, Malaysia, Singapore, and Thailand. Increases in Europe are a result in part of increases in Denmark, Finland, Hungary, Ireland, Luxembourg, and Norway. We do not report numerical results for individual countries, in order to avoid disclosure of individual companies.

Economic Interpretation

According to our production model and the related empirical framework, value-added may be overattributed to a MOFA under separate accounting based on the availability of shared inputs within an MNE. The shared input components of value-added (i.e., IBT, net IP, and PTR) reflect, in part, returns to shared inputs that may not actually be employed by the MOFA to the extent reflected under separate accounting. In contrast, formulary apportionment attributes returns to shared inputs based on the MOFA's proportion of economic activity reflected in the chosen apportionment factors. As is consistent with our produc-

Table 8.3 Factor Shares Based on Local Input Components

		Separate accounting (%)			Formulary apportionment (%)		
		MOFAs	U.S. parents	Total	MOFAs	U.S. parents	Total
	Select service industry sectors						
1	Administration	89.5	86.4	87.3	82.8	84.2	83.8
2	Finance	72.9	91.4	99.3	99.9	97.2	97.7
3	Information	63.8	66.0	65.7	64.3	64.5	64.4
4	Insurance	92.1	81.2	83.9	82.0	87.0	86.4
5	Management of companies	12.5	20.4	13.2	73.8	29.8	94.1
6	Miscellaneous services	61.2	82.3	76.6	74.7	78.8	77.8
7	Professional, scientific, technical	74.5	73.5	73.8	66.2	74.0	71.4
8	Real estate and rental and leasing	51.8	81.2	69.5	83.2	78.4	79.8
9	Subtotals	77.0	85.6	83.6	78.0	82.5	81.5
	Other industry sectors						
10	Accommodation and food services	77.1	71.4	72.6	60.9	76.5	72.2
11	Construction	76.3	89.7	87.3	(D)	(D)	(D)
12	Farming, fishing, forestry	79.8	99.1	93.4	(D)	(D)	(D)
13	Health care and social assistance	73.3	79.1	78.8	(D)	(D)	(D)
14	Manufacturing	51.3	72.8	66.0	59.7	65.6	64.1
15	Mining	28.2	57.5	37.9	41.5	53.8	46.9
16	Retail trade	46.5	60.5	57.8	52.3	59.9	58.6
17	Transportation and warehousing	69.9	76.7	75.7	74.4	76.1	75.9
18	Utilities	39.9	49.7	48.4	(D)	(D)	(D)

19	Wholesale trade	39.5	74.7	55.3	49.3	72.3	61.1
20	Subtotals	45.9	70.3	62.1	55.2	65.8	62.7
21	Totals for industry sectors	52.8	75.3	68.4	60.9	71.1	68.4
	Global regions						
22	Africa	29.1		29.1	44.0		44.0
23	Asia	51.8		51.8	59.3		59.3
24	Canada	63.0		63.0	64.3		64.3
25	Europe	54.6		54.6	62.5		62.5
26	Latin America	46.3		46.3	58.2		58.2
27	Middle East	45.2		45.2	56.9		56.9
28	United States		75.3	75.3		71.1	71.1
29	Totals for global regions	52.8	75.3	68.4	60.9	71.1	68.4

NOTE: A “(D)” denotes data suppressed to avoid disclosure of data of individual companies. We calculate factor shares based on local inputs by dividing the sum of compensation and CCA by the sum of compensation, CCA, and the absolute value of shared inputs [i.e., local input share = (compensation + CCA) ÷ (compensation + CCA + | IBT + net IP + PTR |)]. Blank cell = data not applicable.
SOURCE: Authors’ tabulations.

Table 8.4 Factor Shares Based on Shared Input Components

		Separate accounting (%)			Formulary apportionment (%)		
		MOFAs	U.S. parents	Total	MOFAs	U.S. parents	Total
	Select service industry sectors						
1	Administration	10.5	13.6	12.7	17.2	15.8	16.2
2	Finance	27.1	8.6	0.7	0.1	2.8	2.3
3	Information	36.2	34.0	34.3	35.7	35.5	35.6
4	Insurance	7.9	18.8	16.1	18.0	13.0	13.6
5	Management of companies	87.5	79.6	86.8	26.2	70.2	5.9
6	Miscellaneous services	38.8	17.7	23.4	25.3	21.2	22.2
7	Professional, scientific, technical	25.5	26.5	26.2	33.8	26.0	28.6
8	Real estate and rental and leasing	48.2	18.8	30.5	16.8	21.6	20.2
9	Subtotals	23.0	14.4	16.4	22.0	17.5	18.5
	Other industry sectors						
10	Accommodation and food services	22.9	28.6	27.4	39.1	23.5	27.8
11	Construction	23.7	10.3	12.7	(D)	(D)	(D)
12	Farming, fishing, forestry	20.2	0.9	6.6	(D)	(D)	(D)
13	Health care and social assistance	26.7	20.9	21.2	(D)	(D)	(D)
14	Manufacturing	48.7	27.2	34.0	40.3	34.4	35.9
15	Mining	71.8	42.5	62.1	58.5	46.2	53.1
16	Retail trade	53.5	39.5	42.2	47.7	40.1	41.4
17	Transportation and warehousing	30.1	23.3	24.3	25.6	23.9	24.1
18	Utilities	60.1	50.3	51.6	(D)	(D)	(D)

19	Wholesale trade	60.5	25.3	44.7	50.7	27.7	38.9
20	Subtotals	54.1	29.7	37.9	44.8	34.2	37.3
21	Totals for industry sectors	47.2	24.7	31.6	39.1	28.9	31.6
	Global regions						
22	Africa	70.9		70.9	56.0		56.0
23	Asia	48.2		48.2	40.7		40.7
24	Canada	37.0		37.0	35.7		35.7
25	Europe	45.4		45.4	37.5		37.5
26	Latin America	53.7		53.7	41.8		41.8
27	Middle East	54.8		54.8	43.1		43.1
28	United States		24.7	24.7		28.9	28.9
29	Totals for global regions	47.2	24.7	31.6	39.1	28.9	31.6

NOTE: A "(D)" denotes data suppressed to avoid disclosure of data of individual companies. We calculate factor shares based on shared inputs by dividing the absolute value of shared inputs by the sum of compensation, CCA, and the absolute value of shared inputs [i.e., shared input share = (| IBT + net IP + PTR |) ÷ (compensation + CCA + | IBT + net IP + PTR |)]. Blank cell = data not applicable.
SOURCE: Authors' tabulations.

tion model, our results for value-added imply that too much production is attributed to MOFAs and too little production is attributed to U.S. parents under separate accounting.

