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Comparative Analysis of the Impact of Policy Uncertainty, Agricultural Output, and Renewable Energy on Environmental Sustainability

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Abstract: The comparative analysis of the effect of economic policy uncertainty on environmental sustainability is imperious as it can provide critical insights into the link between economic policies and environmental sustainability. Economic policy uncertainty may have different impacts in different economies. The present study provides a comparative analysis of the effect of economic policy uncertainty on environmental sustainability in developed and emerging economies. The study employs pooled ordinary least squares and panel quantile regression to analyze data from 2001 to 2019. Moreover, the study also compares the impact of economic policy uncertainty on environmental sustainability across two different econometric methods. It also compares the results across different quantiles of the distribution of variables. Moreover, the study includes the agriculture output, renewable energy consumption, and foreign direct investment in the model. The results show that economic policy uncertainty negatively and significantly impacts environmental sustainability as it increases GHG emissions. Moreover, agriculture output increases GHG emissions in developed economies at higher quantiles. Furthermore, the results also confirm the pollution haven hypothesis, while renewable energy consumption has a positive effect on environmental sustainability as it significantly reduces GHG emissions. The study stresses that governments should take measures to minimize economic policy uncertainty to improve environmental sustainability. In addition, effective policies to enhance openness in the policymaking process and offer long-term policy certainty and foster more stable investment conditions would encourage renewable energy and reduce GHG emissions.

Keywords: policy uncertainty; environmental degradation; agriculture production; renewable energy; climate change; quantile regression

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1. Introduction

The significance of economic policy uncertainty (EPU) on economic growth and sustainability has been well-established [1]. Governments all over the globe are trying to balance economic development and environmental protection [2]. In this regard, the relevance of the impact of EPU on environmental sustainability (ES) has increased. EPU refers to a lack of confidence in economic policy among businesses and households and its impact on the economy as a whole. EPU can stem from various factors such as political instability, regulatory modifications, and trade disputes [3]. These uncertainties can lead to market risks and volatility, which can adversely affect the performance of various economic sectors. Policymakers need to understand how EPU affects ES and the implementation of effective policies and initiatives to ensure ES. Nevertheless, a comparative analysis of the impact of EPU on ES can provide valuable insights for policymakers.

Policymakers, economists, and governments across the globe, are increasingly concerned about EPU. The rising level of EPU has significant effects on stability and economic growth. Some studies have also focused on exploring how EPU affects environmental quality. Given the necessity of environmental preservation and sustainable development on a global scale, the paucity of study on this subject is particularly concerning. EPU has the potential to have a substantial influence on ES [4,5]. EPU may result in less investment in renewable energy (RE) and less adoption of energy-efficient technology [4,6,7]. EPU may also cause delays in the execution of environmental regulations [8], which might hinder the advancement of sustainable development. A comparative examination of the impact of EPU on ES in both developed and emerging economies is pivotal to comprehending how the former influences the implementation of environmental policies and ES.

The conservation of natural resources and innovation plays a crucial role in promoting eco-efficiency in developed and developing economies [9]. However, increased EPU can have adverse impacts on environmental innovation [10]. Moreover, the stability of economic conditions is indispensable for firm-level decisions. Governance quality contributes to better investment decisions for the corporation. However, increased EPU has adverse impacts on corporate investments [11], whereas Ren et al. [12] find different impacts of EPU on corporate investments at different ranges of EPU. EPU also has negative impacts on ES and climate change mitigation by increasing CO_2 emissions [13–15]. EPU may have varying effects on ES in developed and emerging economies [15]. Some studies have also shown that EPU and economic growth contribute to carbon emissions [16]. In industrialized economies, there are more solid environmental policies, institutions, and laws that support sustainable growth. On the other hand, emerging economies may have major challenges in passing and implementing environmental laws due to lower financial resources and institutional capacity [17]. Moreover, EPU also can have negative but different impacts across different regions within an economy [18]. Some studies have examined the impacts of EPU on Chinese companies [18], BRICS economies [19], the EPU-green innovation relationship in Chinese cities, the EPU-RE relationship in the US [20], the EPU-energy efficiency association in Chinese cities [21], EPU impacts in G7 economies [22] and South Africa [23], and EPU-CO_2 relationship in South East-Asia [24], China [25], and BRICST nations [26]. However, the authors still believe there is a need to deeply examine the impacts of EPU on ES to better understand how EPU affects GHG emissions in developed and emerging economies. The authors find a strong motivation to analyze how EPU affects ES, since EPU may affect ES differently in different economies. Moreover, there is a dire need for a comparative analysis of the EPU-ES relationship in these economies. The present study extends the analysis of the impact of EPU on ES in a larger panel of countries.

