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ADVANCING ENVIRONMENTALLY SUSTAINABLE GROWTH: A STATISTICAL NARRATIVE

Dependence and Sustainability: A Disaggregated Analysis of Electricity Generation in ASEAN Countries

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Abstract:
The trade-off between different sources of power generation, economic growth, and environmental quality cannot be denied in the literature. To reduce carbon emissions and sustain decent economic growth, there is a need to reduce electricity production based on fossil fuels. In addition, to increase total electricity production, it is necessary to increase the use of renewable sources of electricity generation. This study identifies the various sources of electricity generation used and assesses how these relate to economic growth and environmental quality in six selected ASEAN countries (Indonesia, Malaysia, Filipina, Thailand, Vietnam, and Myanmar) from 1994 to 2014. Using static panel data analysis with random effects model, this study reveals that economic growth in six selected ASEAN countries is enhanced by electricity generation from all sources, while the contribution of electricity production from hydroelectricity remains the largest and strongest. There is little environmental impact of electricity production from hydroelectric, whereas fossil fuel-based electricity production emits carbon dioxide with coal sources being the largest contributor. Based on the results, these six ASEAN countries should invest more in hydropower projects, reduce the coal mix in power generation, and promote clean coal technology to improve economic efficiency and environmental sustainability.

Keywords:
Electricity; energy; environment; economic growth; ASEAN

1. Introduction:
The presence of superior infrastructure facilities is an imperative component in the attainment of self-reliance in any region. Electricity is one of the critical infrastructure sectors that affect the operation and progression of an economy. The transitions in the production process, especially the emergence of mechanised farming, made electricity one of the major energy sources that affect people's lives in emerging economies with significant rural agrarian households. The public policy to ensure the availability,

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accessibility, and affordability of electricity services thus becomes critical in the development of the economy and well-being of people in these countries. These energy policies will have to recognise and integrate different relationships, interdependencies, and stakeholders associated with the electricity sector. Two fundamental relationships in that regard are related to the question of the dependence of economic growth on the electricity sector and the environmental impact of the sector. The basic premise of this study is to integrate these questions and analyse electricity production in the selected countries of the ASEAN region.

The existing literature on the energy-economy nexus is highly skewed towards studies focusing on energy consumption and demand-side management. However, for holistic energy planning, the supply-side analysis will be critical in the short run and long run. Electricity generation is the initial phase of the electricity supply infrastructure of any region. It specifically attracts attention as that primarily affects the availability of electricity for consumption and determines the economy's potential growth. This generation capacity is related to the natural resources of that region and the technology for utilising them. Understanding both utilisation of natural resources for electricity generation and the impact of that utilisation on the environment needs to be prioritized in energy sector policymaking. This aggregated examination of electricity generation forwarded by this study assimilates this broader question.

The choice of sustainable sources of electricity generation for a region depends on factors like institutions, geography, and demography (Villanthenkodath and Shameem, 2023). Thus, identifying reliable sources for electricity generation and energy planning will be different for various countries and regions, where this diversity is assimilated into the economic growth trajectory, energy demand, environmental concerns, and global commitment. On this basis, this study's fundamental objective is to examine the impact of electricity generation from different sources on the economic growth of selected ASEAN countries. Secondly, to assess the difference in the environmental impact of electricity production from major energy sources, namely coal, oil, natural gas, and hydro.

The countries examined under this study from ASEAN are distinct in their nature but possess many transboundary characteristics peculiarly relevant to the context of this study. Apart from the geographical location, similar economic growth paths and aspirations for being new-industrial economies have been instrumental in organizing them. The coordinated thrive for a regional association beyond the economic objective of ASEAN is also associated with shared responsibility in terms of sustainable development, where the energy sector holds a vital space. The ASEAN Vision 2020, the ASEAN Plan of Action for Energy Cooperation (APAEC) 2004 – 2009, the ASEAN Power Grid, and the Trans-ASEAN Gas Pipeline Infrastructure Project (TAGP) are part of these consistent collective efforts for cooperation in pooling and maximum utilisation of resources.

The rapid economic growth achieved by these countries in the last three decades has amplified the energy demand in the region. The increased pace of industrialisation, the growth of a new digital society, and, in general, the higher standard of living attained by the people contributed heavily to the higher demand for electricity (Mercan and Karakaya, (2015). The development of supply infrastructure to cater to this progressing electricity demand opens multiple research arenas. The energy supply scenario of Southeast Asia, in general, shows that 90% of primary commercial energy requirements are fulfilled by fossil fuels (coal, oil, and gas).

