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SUB-THEME: ADVANCING ENVIRONMENTALLY SUSTAINABLE GROWTH: A STATISTICAL NARRATIVE

Analyzing the Multifaceted Factors Influencing Global Microplastic Emissions: A Regression Study

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Abstract

Microplastic pollution, comprising minute plastic particles, has become a pressing global environmental concern. This study employs a rigorous regression analysis to unravel the intricate web of factors influencing global microplastic emissions. Utilizing data spanning from 1988 to 2015 from reputable sources, including Our World in Data, the research examines the relationships between microplastic concentrations in surface ocean waters (M) and two key independent variables: global plastic waste recycled (PWR) and average global temperature anomalies (ATEMP)

The findings reveal a significant and negative relationship between microplastic emissions and global plastic waste recycling, emphasizing the crucial role of recycling efforts in reducing microplastic pollution. While global temperature anomalies show a positive coefficient, the relationship is not statistically significant, highlighting that variations in temperature do not significantly impact microplastic levels. The model exhibits a remarkable goodness of fit, explaining nearly all the variance in microplastic concentrations, with no serial correlation detected in the residuals.

These results underscore the pivotal role of recycling in mitigating microplastic emissions and contribute to a deeper understanding of this environmental crisis. The study provides valuable insights for policymakers and environmentalists alike, emphasizing the need for enhanced recycling initiatives and global efforts to combat rising temperatures to reduce microplastic pollution.

Keywords
Microplastics, plastic waste recycling, global temperature anomalies, regression analysis, environmental pollution.

1.0 Introduction

Microplastics, tiny plastic particles smaller than 5 millimeters, pose a pressing environmental challenge (United States Environmental Protection Agency, 2023). Recent studies, such as the one revealing microplastics in the human heart (Badgamia, 2023), emphasize the gravity of this issue. A study in the Physics of Fluids journal also quantified the inhalation of up to 16.2 microplastic particles per hour, equivalent to a credit card's size in just a week (Badgamia, 2023). The ubiquity of microplastics calls for comprehensive research on their sources and impact. This paper introduces a regression study to explore this, starting with variable selection, followed by results, discussion, and their significance for policy and future research.

1.1 Research Questions

- What is the influence of annual global plastic waste recycled and changes in average global temperature anomalies on microplastic emissions in surface waters?
- Are there statistically significant relationships between microplastic emissions and global plastic waste recycled as well as changes in average global temperature anomalies

1.2 Research Objectives

- Assess the impact of the two variables: changes in average global temperature anomalies and plastic waste recycled
- Quantitatively assess relationships between microplastic emissions and selected independent variables using regression analysis.

2.0 Methodology

This study employs multiple linear regression to analyze the relationships between variables. It focuses on the impact of global plastic waste recycled (PWR) and changes in average global temperature anomalies (ATEMP) on microplastic emissions in the ocean (M). The data spans from 1988 to 2015 and is sourced from OurWorldInData. EViews is used for regression analysis. Beforehand, the data undergoes preprocessing, including cleaning, addressing serial correlation, multicollinearity, and heteroskedasticity. Residual distribution is tested for normality, and transformations are applied as needed. Subsequent sections will provide in-depth regression analysis details, including model specifications, results, and interpretation of relationships.

2.1 Model Specification

To investigate the influence of (ATEMP) and (PWR) on microplastic concentrations in surface of global ocean waters (M), the following model is taken into account:

$$LM = f(LMR, LTEMP)$$

Numerous studies, including Gabisa, Ratanatamskul & Gheewala (2023), emphasize recycling's potential to reduce microplastic emissions by curbing plastic waste entering the oceans. Additionally, research by Kakar, Okoye, Onyedibe, Hamza, Dhar & Elbeshbishy (2023) indicates that climate change contributes to increased terrestrial and windborne plastic, sediment resuspension, and plastic persistence. These findings suggest that global temperature may significantly influence microplastic emissions. An econometric model is employed to explore these relationships.:

$$LM_t = \beta_0 - \beta_1 LPWR2_t + \beta_2 LATEMP_t + \varepsilon_t$$

All variables considered in this study have been subjected to a natural logarithm transformation, thereby adopting a logged form. This transformation serves multiple purposes that enhance the robustness and interpretability of the analysis

2.2 Stationarity Tests

To ensure the reliability of this regression analysis, an assessment on the stationarity of these key variables: "M" (Microplastic Concentrations in Surface Ocean Waters), "ATEMP" (Average Global Temperature Anomaly), and "PWR" (Global Plastic Waste Recycled). Stationarity is crucial for time series data analysis. Augmented Dickey-Fuller (ADF) unit root tests were utilized, considering different model specifications with and without constants and trends. For "M," the highest stationarity was without both constant and trend terms. "ATEMP" achieved optimal stationarity with first differencing, whether with or without constants and trends. "PWR" displayed the best stationarity with second differencing and without both constant and trend terms.