Since EPU significantly impacts the trajectory of environmental sustainability initiatives, adopting environmentally friendly practices and a lack of clear and consistent rules might hamper cleaner technology innovation and its adoption [19–21,27]. The lack of evidence in the existing literature on how EPU impacts ES provides the authors with motivations to shed light on the relevance of stable and predictable policy frameworks for encouraging sustainable practices and RE uptake by investigating the influence of policy uncertainty. Furthermore, agriculture contributes significantly to environmental issues such as deforestation, GHG emissions, and soil deterioration [22]. Agriculture, on the other hand, has enormous potential to foster long-term growth. Investigating the link between agricultural production and environmental sustainability can provide valuable insights into optimizing agricultural practices, lowering environmental footprints, and encouraging regenerative farming strategies. In addition, RE sources are gaining traction as critical alternatives for mitigating climate change and reducing dependency on fossil fuels [23,24]. Analyzing the effects of RE deployment on environmental sustainability can give a thorough knowledge of their effectiveness in lowering carbon emissions and promoting a transition to greener energy systems [2,5,19,20,25,28]. Identifying the hurdles and enablers of RE adoption can also aid in developing policies that expedite the deployment of renewable technology [29]. The current study primarily focusses on the investigation of the research question on whether EPU affects the environmental sustainability in developed and emerging economics. Furthermore, the authors find it imperative to explore whether EPU affects the environmental sustainability in developed and emerging economies differently. Furthermore, a comparative approach to determine the relative contributions of policy uncertainty, agricultural production, and RE to environmental sustainability would provide a deeper insight into the issues on the way to sustainable development. Comparisons across various economies might show effective policies and practices in fostering sustainable development. A comparative method also allows for discovering distinct contextual factors that impact the connection between these variables, resulting in nuanced policy suggestions customized to individual circumstances. The findings of this study would have important implications for policymakers, stakeholders, and practitioners involved in environmental sustainability initiatives. The study findings may be used to inform policy formation, resource allocation, and strategic decision-making. This research aims to contribute to developing effective policies and interventions that foster a harmonious relationship between economic development, agricultural productivity, RE, and environmental preservation by addressing the key factors influencing environmental sustainability.

This study is primarily focused on analyzing the influence of EPU, agricultural output, foreign direct investment (FDI), and REC on ES in developed and emerging economies. The contributions of the study are:

- The study contributes to the empirical literature on how EPU affects ES in developed and emerging economies.
- The study assesses the impacts of agricultural output per worker (AGRPW) growth, FDI, and REC on ES in these economies.
- To these objectives, data from 12 developed and 7 emerging economies were obtained, and multiple econometric methods are used to assess this relationship. This study employs pooled ordinary least squares (OLS) and quantile regression to assess the impacts of these variables on ES measured by GHG emissions.
- Moreover, the study also provides a comparative analysis of the EPU-ES association in the total panel, developed, and emerging economies. Further, the quantile regression, at different quantiles of the distribution of these variables, also provides profound insight into how the EPU along with other variables affects ES at different quintiles of their distribution. Pooled regression estimates the model with the conditional mean of the response variable across values of the predictor variables whereas quantile regression calculates the conditional median (or other quantiles) of the response variable across those values. Compared to pooled regression, quantile regression offers various advantages, including being more resistant to outliers in the response measurements and making no assumptions about the distribution of the target variable [30,31]. Since EPU may have different impacts at its different ranges [12], the quantile regression could be helpful to understand the impact of EPU at its different levels.