The prevalence of fossil fuels as the primary energy source, both overall and specifically in electricity production, gives rise to apprehensions regarding carbon emissions and environmental impact (Farabi et al., 2019). First of all, energy

consumption, particularly fossil fuel-based consumption itself, is considered to be a major contributor to global ecological damage (IPCC, 2014). In the case of the ASEAN region, emissions from electricity generation plants are found to be a major stakeholder in the ecological damage (Lean and Smyth, 2010). The countries in the region are more sensitive and vulnerable to the effects of global climate change, which is intensified by this emission. The passive commitments under the Paris Agreement and the low proportion of renewable energy in the total energy mix also give a pessimistic outlook of the future on development, environment, and sustainability (Overland, 2021; Raihan, 2023). Against the backdrop of previous collaborative endeavors aimed at achieving low carbon targets for the region[1], there are policies in place that strive to realize Sustainable Development Goal 13 (Climate action) and attain a targeted 23% share of renewable energy in the energy supply by 2025. However, achieving these objectives requires comprehensive research (Vakulchuk et al., 2023). To the best of our knowledge, no research has examined the relationship between electricity production, environmental quality, and economic growth in South East Asian nations. Therefore, the outcome of this study is expected to provide insightful results to supplement in framing and implementing national and collective regional strategies for sustainable electricity generation in ASEAN countries.

The study will contribute to the growing literature in multiple ways. First, this is the first study that analyses different sources of electricity production, including coal, oil, natural gas, and renewable sources, with their impact on economic growth and CO_2 emission in these selected countries, employing a panel-based econometric analysis. The panel-based approach provides greater insights than single-country studies as they impart more informative data, more variability, more degrees of freedom, and thus greater efficiency in estimation. Secondly, this study will bring focus on Southeast Asian countries to this growing domain in energy economics research. Thirdly, by incorporating the production side of electricity into the dynamic "energy - economic growth – environment" nexus, the study brings a new approach to understanding emission and economic growth. Fourth, the disaggregated examination of electricity production will enable a comparative assessment among different sources of electricity generation based on their impact on growth and emission, which will be pivotal for policymakers in planning future electricity production mix.

The rest of the paper is structured into five sections. A survey of the literature related to the context of the study is presented in the following section. The next section explains the data and methodology used in the study, which is followed by a discussion of the results. The final section summarizes the study with empirical findings and concludes the study.

2. Methodology:

This study aims to explore the diverse sources of electricity generation and their respective associations with economic growth and environmental quality. The research hypothesizes that electricity production relying on fossil fuels, such as coal, oil, and natural gas, could offer electricity at low production costs, potentially driving economic activity. However, this approach may harm the environment due to CO_2 emissions (Shan et al., 2021). In contrast, the study incorporates renewable power generation sources, particularly hydro sources, into the model. Based on existing literature, it is posited that electricity production from renewable sources could not only stimulate economic growth but also mitigate emissions into the atmosphere (Rahman et al., 2020). Consequently,

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[1] The regional agreement for renewable energy development signed in 1986, proactive involvement in the Kyoto Protocol and subsequent Bali negotiations in 2008, and commitments to the Paris Agreement.

the shift towards a green economy can be realized by establishing the availability of renewable electricity sources at minimal costs, aligning with the theoretical background. To understand the relationships between the variables, the study employs a multiple regression model based on the mathematical specifications as in equations (1) and (2). The aim is to gain empirical insights into how different sources of electricity generation impact economic growth and environmental quality. Through rigorous analysis, this study aims to contribute to the understanding of the complex dynamics between electricity production, economic development, and environmental sustainability.

$$GDP_t = f\left(Coal_t, Hyd_t, Gas_t, Oil_t\right) \tag{1}$$
$$CO_2 = f\left(Coal_t, Hyd_t, Gas_t, Oil_t\right) \tag{2}$$

After considering the variables, the following econometric model is proposed to conduct the empirical analysis:

$$GDP_t = \alpha_0 + \alpha_1 Coal_t + \alpha_2 Hyd_t + \alpha_3 Gas_t + \alpha_4 Oil_t + \varepsilon_t \tag{3}$$
$$CO_2 = \beta_0 + \beta_1 Coal_t + \beta_2 Hyd_t + \beta_3 Gas_t + \beta_4 Oil_t + \mu_t \tag{4}$$

where:
GDP_t represents the rate of economic growth at time t and CO_2 stands for carbon dioxide emissions associated with the production of electricity and heat at time t. $Coal_t$ denotes the percentage of coal-fired power plants relative to the total number of power plants at time t, while Hyd_t represents the percentage of the number of hydropower plants relative to the total number of power plants at time t. Gas_t stands for the number of natural gas power plants relative to the total number of power plants at time t, and finally Oil_t denotes the percentage of power plants using oil resources relative to the total number of power plants at time t. α_n and β_n are the coefficients of the respective variables, representing the impact of each variable on economic growth. ε_t is the error term representing the unexplained variation in the economic growth equation at time t.

The model aims to examine the relationships between electricity generation sources (*Coal*, *Hyd*, *Gas*, and *Oil*) and carbon dioxide emissions (CO_2), as well as their impact on economic growth (*GDP*). Through empirical analysis, the study seeks to understand how each source of electricity generation influences economic growth, considering the associated CO_2 emissions. The results of this econometric model will shed light on the dynamics between energy production, economic growth, and environmental implications, providing valuable insights for policymakers and researchers concerned with sustainable development.