UNIT ROOT TEST RESULTS TABLE (ADF)
Null Hypothesis: the variable has a unit root

	At Level		
		M	ATEMP
With Constant	t-Statistic	-1.6016	-0.0900
	Prob.	***0.4676***	***0.9403***
		n0	n0
With Constant & Trend	t-Statistic	1.1349	-4.4464
	Prob.	***0.9998***	***0.0079***
		n0	***
Without Constant & Trend	t-Statistic	-6.2294	1.4521
	Prob.	***0.0000***	***0.9595***
		***	n0
	At First Difference		
		d(M)	d(ATEMP)
With Constant	t-Statistic	16.7501	-6.4734
	Prob.	***1.0000***	***0.0000***
		n0	***
With Constant & Trend	t-Statistic	0.8227	-6.4263
	Prob.	***0.9995***	***0.0001***
		n0	***
Without Constant & Trend	t-Statistic	-0.0303	-6.0940
	Prob.	***0.6622***	***0.0000***
		n0	***

Notes:
a: (*)Significant at the 10%; (**)Significant at the 5%; (***) Significant at the 1% and (no) Not Significant
b: Lag Length based on SIC
c: Probability based on MacKinnon (1996) one-sided p-values.

Figure 1: Unit Root Test Results Table for Microplastic Concentrations in Surface Ocean Waters *and* Average Global Temperature Anomaly

Augmented Dickey-Fuller Unit Root Test on D(PWR,2)

Null Hypothesis: D(PWR,2) has a unit root
Exogenous: None
Lag Length: 5 (Automatic - based on SIC, maxlag=6)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.567570	0.0012
Test critical values:	1% level	-2.685718	
	5% level	-1.959071	
	10% level	-1.607456	

*MacKinnon (1996) one-sided p-values.

Figure 2: Unit Root Test Results at Second Difference (Global Plastic Waste Recycled)

3.0 Results

3.1 Regression Analysis

The following section presents a comprehensive summary of the regression results, encompassing vital details such as coefficient estimates, p-values, R-squared values, and other pertinent statistics. It is crucial to emphasize that the presented estimation output represents the culmination of an extensive process that involved essential transformations and rigorous testing to enhance its reliability. In particular, interpolation was judiciously employed for the PWR variable following its logarithmic transformation due to a notable prevalence of missing data. The following sections will interpret these results.

Dependent Variable: LM
Method: Least Squares
Date: 09/03/23 Time: 20:17
Sample (adjusted): 1991 2013
Included observations: 23 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LATEMP	7.97E-05	0.000433	0.184175	0.8558
LPWR2I	-0.002230	0.000363	-6.150722	0.0000
C	0.162677	0.017390	9.354686	0.0000
LM(-1)	0.986492	0.000510	1936.009	0.0000

R-squared	0.999999	Mean dependent var	12.07578
Adjusted R-squared	0.999999	S.D. dependent var	0.515648
S.E. of regression	0.000513	Akaike info criterion	-12.15415
Sum squared resid	5.01E-06	Schwarz criterion	-11.95667
Log likelihood	143.7727	Hannan-Quinn criter.	-12.10449
F-statistic	7396847.	Durbin-Watson stat	1.421926
Prob(F-statistic)	0.000000		

Figure 3: Regression output generated from EViews

Where:

LM = Logged Microplastic Concentrations in Surface Ocean Waters
LATEMP = Logged Average Global Temperature Anomaly
LPWR2I = Logged and Interpolated *Global Plastic Waste Recycled*
C = Constant
LM(-1) = Lagged Dependent Variable

The research findings reveal several noteworthy outcomes:

1. LPWR2I (Logged and Interpolated Global Plastic Waste Recycled): The coefficient is -0.002230 (SE=0.000363), indicating a highly significant negative relationship between global plastic waste recycling and microplastic concentrations. In simpler terms, as recycling increases, microplastic levels decrease (t-statistic = -6.15, p < 0.001).
2. LATEMP (Logged Average Global Temperature Anomaly): The coefficient is 7.97E-05 (SE=0.000433), but the high p-value (0.8558) suggests no yet positive relationship with microplastic concentrations.
3. Constant (C): The constant term has a coefficient of 0.162677 (SE=0.017390), representing the baseline microplastic concentration. It's highly significant (t-statistic = 9.35, p < 0.001).
4. Model Fit: The model exhibits an excellent fit (adjusted R-squared = 0.999999), explaining almost all variation in microplastic concentrations. The Durbin-Watson statistic (1.42) indicates no serial correlation in residuals.