This study adds to the literature related to EPU-ES by providing a comparative analysis of the group of developed and emerging economies. It also provides an examination of how EPU affects ES across different quantiles. The policymakers might benefit from the findings of this study that show the influence of EPU on ES in both industrialized and emerging nations and it would be productive to establish effective strategies for sustainable development. Policymakers may be able to develop more specialized and effective responses if they have a better grasp of the similarities and differences in the impact of EPU on ES.

This paper is structured into 5 sections. Section 2, following the introduction, represents the literature review. Section 3 comprises the methodology section which explains the model, description of variables, and data sources. In addition, it also represents the econometric methodologies used for the estimations of the model(s). Section 4 comprises the summary statistics, correlation matrix, results, and discussion on the results of the econometric estimates. Section 5 consists of the conclusion(s), implications, and prospects of research.

2. Literature Review

In recent years, the impact of EPU on macroeconomic variables has been widely studied. One of the strands of empirical studies focused on the analysis of how EPU impacts renewable energy consumption (REC). Table 1 provides a summary of these studies. Kong et al. [32] explore the impact of EPU on the investment decisions of Chinese A-share listed companies from 2007 to 2019. The results show that macro EPU decreases investment scale and efficiency while increasing the risk of overinvestment or underinvestment. On the other hand, local EPU increases investment scale but also increases the risk of overinvestment or underinvestment, hindering investment efficiency. The study also found that macro EPU boosts R&D investment but hinders green investment, while local EPU has the opposite effect. Moreover, macro EPU negatively affects firms' business performance while local EPU has a smaller effect. The authors suggest that the government should stabilize the macroeconomic environment and firms should optimize investment structures and improve risk prevention mechanisms in an uncertain environment.

Table 1. Summary of literature review.

Study	Objective	Findings
Kong et al. [32]	Analysis of the impact of EPU on firms' investment decisions in Chinese A-share listed companies in China.	Macro EPU promotes R&D investment, but it inhibits green investment.
Xu and Yang [33]	Examination of the impact of EPU on green innovation in Chinese cities.	EPU promotes green innovation within a threshold.
Zhang et al. [34]	The analysis of the nexus between EPU and RE in BRIC economies.	Asymmetric impacts run from EPU, FDI, and FD to REC, especially in the long run.
Shafiullah et al. [35]	Analysis of EPU and REC relationship in the USA.	Higher levels of EPU reduce REC.
Wei et al. [36]	Investigation of the distributional impacts of EPU on energy efficiency in Chinese cities.	EPU reduces energy efficiency.
Chu and Le [21]	Examination of the relationship between EPU, economic complexity, RE, energy intensity and CO_2 emissions, and ecological footprint in G7 economies.	The EKC of economic complexity and environmental quality holds for G7 countries. Furthermore, EPU strongly moderates the environmental effect of RE, economic complexity, and energy intensity.
Udeagha and Muchapondwa [37]	Analysis of the moderating role of EPU in EKC in South African economy.	The study confirms the EKC in South Africa. EPU increases environmental degradation in the short and long run.
Khan et al. [38]	Investigation of the relationship between CO_2 and EPU for East Asian countries.	There is 2-way causality between CO_2 emissions and EPU.
Syed et al. [39]	Examination of the impact of EPU and geo-political risk (GPR) impedes CO_2 emissions in BRICST economies.	EPU adversely affects CO_2 emissions at lower and middle quantiles, while it surges the CO_2 emissions at higher quantiles, whereas GPR surges CO_2 emissions at lower quartiles.
Huang et al. [5]	Exploring the impact of EPU on GHG emission in developed and developing economies.	EPU increases GHG emissions.