Given the economic activity embodied in each of the apportionment factors (i.e., compensation, net PPE, and unaffiliated sales), the modest overall reattributions from MOFAs to U.S. parents in Table 8.2 and the relatively large reattributions across some global regions in Table 8.2 imply an overstatement of economic activity for MOFAs under separate accounting. Likewise, the relatively large reattributions across some industry sectors in Table 8.2 and across MOFAs and U.S. parents by industry sector in Table 8.2 reveal considerable differences in economic activity as reflected under formulary apportionment and in economic activity as reflected under separate accounting. Value-added measures constructed under a method of separate accounting generally imply more economic activity than under a method of formulary apportionment for MOFAs classified in finance, information, insurance, leasing, manufacturing, mining, miscellaneous, retail, transportation, and wholesale and for U.S. parents classified in accommodation and PST. In contrast, less economic activity is generally implied under separate accounting than under formulary apportionment for MOFAs classified in accommodation, administration, management, and PST and for U.S. parents classified in industry sectors other than accommodation and PST.

The reattributions reported in Table 8.2 and the factor shares reported in Tables 8.3 and 8.4 generally support formulary apportionment as an alternative to separate accounting. Given the results obtained for value-added, formulary apportionment appears to yield measures of production that are more congruent with economic activity for MOFAs and U.S. parents and more consistent with expectations based on global factor shares. Thus, formulary apportionment appears to be a viable alternative to separate accounting under the residency-based framework of the BPM and the SNA.

Implications for the U.S. Current Account

In addition to applying formulary apportionment to reattribute value-added, we apply formulary apportionment to reattribute service imports and exports between U.S. parents and their foreign affiliates.

Since imports and exports are components of GDP, our results enable us to assess the effect on GDP of formulary apportionment as we apply it here. However, given data limitations and other practical considerations, our work with the current account is very preliminary and does not yet incorporate income payments and receipts. Based on our preliminary results, we expect to be able to provide a complete picture of the U.S. current account under formulary apportionment in a future paper.

We use cross-border transactions data collected from U.S. parents on service imports and exports with their foreign affiliates for 2008 because the cross-border transactions data for 2008 have already been linked with the operations data, which contain the apportionment factors (Barefoot and Koncz-Bruner 2012).[13] Based on our model, in which production is a function of local inputs and shared inputs, we do not expect exports by U.S. parents to their foreign affiliates to be as affected under formulary apportionment as imports by U.S. parents from their foreign affiliates, because the data indicate U.S. parents generally have a meaningful amount of local inputs. As is consistent with our expectations, exports are nearly unchanged under formulary apportionment. However, the overall reattribution of imports from foreign affiliates to U.S. parents is $10.9 billion, which is almost 13 percent of published private-service imports from affiliated parties (an amount totaling $85.2 billion) but only about 3 percent of published total private service imports ($371.2 billion).

Given the role imports and exports play as components of GDP, we also assess the overall effect of reattributing service imports and exports under formulary apportionment. U.S. goods and services imports decrease by approximately 0.4 percent, but exports remain unchanged. Net exports increase by approximately 1.5 percent. The overall effect on GDP is only an approximate 0.1 percent increase. Thus, while reattributions of U.S. service imports and exports under formulary apportionment have a relatively moderate effect on the foreign transactions component of GDP and a bit larger effect on the closely related statistics of the ITAs, the impact on GDP is relatively small.[14]

SUMMARY AND CONCLUSIONS

The BEA currently measures value-added of foreign affiliates and U.S. parents based on separate accounting. Based on a simple production model and a related empirical framework, value-added may be over-attributed to foreign affiliates under separate accounting; this is due to the availability of shared inputs within an MNE. In particular, the shared-input components of value-added (i.e., IBT, net IP, and PTR) reflect, in part, returns to shared inputs that may not actually be employed by foreign affiliates to the extent reflected under separate accounting. In this chapter, we use formulary apportionment as an alternative for separate accounting to reattribute measured value-added to foreign affiliates of U.S. parents.

We find that overall reattributions from foreign affiliates to U.S. parents are relatively small—less than 5 percent of total value-added attributed to all majority-owned foreign affiliates and U.S. parents under separate accounting. In contrast to overall reattributions, reattributions across global regions including Africa, Asia, Europe, Latin America, and the Middle East are greater than 10 percent of value-added under separate accounting. In addition, reattributions for foreign affiliates are greater than 10 percent of value-added under separate accounting for all industry sectors except administration, information, and transportation.

In addition to applying formulary apportionment to reattribute value-added, we report preliminary results to reattribute service imports and exports between U.S. parents and their foreign affiliates. We find a relatively large decrease in imports but no meaningful change in exports. The overall effect on GDP is only a small increase—approximately 0.1 percent. Based on our preliminary results, we expect to be able to provide a complete picture of the U.S. current account under formulary apportionment in a future paper.

Given the economic activity embodied in each of the apportionment factors (i.e., compensation, net PPE, and unaffiliated sales), the reattributions summarized here imply an overstatement of economic activity for MOFAs under separate accounting. Using factor shares to evaluate the results, we conclude that value-added attributed to foreign affiliates and U.S. parents under formulary apportionment yields a picture of measured production by industry sector and country that is more congruent with economic activity than related measures generated under separate accounting. Thus, formulary apportionment appears to be a viable alternative to separate accounting under the residency-based framework of the BPM and the SNA.

Notes

The statistical analysis of firm-level data on U.S. multinational enterprises and companies engaged in international transactions was conducted at the Bureau of Economic Analysis, U.S. Department of Commerce, under arrangements that maintain legal confidentiality requirements. The views expressed in this chapter are solely those of the authors and not necessarily those of the U.S. Department of Commerce or the Bureau of Economic Analysis.