3. Result:

The primary objective of this research is to investigate the diverse array of electricity generation sources and their corresponding associations with both economic growth and environmental quality. The outcomes of the Ordinary Least Squares (OLS), Fixed Effect Model (FEM), and Random Effect Model (REM) estimations are detailed in Table 1. The results from these three approaches exhibit consistency between the random effect and fixed effect models, with a slight variance observed within the OLS method concerning statistical significance. However, our primary emphasis is directed toward the random effect estimation due to its favorable attributes as indicated by the

Hausman test. The Hausman test statistics for Model 1 and Model 2 are 3.00 and 8.72, respectively. The chi-square probabilities of these statistics are greater than the 0.1 and 0.05 significance levels, respectively, thereby leading to no rejection of the null hypothesis and affirming the presence of a random effect within both models.

It is evident from Table 1 that electricity production from coal sources contributes to higher economic growth, but it also leads to a significant increase in pollution due to carbon dioxide emissions in six ASEAN countries. This finding poses a challenge to the environmental sustainability of these nations during their development progress aimed at achieving economic growth. Similar trends are observed for natural gas and oil as fossil fuel-based sources. A scenario in which economic growth coincides with CO_2 emissions within an economy could potentially trigger environmental deterioration, which consequently affects economic progress by giving rise to human health issues.

Table 1. Panel Data Estimation

Regressors	Model 1 Dependent variable: GDP			Model 2 Dependent variable: CO_2		
	Common Effect	Fixed Effect	Random Effect	Common Effect	Fixed Effect	Random Effect
Coal	0.055 (0.074)	0.379** (0.168)	0.215* (0.118)	0.056 (0.096)	0.703*** (0.139)	0.638** (0.127)
Hydro	0.127** (0.060)	0.386** (0.173)	0.238** (0.104)	-0.301*** (0.078)	0.261* (0.142)	0.188 (0.126)
Gas	0.054 (0.057)	0.355** (0.170)	0.190* (0.105)	0.032 (0.073)	0.494*** (0.140)	0.427*** (0.124)
Oil	0.043 (0.077)	0.365** (0.174)	0.197* (0.119)	-0.234** (0.100)	0.347** (0.144)	0.281** (0.130)
Constant	-0.827 (5.934)	-29.24* (16.06)	-13.91 (10.24)	45.29*** (7.69)	-6.29 (13.27)	0.167 (11.97)
Hausman chi2 Prob>chi2		3.00 0.559			8.72 0.069	

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' calculations

Conversely, hydroelectricity generation, a potential renewable energy source, considerably enhances economic growth without negatively impacting environmental quality in these countries. This finding corroborates with previous studies in various countries (Ziramba 2013; Xiaosan et al., 2021; Villanthenkodath and Shameem, 2023). The environmental implications of electricity production from hydroelectric sources appear promising, as it has minimal effect on carbon dioxide emissions while maintaining its position as the primary and most influential contributor to economic growth. Moreover, the adverse impact of hydroelectricity production on environmental pollution aligns with the notion that hydropower serves as an eco-friendly energy solution capable of enhancing environmental well-being. The result of analysis within the environmental quality model further substantiates the concept that hydroelectricity stands as a viable and sustainable energy source.

4. Discussion and Conclusion:

The research findings presented in the remarks highlight the importance of electricity generation in driving economic growth in six selected ASEAN countries. It also emphasizes the significant role of hydroelectricity in contributing to economic growth

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compared to other sources of electricity generation. Additionally, the study points out the environmental impact of different electricity production methods, with hydroelectric power showing little impact, while fossil fuel-based electricity production, particularly from coal, is a major contributor to carbon dioxide emissions.

Based on these findings, the study proposes several policy recommendations to promote sustainable development in these ASEAN countries. Given the significant positive impact of electricity production from hydroelectricity on economic growth, the countries should prioritize investments in hydropower projects. This can be achieved by effectively utilizing untapped water resources to generate electricity. Since fossil fuel-based electricity production, especially from coal, has a detrimental environmental impact, countries should take measures to reduce the reliance on coal in their power generation mix. This can be accomplished through the implementation of subsidies and tax incentives for cleaner alternatives, such as hydroelectric power. For countries that heavily depend on coal for electricity production, promoting and investing in clean coal technology is crucial. This technology aims to improve economic efficiency while minimizing the environmental impact associated with coal-based power generation.

By implementing the above policy measures, these countries can work towards achieving both higher economic growth and better environmental quality, thus contributing to their overall sustainable development goals. However, it is important to note that these policy recommendations are based on the specific context of the research findings and the six ASEAN countries studied. Before implementing these policies, careful consideration of local factors, economic feasibility, and environmental impacts should be undertaken. Policymakers should also collaborate with experts and stakeholders to ensure effective implementation and monitoring of these measures to achieve the desired outcomes.

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