Xu and Yang [33] fills a knowledge gap about how EPU influences green innovation. The paper examines the moderating influence of resource endowment. The findings indicate that EPU can encourage green innovation up to a certain extent but afterward has a negative inhibitory effect. The study emphasizes the need for governments and businesses collaborating to encourage innovation and mitigate the negative consequences of uncertainty, as well as update economic development models to promote green innovation and reduce resource dependency in Chinese resource-based cities. Zhang et al. [34] provide a piece of new evidence on the relationship between EPU, REC, FDI, and financial development (FD) in BRIC nations. The study using multiple econometric techniques shows the long-run relationship between EPU, FD, FD, and REC in BRIC nations. The ARDL estimation shows the negative impacts of EPU on REC. The positive and significant relationship between FDI and FD with REC implies that the integration of clean energy can be increased through continuous inflows of FDI and the financial sector. The asymmetric assumption model showed asymmetric effects of EPU, FDI, and FD on REC, particularly in the long run. The results also showed unidirectional causality between REC and EPU, while FDI and FD have a feedback relationship with REC.

Utilizing monthly data, Shafiullah et al. [35] examine how EPU affects the use of RE in the USA. The results demonstrate that the model variables are non-stationary and feature nonlinear co-integration, utilizing sophisticated nonparametric econometric approaches. The use of RE has been proven to have a negative long-term connection with policy uncertainty, indicating that reduced EPU causes lower RE usage. The findings emphasize the significance of consistent economic policies for encouraging the use of RE in the USA. Wei et al. [36] investigate the distributional impacts of EPU on energy efficiency in 39 Chinese cities from 2003 to 2019. The findings reveal that EPU has a detrimental impact on energy efficiency in cities with medium and high efficiency, with higher EPU resulting in even poorer energy efficiency performance. The negative impacts are more in central and western cities and weaker in eastern cities, showing that cities with a better economic basis and higher technological development can more readily deal with EPU's effects on energy efficiency. Overall, the analysis reveals the diverse effects of EPU on energy efficiency in Chinese cities at various quantiles of the distribution.

In the Group of Seven (G7) countries, Chu and Le [21] examine the connections between EPU, economic complexity, RE, energy intensity, and CO_2 emissions and ecological footprint. The paper uses robust fixed effects models and completely modified OLS to analyze panel data from 1997 to 2015. The findings indicate a sustained association between the factors and environmental quality. The results show that while significant EPU and RE assist in slowing down environmental deterioration, high energy intensity leads to environmental damage. The environmental Kuznets curve (EKC) for economic complexity and environmental quality in G7 nations is also supported by the study. The study also discovers the influence of EPU on economic complexity, energy intensity, and the environmental impact of RE. EPU intensifies the detrimental impacts of energy intensity on environmental quality while enhancing the favorable environmental benefits of RE and economic complexity. For governments looking to lessen environmental damage, these studies offer insightful information. In another study, Udeagha and Muchapondwa [37] investigate the effects of trade openness, economic uncertainty, energy intensity, and use of renewable and non-RE sources on environmental quality in South Africa from 1960 to 2020. The findings demonstrate that EPU has an unfavorable effect on the environment over the long and short terms. Economic expansion accelerates environmental deterioration, while the square of growth slows it down, supporting the EKC concept. Environmental quality is negatively impacted by energy intensity, the use of non-RE, and trade openness, while positively impacted by technical innovation and RE. Uncertainty in economic policy enhances the environmental effects of economic complexity while exacerbating the negative effects of energy intensity. These findings offer crucial policy suggestions for raising South Africa's environmental standards.