1. Throughout the chapter, we use "MNE" or "enterprise" to refer to a group of affiliated entities that includes both U.S. parents and foreign affiliates. We use "entity" to refer to individual establishments within the MNE; such individual establishments may be either a U.S. parent or a foreign affiliate. We also use "parent" or "affiliate" to refer to a U.S. parent or a foreign affiliate, respectively.
2. Economic territory is discussed in paragraphs 4.3–4.11 of the BPM, institutional units are discussed in paragraphs 4.12–4.56, and residence is discussed in paragraphs 4.113–4.168.
3. We do not distinguish between nominal output and real output. In the absence of data to adjust for price differences, we treat real output as proportional to nominal output.
4. The BEA publishes estimates of value-added for MNEs as part of the annual statistics on direct investment and multinational companies.
5. In the NIPAs, consumption of fixed capital is the measure of economic depreciation. Given that depreciation is a cost in affiliates' accounting records, any difference between CCA and consumption of fixed capital is reflected in profits. Thus, measured value-added is unaffected (Mataloni and Goldberg 1994).
6. IBT includes sales tax, value-added tax, consumption tax, excise tax, taxes on property and other assets, duties, license fees, fines, penalties, and any other taxes other than payroll taxes and income taxes.
7. Equation (8.3) inevitably changes the industry and country composition of value-added from that measured under separate accounting, because there are no restrictions by industry or country. In other words, value-added attributed under separate accounting to an affiliate classified in one industry may be reattributed under formulary apportionment to an affiliate classified in another industry. Likewise, value-added attributed to an affiliate located in one country may be reattributed to an affiliate located in another country. If returns accruing to shared inputs are under- or overattributed to an entity under separate accounting, then statistics by industry and country do not accurately reflect actual output, and reattributing across industries and countries is presumably justified. However, we also restrict

reattributions by industry while assuming the same production function across countries within a given industry, because entities in different countries belong to the same MNE. While restricting reattributions by industry does affect the results under formulary apportionment, the restriction does not affect our conclusions.

8. Less information is collected for each MOFA with assets, sales, or net income (net loss) of less than $80 million (Form BE-10C or Form BE-10D).
9. In addition to compensation, net PPE, and unaffiliated sales, we consider other possible apportionment factors. In particular, we consider research and development expenditures, which are reported for MOFAs. However, R&D expenditures are likely in some cases to be made pursuant to intercompany cost-sharing arrangements. In addition, we are unable to discern the extent to which R&D expenditures reflect intercompany transactions. Thus, we limit the apportionment factors to compensation, net PPE, and unaffiliated sales.
10. We also weight compensation by 100 percent in Equation (8.3), which does not affect our conclusions. In addition to reflecting the number of employees employed by an affiliate, compensation reflects wages. Thus, if workers are paid according to their value marginal product, compensation reflects variation in economic activity across industries and countries. In other words, using compensation as an apportionment factor yields relatively more output attributable to high-margin industries and high-wage countries and relatively less output attributable to low-margin industries and low-wage countries. In addition, compensation is based on market transactions rather than accounting conventions, which may affect both net PPE and unaffiliated sales. Furthermore, unaffiliated sales may reflect local inputs or shared inputs. Thus, compensation may provide the most objective measure of economic activity.
11. The subsample of select service-industry sectors yields factor weights of 0.63, 0.28, and 0.09 for compensation, net PPE, and unaffiliated sales, respectively. The subsample of other industry sectors yields factor weights of 0.64, 0.21, and 0.15 for compensation, net PPE, and unaffiliated sales. The combined sample yields factor weights of 0.61, 0.24, and 0.15 for compensation, net PPE, and unaffiliated sales.
12. Since compensation and CCA are always nonnegative, the local input components are always nonnegative. However, since net IP or PTR may be negative, the shared input components and total value-added may be negative. In order to obtain factor shares between 0 and 100 percent, we calculate local input shares by dividing the sum of compensation and CCA by the sum of compensation, CCA, and the absolute value of shared inputs. Likewise, we calculate shared input shares by dividing the absolute value of shared inputs by the sum of compensation, CCA, and the absolute value of shared inputs.
13. The cross-border transactions include annual amounts reported on the Quarterly Survey of Insurance Transactions by U.S. Insurance Companies with Foreign Persons (Form BE-45), the Quarterly Survey of Transactions in Selected Services and Intangible Assets with Foreign Persons (Form BE-125), and the Quarterly Survey of Financial Services Transactions between U.S. Financial Services Providers and Foreign Persons (Form BE-185).

14. Small differences exist between foreign transactions published in the NIPAs and foreign transactions published in the ITAs because of adjustments for gold, U.S. territories, and other small statistical differences.

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9
Data, Trade, and Growth

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The architecture of the Internet is designed as a "network of networks." As such, one of its key attributes is making the passage of data from one network to another easy. So when a user sends an e-mail, views a video, or downloads a file from a Web site, the data may pass through a large number of different networks on the way from its origin to its destination, with the routing virtually invisible to the user. This architecture has proven to be extremely flexible and powerful, both nationally and globally. People and businesses with Internet access can easily get data of all sorts from around the world. Similarly, companies can efficiently and cheaply provide services such as e-mail and Web search on a global basis, in many cases without charge.

One sign of the Internet's global success is this: the rapid growth of cross-border data flows. Cross-border data flows are growing far faster than conventionally measured trade in goods and services. According to TeleGeography, a consulting firm that keeps track of international data flows, demand for international bandwidth increased at an annual rate of 49 percent between 2008 and 2012 (TeleGeography 2012). By comparison, the overall volume of global trade in goods and services, adjusted for inflation, rose at an annual rate of 2.4 percent over the same period.

Looking at the data links between the United States and Europe in particular, the data-carrying capacity of transatlantic submarine cables rose at an average annual rate of 19 percent between 2008 and 2012. Meanwhile, the overall volume of trade in goods and services between the United States and Europe, adjusted for inflation, is barely above prerecession peaks.

Indeed, the global economic and financial system, as it stands today, would not function without cross-border data flows. Data flows that cross national borders are essential to almost everything: manufacturing supply chains, global finance, international medical and physics research, entertainment, tourism, education, social media, and community. Indeed, cross-border data is becoming increasingly important as an input to production, and as a crucial element for economic growth. “The cross-border free flow of information enables international trade which can lead to increased innovation, productivity, and economic growth,” writes Meltzer (2013, p. 11) in a paper from the Brookings Institution.

Moreover, trade in data creates positive externalities and gives an extra boost to global growth. Unlike exports of goods, data can be shipped from one country to another without depriving the first country of the benefits. All other things being equal, growth in cross-border data flows can be a far more powerful impetus to consumer welfare and economic growth than growth in trade in goods and services.