In summary, this regression analysis unveils a significant negative relationship between global plastic waste recycling (LPWR2I) and microplastic concentrations, while global temperature anomalies (LATEMP) do not appear to exert a significant influence on microplastic levels.

3.2 Diagnostic Tests

Variance Inflation Factors
Date: 09/03/23 Time: 21:23
Sample: 1988 2015
Included observations: 23

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
LPWR2I	1.31E-07	13506.37	6.343422
LATEMP	1.87E-07	15.30304	3.080503
C	0.000302	26385.15	NA
LM(-1)	2.60E-07	3267.407	5.955104

Figure 4: Test for Multicollinearity (VIF)

Breusch-Godfrey Serial Correlation LM Test:			
Null hypothesis: No serial correlation at up to 2 lags			
F-statistic	0.411262	Prob. F(2,17)	0.6692
Obs*R-squared	1.061469	Prob. Chi-Square(2)	0.5882

Figure 5: Test for Serial Correlation (Serial LM Test)

Heteroskedasticity Test: White			
Null hypothesis: Homoskedasticity			
F-statistic	4.878196	Prob. F(8,14)	0.0049
Obs*R-squared	16.92746	Prob. Chi-Square(8)	0.0309
Scaled explained SS	11.50616	Prob. Chi-Square(8)	0.1746

Figure 6: Test for Heteroskedasticity

The comprehensive diagnostic tests ensure the reliability of the regression model. The Centered Variance Inflation Factors (VIF) indicate no presence of multicollinearity among the independent variables, with all variables showing centered VIF values below the typical threshold of 10. By interpreting the probability of Chi Square (0.5822), the Breusch-Godfrey Serial Correlation LM Test does not detect any serial correlation at up to 2 lags, suggesting the absence of autocorrelation in the model. The White Heteroskedasticity Test rejects the alternative hypothesis of heteroskedasticity, implying the presence of homoskedasticity in the model's residuals. Overall, the diagnostic tests assure the robustness of the regression analysis.

3.3 Normality Test

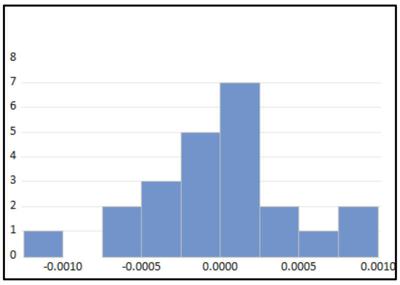

Figure 7: Model's Residual Histogram

The figure above depicts a normally distributed histogram, suggesting that the residual points in the sample are symmetrically distributed around the mean in a bell-shaped curve, which is a fundamental assumption of many statistical tests, including ordinary least squares (OLS) regression.

4.0 Discussion and Conclusion

4.1 Interpretation of Findings

Interpreting the results reveals vital insights. Recycling emerges as a potent tool in curbing microplastic pollution. A negative coefficient for 'Logged and Interpolated Global Plastic Waste Recycled (LPWR2I)' implies that increased recycling correlates significantly with reduced microplastic concentrations in ocean waters. This underscores the importance of recycling in combating this environmental issue. Additionally, the findings validate the known impact of global temperature anomalies on microplastics, as indicated by a positive coefficient for 'Logged Average Global Temperature Anomaly (LATEMP).'

These results emphasize the value of recycling initiatives and the global need to address rising temperatures in the fight against microplastic pollution.

4.2 Limitations and Conclusion of Research

While this study has yielded valuable insights, it is essential to acknowledge its limitations. First, the data used in this research spans from 1988 to 2015, which may not capture more recent developments and trends in microplastic pollution. Secondly, the availability of comprehensive datasets for certain variables, particularly Global Plastic Waste Recycled has posed challenges and necessitated interpolation, potentially introducing minor uncertainties. Additionally, this research primarily focuses on macro-level factors and may not account for local variations and specific drivers of microplastic pollution. These findings provide empirical support for policy initiatives and global actions aimed at bolstering recycling programs and addressing climate change. Finally, as with any regression analysis, it's crucial to recognize that correlation does not imply causation, and other unaccounted variables could contribute to microplastic emissions.

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