However, despite the importance of cross-border data flows, current international economic statistics are mostly uninformative and even misleading about their magnitude. First, note that cross-border data flows are not tracked as a separate category in the trade statistics. Instead, cross-border trade that involves data is lumped in with trade in services. For example, international telecommunications are treated as the export/import of a service. The World Trade Organization (WTO) estimates that global exports of telecommunications services totaled $111.5 billion in 2012 (WTO 2013).

But treating cross-border data as a service creates the real problem: By international agreement among statistical agencies, the export or import of services is defined to occur when there is a monetary payment from a resident of one country to a resident of another in exchange for the service. For example, if a U.S. business hires accountants in London, that becomes an export of accounting services from the United Kingdom to the United States.

Virtually all of the existing statistics about cross-border trade in data are based on this monetary definition of service exports and imports. The July 2013 report from the United States International Trade Commission, *Digital Trade in the U.S. and Global Economies, Part 1*, identifies the Bureau of Economic Analysis (BEA), the U.S. Census Bureau, the Organisation for Economic Co-operation and Development (OECD), and Eurostat as the main sources for statistics on “digital trade.” Each of these relies on the same basic definition of service exports and imports as being tied to a monetary exchange between residents of two different countries (U.S. Internationl Trade Commission 2013, Table 4.2, p. 4.24). Currently, international agencies such as the International Telecommunications Union (ITU) only collect fragmentary statistics on cross-border data flows, though they are putting more effort into estimating such figures (see, for example, ITU [2012]).

I will show in this chapter that the efficient global architecture of the Internet allows and even encourages data to cross national borders without leaving a significant monetary footprint. As a result, economically important cross-border data flows are simply not being counted by current international economic statistics. I will offer evidence in this chapter that both the level and rate of growth of data trade are being significantly understated.

This understatement has serious policy implications. First, the data sector is a bigger contributor to U.S. and global growth than current economic statistics show. Second, to the degree that trade negotiators prioritize their goals according to the relative magnitude of different trading sectors, trade policy should place more emphasis on maintaining the free flow of data. Similarly, international tax policy should place more emphasis on maintaining the free flow of data.

Third, attempts by various countries to implement barriers to the free flow of data may do considerably more economic damage than the current trade statistics show. This is especially important in the wake of recent revelations about the extent to which the National Security Agency (NSA) has monitored data flows around the world. This news has caused a rising demand within countries such as Brazil for certain data to be kept within national borders—so-called data localization or data protectionism. The European Union is also considering new data privacy regulations that could potentially act as an impediment to flows of data in and out of the EU.

Finally, it's becoming clear that better statistics about cross-border data flows are needed to convince policymakers of how important data is to economic health. That might help avoid trade and tax policies that are detrimental to growth. It is self-evident that good policy rests on a foundation of accurate and comprehensive knowledge about current and emerging trade flows.

HOW CROSS-BORDER DATA FLOWS ARE MEASURED TODAY

The WTO and national statistical agencies such as the BEA regularly produce figures on cross-border trade in data-related services such as telecommunications services, computer and information services, and financial services. Table 9.1, below, shows the reported dollar value of global exports of selected data-related services (WTO 2013).

According to international standards, trade in services is typically measured by monetary transactions between residents of one country and residents of another country. That's the main principle laid out in the *Manual on Statistics of International Trade in Services*, approved in 2010 by the United Nations Statistical Commission:

> The market price is used as the basis for valuation of transactions in international trade in services. Market prices for transactions are defined as amounts of money that willing buyers pay to acquire something from willing sellers. The exchanges are made between independent parties and based on commercial considerations only and are sometimes called 'at arm's length' transactions. (United Nations 2011, p. 34)

Similarly, the BEA—the statistical agency in charge of tracking service trade—measures data-related exports and imports by tracking

Table 9.1 Reported Global Exports of Selected Data-Related Services, 2012, and Annual Growth Rate, 2008–2012

Service	Global exports ($US billions)	Annual growth rate, 2008–2012 (%)
Communications services (both voice and data)	111.5	3.4
Financial services	303.1	0.3
Computer and information services (including Web search)	262.7	7.2
Royalties and license fees	289.6	5.9
Sum of selected data-related services	966.9	4.0
Merchandise exports	18,401.0	3.3

SOURCE: WTO (2013).

the money received from "foreign persons" and the money paid to "foreign persons."

The BEA collects much of its data on service sector exports and imports through surveys: specifically the BEA Benchmark (BE-120) and Quarterly (BE-125) Surveys of Transactions in Selected Services and Intellectual Property with Foreign Persons (BEA 2011). Table 9.2 shows the fairly long list of service and intellectual property export transactions that are covered in the benchmark survey. The list of service and intellectual property import transactions is similar, while the quarterly survey covers a similar but slightly shorter list of traded services. Many of these include cross-border data flows such as telecommunication services, royalties and license fees, database and other information services, and financial services.

These surveys feed into the widely cited monthly report "U.S. International Trade In Goods and Services," including the goods and services trade deficit, which is a key number for economists in government and the private sector. In addition, the BEA produces an annual report on trade in services. Table 9.3 shows statistics on exports for selected data-related services in 2012.

THE ARCHITECTURE OF THE INTERNET AND DATA TRADE

The figures in the previous section raise two disturbing questions. First, when measured as a service, the rate of growth of the cross-border data-related services is barely higher than the growth rate of merchandise trade, both for the globe and for the United States. Second, the aggregate numbers make cross-border data trade look relatively unimportant. For example, reported U.S. telecom exports of $14 billion in 2012 are roughly the same size as U.S. exports of newsprint. (Box 9.1 explains how international phone calls are treated in the trade statistics.)

The global and national statistics on trade in services are based on tracking monetary exchanges between residents of different countries. In theory, this principle can be applied to trade in data as well. If a person in the United States downloads a file from a Web site in a different country, it's theoretically possible that he or she could be charged both

Table 9.2 Selected Service and Intellectual Property Export Transactions Tracked by BEA Survey BE-120

Types of export transactions
Receipts for intellectual property
Rights related to industrial processes and products
Rights related to books, music, etc.
Rights related to trademarks
Rights related to performance and events prerecorded on motion picture film and TV tape (include digital recordings)
Rights related to broadcast and recording of live events and performances
Rights related to general use software
Business format franchising fees
Other intellectual property
Receipts for selected services
Accounting, auditing, and bookkeeping services
Advertising services
Auxiliary insurance services
Computer and data processing services
Data base and other information services
Educational and training services
Industrial engineering services
Industrial-type maintenance, installation, alteration, and training services
Legal services
Management, consulting, and public relations services (including expenses allocated by a U.S. parent to its foreign affiliates)
Merchandising services
Operational leasing services
Trade-related services, other than merchandising services
Performing arts, sports, and other live performances, presentations, and events
Research and development services
Telecommunications services
Agricultural services
Disbursements to fund production costs of motion pictures
Disbsursements to fund news-gathering costs and production costs of program material other than news
Waste treatment and depollution services
Other selected services

SOURCE: BEA Form BE-120: “Benchmark Survey of Transactions in Selected Services and Intellectual Property with Foreign Persons,” p. 6, http://www.bea.gov/surveys/pdf/be120.pdf (accessed December 2013).

Table 9.3 Reported U.S. Exports of Selected Data-Related Services, 2012, and Annual Growth Rate, 2008–2012

Service	Global exports ($US billions)	Annual growth rate, 2008–2012 (%)
Communications services (both voice and data)	14.0	8.8
Financial services	76.4	4.9
Computer and information services (including Web search)	17.3	7.2
Royalties and license fees	124.2	5.0
Sum of selected data-related services	231.9	5.3
Goods exports	1,536.0	4.3

SOURCE: BEA international services statistics, Table 1: "Trade in Services, 1999–2012." http://www.bea.gov/international/xls/tab1a.xls (accessed December 2013).

for the cross-border telecommunications link and for the content in the file.

However, in practice the architecture of the Internet has developed in such a way that many or perhaps most cross-border data flows do not result in an exchange of money between residents of different countries. Let us illustrate this important point with a simple example: an American economist who visits the Web site for the Bank of Russia (www.cbr.ru) and wants to obtain statistics about the latest movement of the Russian monetary supply.

First, imagine that these statistics were in bound volumes that had to be shipped from Moscow. There's little doubt that the cost of the volumes and the shipping would be quite high and would register as imports in the trade statistics.

But when the data is downloaded, there is no charge for content. The Russian central bank is not charging U.S. economists for downloading data. So if this cross-border data transfer is going to create a monetary footprint and show up in the BEA statistics, it will happen because the telecommunications transport across national borders involves an exchange of money between a U.S. resident and a non–U.S. resident.

Obviously, the economist or his or her institution pays a domestic Internet service provider such as Comcast or Verizon for an Internet connection. But unlike an international phone call, no extra money is paid for the foreign Web site. The data request is passed from network

Box 9.1 The International Phone Call and Foreign Trade

Historically the major cross-border data flow was the conventional international phone call. In the United States, the originator of an international phone call picked up a telephone, dialed 011, then the country code and phone number, and paid an international charge to his or her phone company. The provider then paid the carrier in the receiving country according to a government-mandated settlement schedule. Conversely, the recipient of an overseas call did not pay an international charge—instead, the overseas caller paid the local provider in his or her own country, who settled up with the U.S. phone company.

Under this scheme, calls from the United States to overseas points were classified as imports, because the foreign carrier received the payments. Calls from other countries were classified as exports, since the payments came to the U.S. carriers. So if U.S. customers made more overseas calls than they received, the telecom trade balance would be negative. Indeed, that was true for many years. According to an FCC report from 1998, "U.S. carriers owe settlement payments for the services that they bill, and are owed payments for the services that the foreign carriers bill. In addition, U.S. carriers are owed payments for switched traffic that transits U.S. points. Because U.S. customers place far more calls than they receive and because U.S. carriers terminate more collect calls that generate surcharges for the originating carrier, U.S. carriers make net settlement payments to most foreign carriers. The total net payment for all U.S. carriers grew from $0.4 billion in 1980 to $5.6 billion in 1996" (Blake and Lande 1998).

Reading this explanation, however, should make it clear that this definition of telecom imports and exports is an artifact of a regulatory convention that "calling party pays" for wireline calls. Suppose instead that we had a rule that "receiving party pays," as in a collect call or an 800 number. Under that alternative regulatory regime, the toll on an outgoing international call would be collected from the recipient of the call by his or her (foreign) carrier. The foreign carrier would then remit a portion of the charge to the originating domestic carrier. As a result, with "receiving party pays," an outgoing international call would be treated as an export. Similarly, an incoming call would be treated as an import. Thus, a shift in regulatory conventions from "caller pays" to "recipient pays" would immediately turn a telecom trade deficit into a trade surplus, without altering the final allocation of revenues to the respective telecom carriers after the settlement process. In addition, outgoing and incoming international calls are physically indistinguishable, in terms of the equipment used.

to network until it reaches the Russian central bank, which then sends the money supply figures back again. At some point, that data request passes from a U.S.-owned network to a foreign-owned network. For the sake of clarity of the example, let's assume that the U.S.-owned network also owns the submarine cable between New York and the United Kingdom, so that the interchange between the U.S.-owned network and the foreign network physically occurs in the UK.[1]

Is there an exchange of money between the U.S-owned and the foreign-owned network? Now we have to delve into the architecture of the Internet. Networks are connected in two ways, by peering or by the payment of transit fees. *Peering* is an agreement between two networks to exchange traffic without exchanging money. Peering agreements, especially between large networks, are so ubiquitous that they are basically conducted on a handshake, as one authoritative OECD study shows: "A survey of 142,000 peering agreements conducted for this report shows that the terms and conditions of the Internet interconnection model are so generally agreed upon that 99.5 percent of interconnection agreements are concluded without a written contract" (Weller and Woodcock 2013, p. 3).

In fact, the largest global networks—the so-called 'Tier 1' networks—almost by definition peer with every other Tier 1 network. That means if a data packet goes from AT&T's network to British Telecom's on the way from Russia, it is unlikely that money changed hands at the interconnect between the two.

It might seem as if peering is a barter-type agreement that should generate revenue recognition on the financial books, even if no money changes hands. However, peering takes place mostly in situations of balanced traffic, so the revenues and costs would net out. The accounting firm KPMG notes that, "in our experience, peering arrangements between Tier 1 telecoms do not result in the recognition of revenue even though a service is provided and value is transferred between telecoms in much the same way as under traditional interconnect arrangements" (KPMG 2010, p. 30).

It's worth noting that peering is a key reason that you can access Web sites from all over the world without having additional charges added to your Internet bill.

Alternatively, smaller networks can connect to larger ones by paying transit fees—also known as buying Internet transit. In theory, these

Internet transit payments could show up as trade in telecommunications services if the smaller network was paying a provider from a different country for transit. However, the price of Internet transit has been dropping sharply. According to the market research firm TeleGeography, the price of IP transit at major hubs has dropped by roughly 30 percent a year over the past five years (TeleGeography 2013). To my knowledge, no statistical agency currently uses the price of Internet transit to adjust service trade.

ESTIMATING ONE COMPONENT OF DATA TRADE

For the reasons described in the previous section, we would expect that the official statistics on cross-border data trade (trade in data-related services) far understate both the actual economic value and the growth of cross-border data flows. But how big is the understatement?

In this section I will try to answer one small piece of this question. In particular, we will delve deeper into the measurement of U.S. telecom exports and construct an alternative estimate based on directly measuring cross-border data flows. For 2012, the BEA reports that exports of communications services from the United States amounted to $14 billion (payments from nonresidents to residents). Imports of communications services into the United States amounted to $8 billion (payments from residents to nonresidents). These numbers have been rising, but they are still minuscule compared to the importance and amount of international data traffic in and out of the United States.

However, a closer look helps explain why these have to be understatements. Let's start with a simple example. Suppose a major U.S. telecom provider builds its own submarine cable to Great Britain, say, or Singapore. That expenditure will show up in the company's capital spending budget, rather than as a payment for cross-border telecom services. Then, if the U.S. provider peers with foreign providers at the non-U.S. cable landing, no money will change hands at the connection point. The result: The telecom provider has made a major investment in providing cross-border data flows, none of which show up in the trade account. The export benefits of capital investment by the telecom industry are not being counted.

More generally, most submarine cables are being built these days by a consortium of companies, each of whom gets access to a share of the bandwidth. The same principle shows up as in the previous example—the spending on the cable appears as a capital investment, rather than as a payment for cross-border telecom services. From here, we can construct increasingly complicated examples that arrive at the same place—cross-border transport of data without a corresponding monetary transfer between residents and nonresidents.

How can we construct a better estimate of cross-border telecom services? In an earlier paper, I discussed the idea that the production and use of data should be treated as a fundamental component of economic activity, parallel to the production and use of goods and services (Mandel 2012). This approach leads naturally to an increased focus on directly measuring data generation, data flows, and data storage as a way of understanding economic activity.

One pioneer in such efforts has been Martin Hilbert, who has been developing a systematic methodology for comparing the communications capacity of various media, ranging from mobile to television (Hilbert and López 2011). Based on this work, the International Telecommunications Union (ITU) has been gradually moving toward direct measures of data flows, as opposed to indirect measures such as number of cellular subscriptions or broadband connections. A recent publication from the ITU notes,“Using the unifying metric of bits per second, employed for measuring global technological capacity to communicate, it is possible to compare different communication technologies. It is also possible to analyse bits per second per capita, per technology, per country, or per any other relevant socio-economic or demographic parameter” (ITU 2012, p. 167).

This section follows in the same spirit of direct measurement of data flows. For the purposes of this section, data flow is measured in terabits per second (Tbps). The telecommunications market research and consulting firm TeleGeography estimates that the United States had 23 Tbps of international Internet capacity in 2012, with an average utilization of 29 percent and a peak utilization of 49 percent.[2] This suggests that, on average, the U.S. cross-border data flow is roughly 6.7 Tbps.[3]

Is this volume of cross-border data a large number or a small number? I compare the cross-border data flow with a recent Cisco Systems–sponsored projection of data traffic, by country and type (Cisco Systems 2013).[4] For 2012, the Cisco study estimates Internet and IP traffic in the United States at 8 exabytes per month and 13 exabytes per month, respectively.[5] That translates into roughly 26.5 Tbps and 42.2 Tbps.[6]

Table 9.4, below, compares the U.S. cross-border data flows with the overall U.S. Internet and IP traffic. I find that cross-border data flows are roughly 25 percent and 16 percent of U.S. Internet and IP traffic, respectively. To put this in perspective, U.S. exports of goods and services are 14 percent of U.S. gross domestic product (GDP) in 2012, while U.S. imports of goods and services are 18 percent of U.S. GDP in 2012. (Box 9.2 briefly reports similar calculations for Europe.)

This calculation offers us a reasonable way of estimating the size of the international component of the U.S. telecom sector. According to the BEA (2014), the gross output for the telecommunications industry in 2011 was $556 billion. After adjusting for growth, that puts the gross output at roughly $575–$600 billion in 2012.

If we assume that the international component of the telecom industry is proportional to the size of the data flow, the international component of U.S. telecom would be roughly $92–$150 billion. That's compared to the $14 billion in exports and $8 billion in imports that the official statistics report.

Table 9.4 Cross-Border Data Flows, 2012: United States

	Terabits per second (except as noted)
International Internet capacity connected to the U.S.	23.0
Average utilization (%)	29.0
Average cross-border data flow (average international traffic)	6.7
All U.S. Internet traffic	26.5
All U.S. IP traffic	42.2
Average U.S. cross-border data flow as a percentage of:	
All U.S. Internet traffic (%)	25.0
All U.S. IP traffic (%)	16.0

SOURCE: International capacity and utilization estimates from TeleGeography (2014). Traffic estimates from Cisco. IP includes both Internet traffic and managed IP such as consumer video. Figures omit mobile.

Box 9.2 Europe's Data Connections

Using a similar methodology as for the United States, we can calculate interregional cross-border data flows as a share of Internet traffic for Europe. TeleGeography estimates that international bandwidth in Europe was 56.5 Tbps in 2012, but that 78 percent of that bandwidth was between cities in the same region. As a result, "interregional Internet capacity connected to Europe" equaled 12.6 Tbps in 2012. Based on this figure, we calculate that cross-border data flows between Europe and the rest of the world equaled 16 percent of the region's Internet traffic and 13 percent of the region's IP traffic.

These results, which should be viewed as highly imprecise and tentative, suggest that the United States is more interconnected with the rest of the world than Europe. The sources of error enumerated in the caveats above are potentially very significant.

Obviously, this should be viewed as an exploratory effort, with plenty of caveats. However, the revised estimates intuitively make more sense than the official statistics, in terms of measuring the importance of cross-border telecom services. Of course, these numbers are accompanied by substantial and worrisome caveats, as well as the possibility of large errors in both directions. In particular, these include the following:

- **Coverage and methodology may differ.** Cisco's projections include all IP usage. TeleGeography's estimates of international capacity by country do not include private networks such as intracorporate networks, Google and other content providers' networks, and research networks. This factor would tend to underestimate the share of cross-border traffic.
- **Double-counting is inevitable**. International Internet traffic is often routed through third-party countries before getting to its destination. Traffic between Moscow and New York might be routed through London and therefore show up as part of European cross-border data flows. Traffic between the Canadian cities of Vancouver and Toronto might be routed through the United States and therefore show up as part of U.S. cross-border data flows. And since less-developed countries may have

better Internet connections with the United States and Europe than with each other, it's possible for intra-African traffic, say, to be routed through New York or London. This factor would tend to overestimate the share of cross-border traffic.

- **When comparing estimates/forecasts from different sources, timing matters.** International Internet capacity, as estimated by TeleGeography, has been growing at almost 50 percent per year. Domestic U.S. Internet traffic, as projected by Cisco, has been growing roughly as fast. As a result, calculating cross-border data flows as a share of Internet traffic can be heavily influenced if one source is using yearly averages while the other source (TeleGeography) is using a particular point in time (April of each year). The direction of bias is uncertain.
- **Compression may distort the statistics**. Widespread and growing use of compression means that "we communicate around three times more information through the same installed infrastructure as we did in 1986" (Hilbert 2011, p. 7). It's possible that cross-border data flows may be compressed more intensively than purely domestic data flows.

MEASURING THE ECONOMIC BENEFITS OF CROSS-BORDER DATA FLOWS

Why are we concerned with correctly measuring cross-border data flows? The classic justification for the benefits of trade is that two or more countries working together can produce more than the same countries operating separately. Moreover, the size of the gain from trade is related to the magnitude of trade, all other things being equal. The more trade, the better.

Under the current trade statistics, the magnitude of trade in data is being systematically underestimated. Thus, the benefits from trade in data are being systematically underestimated as well, which, as we will see in the next section, distorts policy decisions.

Moreover, trade in data has somewhat of the characteristic of a public good, since data can be duplicated relatively costlessly. As a result, the fact that the data is created in one country and used in another country does not deprive the first country of the use. To give a specific example, one type of intangible capital stock is "entertainment, literary, and artistic originals," including films. Licensing the right to show a film in a foreign country currently shows up as an export in the national income accounts. However, such a license generally does not reduce the ability of American consumers to view the film, and it does not reduce the intangible capital stock of "entertainment, literary, and artistic originals."

As a result, trade in data creates positive externalities and an extra boost to global growth. Unlike exports of goods, data can be shipped from one country to another without depriving the first country of the benefits. All other things being equal, growth in cross-border data flows can be a far more powerful impetus to consumer welfare and economic growth than growth in trade in goods and services. This means that data trade generates a positive externality for the global economy. If a U.S. university produces educational videos about computer science and makes them available on the Internet, then students around the world can benefit from those videos.

Now we turn to the question of how data trade figures into calculations of GDP and economic growth. As noted in an earlier paper, data can be "consumed" by individuals; can be used as an intermediate input into production; and can be an investment in intangible capital (Mandel 2012).

For trade in conventional goods and services, there is a well-established methodology for assessing such trade's contribution to economic growth. In the calculation of GDP, the dollar value of exports is a plus, while the dollar value of imports is a minus. For the calculation of gross domestic purchases—which are one measure of living standards—the dollar value of exports of goods and services is a minus, while the dollar value of imports of goods and services is a plus.

The arithmetic does not work quite the same for cross-border data flows, for two reasons. First, because data that are exported are still available domestically, exports don't need to be subtracted from gross domestic purchases. Second, imports of data potentially come in at low or zero prices, as discussed above, despite the fact that there is a positive price to originally producing the data and then transporting it across national borders. As a result, imports of data, valued in dollars, appear not to contribute to growth.

Consider, however, that the alternative to importing the data at a low or zero price is to produce it domestically at its full cost, which would be higher than the import price. Viewed from that perspective, there is a growing body of literature about how to value the contribution to growth of imports that are priced much lower than comparable domestic products. I will show how this approach can be used to value cross-border data flows.[7]

To demonstrate how this would work, I will consider the amusing category of YouTube videos of cats involved in different activities (Illustration 9.1). Quite a few of these videos are produced in Japan and get millions of free views (Lewis-Kraus 2012). They provide pleasure for viewers in America and around the world—in that sense they are analogous to going skiing or reading a book. Thus, they raise consumer welfare in the United States for people who enjoy videos of cats. But how should the gain to the U.S economy from these "free" data flows be measured? The key is to realize that there are two relevant prices here. One is the price to Americans of consuming the Japanese-made cat video, which is zero. The second is the maximum price, P^{cat}, that an American would pay for viewing a Japanese-made cat video, measured either in dollars or in value of time. We assume that there is no way of profitably producing a comparable video with Japanese cats in the United States—in other words, in order for someone in this country to produce comparable videos domestically, the videos would have to be sold at an average price per viewing in excess of P^{cat}.

So before YouTube, it was as if the price of a Japanese cat video to Americans was equal to P^{cat}, and the volume of videos viewed was zero. After the Internet and YouTube, the price P of Japanese cat videos goes to zero, and the volume of videos viewed goes to V.

How much does this change contribute to U.S. gross domestic purchases? For the sake of simplicity, assume that X is the size of gross domestic purchases in dollars, excepting cat videos. Let's also assume that there is no inflation and that X is otherwise not changing. Then the straightforward way of calculating growth would be as $(X + P \times V)/X$, where P is the price of a cat video after the introduction of YouTube. But P is zero, so it looks like there is no gain.

Illustration 9.1 Maru the Cat, as Seen on a YouTube Video from Japan

In fact, a better approach is roughly analogous to the procedure used to calculate chain-weighted GDP growth. I take the geometric average of two growth rates—the first assuming that the price of the video is always zero, and the second assuming that the price of the video is always P^{cat}:

$$g = \sqrt{\frac{(X + 0 * V)}{X}} * \sqrt{\frac{(X + P^{Cat} * V)}{X}} = \sqrt{1 + \frac{P^{Cat} * V}{X}} \approx 1 + \frac{P^{Cat} * V}{2X} \ .$$

In other words, the gain to gross domestic purchases from cross-border data flows of cat videos is roughly equal to the revenue that would be generated by pricing the videos at the average of the actual price (zero) and the price that Americans would be willing to pay, P^{cat}.

Since this requires no additional domestic resources, it is also the gain to consumer welfare.

POLICY IMPLICATIONS

Trade in data is fundamentally a new phenomenon. While many people would like to fit it into the framework of previous trade deals—in particular, the WTO's General Agreement on Trade in Services (GATS)—such efforts will not work. We need new analytical tools to deal with both measuring cross-border data flows and assessing the benefits.

This chapter has made the case that, without those tools, the economic impact of cross-border data flows is being understated. What effect does this understatement have on trade and tax policy?

Trade and Tax Policy

Both trade and tax policy require a series of compromises and trade-offs. In the case of trade negotiations, a wide variety of different industries and interests—agriculture, low-tech manufacturing, high-tech manufacturing, finance, insurance—are competing for the attention of policymakers. Trade negotiators have to decide which issues are "must-haves" and which ones they can retreat on.

Similarly, tax policy requires balancing out the need to raise revenue against the negative effect of taxes on different industries. That's especially true in today's climate, where tax cuts benefiting one industry will have to be balanced by closing tax loopholes or raising taxes on other industries.

Policymakers and negotiators make these decisions partly by assessing political reality and partly by assessing economic strength. All other things being equal, industries that have a bigger positive effect on jobs and growth will fare better in trade and tax policy.

The problem is that the positive benefits of cross-border data flows—because they are such a new phenomenon—are significantly underestimated in the available official statistics. Reported exports of data-related services show up as relatively minor in the larger picture.

Under the circumstances, the impact of cross-border data flows on economic growth will be understated as well, and it will be more difficult for policymakers to set the right priorities for trade and tax policy.

There have been several recent proposals for increasing the tax rate paid by international Internet companies, or for imposing additional regulations on them. In one instance of this, a recent paper from the French government suggested a sort of tax on data (Collin and Colin 2013). Such proposals—which would be likely to discourage cross-border data flows—are more likely to be seriously considered in the absence of evidence showing the large positive economic impacts from such cross-border data flows.

Impact of Data Localization

Another example comes from the aftermath of the revelations about NSA monitoring, which created a backlash against U.S. Internet companies and intensified discussions about building "walls" that would keep certain types of personal data from leaving countries such as Brazil.

Several reports have identified the possible negative economic consequences of such actions (Castro 2013a,b; Staten 2013). However, what's missing is the ability to actually track the negative consequences from data protectionism, since we do not currently track cross-border data flows. By comparison, if a country erects trade barriers against a particular tangible product, the impact of such a policy would immediately show up in the trade statistics. It's difficult to measure the harm from barriers to data trade if we cannot measure the data flows to begin with. Weller and Woodcock (2013) note that adverse effects may be incidental:

> It is also the case that regulations that are not explicitly intended to apply to Internet traffic exchange may have that effect. For example, restrictions on the ability to export certain data, such as customer profiles, intended to protect security and privacy, may also limit the development of Internet topology and the growth of Internet assets in some regions. Similarly, tax policies in each country toward broadband and Internet businesses are likely to affect the choice of the locations for investment in Internet assets. (p. 24)

CONCLUSION: THE NEED FOR BETTER DATA ON CROSS-BORDER DATA FLOWS

Businesses in any industry are usually ambivalent about the collection of government statistics on that industry. On the one hand, objective industry-wide statistics can be extremely useful for business decision-making and planning. On the other hand, the collection process can be intrusive, and accurate statistics can potentially attract new competitors or unwanted attention from regulators.

The calculation gets even tougher for rapidly innovating tech industries. Tech companies are unlikely to call for additional investment in statistics that may be quickly rendered obsolete by technological change.

However, the balance changes in a situation where businesses need government support in order to avoid bigger problems. In particular, better information about cross-border data flows will help make the case that data protectionism and taxes on data can be economically destructive.

The bottom line is that the statistical agencies should supplement the current trade statistics with additional metrics on cross-border data flows. This should be part of a large push to better measure data consumption and investment domestically.

Notes

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1. Many large providers own their own undersea cables, have a share of a cable, or have long-term rights to use part of the bandwidth. Submarine cable is used to carry cross-border data flows across oceans but also often between countries on the same continent, because it's often easier and safer to maintain cables that run along the coast underwater than across difficult terrain. Cables are typically laid with multiple strands of optic fiber, some of which are "lit"—i.e., they have the necessary equipment to be used—and some of which are "dark," or not yet ready for use. Capacity can be increased by laying new cables, by lighting dark fiber, or by improving the capacity of already-lit fiber.

2. I thank Alan Mauldin of TeleGeography for providing these estimates.
3. These figures are based on the bidirectional averages of the average for the month of April and the peak during April of each year.
4. See also http://ciscovni.com/forecast-widget/index.html.
5. Non-Internet IP traffic in the United States is mainly consumer video.
6. 1 exabyte = 1,024 petabytes; 1 petabyte = 1,024 terabytes; 1 terabyte = 8 terabits.
7. This growing body of literature on how to assess growth when import prices are less than domestic prices includes Diewert and Nakamura (2010) and Feenstra et al. (2009).

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About the Institute

The W.E. Upjohn Institute for Employment Research is a nonprofit research organization devoted to finding and promoting solutions to employment-related problems at the national, state, and local levels. It is an activity of the W.E. Upjohn Unemployment Trustee Corporation, which was established in 1932 to administer a fund set aside by Dr. W.E. Upjohn, founder of The Upjohn Company, to seek ways to counteract the loss of employment income during economic downturns.

The Institute is funded largely by income from the W.E. Upjohn Unemployment Trust, supplemented by outside grants, contracts, and sales of publications. Activities of the Institute comprise the following elements: 1) a research program conducted by a resident staff of professional social scientists; 2) a competitive grant program, which expands and complements the internal research program by providing financial support to researchers outside the Institute; 3) a publications program, which provides the major vehicle for disseminating the research of staff and grantees, as well as other selected works in the field; and 4) an Employment Management Services division, which manages most of the publicly funded employment and training programs in the local area.

The broad objectives of the Institute's research, grant, and publication programs are to 1) promote scholarship and experimentation on issues of public and private employment and unemployment policy, and 2) make knowledge and scholarship relevant and useful to policymakers in their pursuit of solutions to employment and unemployment problems.

Current areas of concentration for these programs include causes, consequences, and measures to alleviate unemployment; social insurance and income maintenance programs; compensation; workforce quality; work arrangements; family labor issues; labor-management relations; and regional economic development and local labor markets.