A strand of empirical literature primarily attempted to explore the impact of EPU on CO_2 emissions. For instance, Khan et al. [38] examined the link between CO_2 emissions and economic policy uncertainties in East Asia from 1997 to 2020. The study makes use of sophisticated econometric techniques to examine connections between the chosen variables, such as trade, RE, FDI, and EPU. The findings indicate that GDP, trade, and EPU all have a positive effect on carbon emissions, but usage of RE and FDI are linked to better environmental quality. Additionally, the study discovered two-way causal links between carbon emissions and commerce, energy consumption, economic growth, and EPU. The results show that decision-makers should take into account the adverse consequences of EPU. The results imply that decision-makers should take into account the detrimental effects of EPU on policies addressing CO_2 emissions and look for alternative means of reducing both EPU and carbon emissions, such as investing in green technology, foreign capital, and RE. The influence of EPU on the cost of China's carbon emissions trading market from 2013 to 2021 is examined [40]. The findings indicate that although exchange rate policy uncertainty has a negative influence on the price of the carbon emissions trading market, trade policy and monetary policy uncertainty have a favorable impact. The study also reveals that the price of the carbon emissions trading market is more affected by rising trade policy uncertainty, monetary policy uncertainty, and exchange rate policy uncertainty. The findings are in line with the hypothesis that uncertainty unequally affects financial assets. Policymakers should take steps to lessen volatility and be cognizant of how economic policies affect the price of carbon emissions trading.

Some studies looked into how geopolitical risk and EPU affect CO_2 emissions. In this regard, Syed et al. [39] concluded that EPU and GPR both have a heterogeneous impact on CO_2 emissions over various quantiles in the BRICST economies. EPU has a negative impact on CO_2 emissions at the lower and middle quantiles but raises them at the higher quantiles, whereas GPR causes CO_2 emissions to rise at the lower quantiles and fall at the middle and higher quantiles. The study also discovers that the influence of urbanization, GDP per capita, RE and non-RE, and other variables on CO_2 emissions varies. The study makes policy recommendations to address these concerns in light of the findings. In conclusion, research indicates that uncertainty in economic policy can have a big influence on attempts to mitigate climate change. Investments in alternative energy and other mitigation measures may be lessened by uncertainty, but policy predictability and stability may encourage such investments. The conclusions of this research emphasize the significance of policy predictability and stability for encouraging investment in initiatives to mitigate climate change. In a recent study, Huang et al. [5] examined the effects of EPU on GHG emissions and climate change in 19 industrialized and developing nations. The authors tested the EKC and pollution halo/haven hypotheses using panel data analysis techniques, including PCSE and GLS. The analysis also discovers a U-shaped EKC and the pollution haven theory in the chosen nations.

3. Research Methodology

3.1. The Model

Since the study is primarily focused on the examination of the influence of EPU [3] on ES, GHG emissions are taken as an indicator of ES in the model. GHG gas emissions are major contributors to climate change, resulting in an adverse impact on ES, whereas some previous studies considered carbon emissions as a dependent variable while exploring the impact of EPU on ES [13,14,16,18,41]. Some studies also included agriculture output growth as an independent variable to assess its impact on GHG and ES [42]. Since the FDI inflows play a pivotal role in economic growth, innovation [10], industrial development [43], and thereby affecting environmental quality [43–45] in host economies, the present study also includes FDI as an independent variable in the model to assess the pollution haven/halo hypothesis. Moreover, RE has its core importance in climate change mitigation efforts and achieving the carbon peak and carbon neutrality [2,30], this study also considers RE as one of the response variables in the model. This study proposes and estimates the following model for the comparative analysis of EPU-ES association in developed and emerging economies.

$$LGHG_{it} = \alpha_1 LEPU_{it} + \alpha_2 LAGRPW_{it} + \alpha_3 LFDI_{it} + \alpha_4 LREC_{it} + \epsilon_{it} \tag{1}$$

In model (1), *EPU*, *AGRPW*, *FDI*, and *REC* are the economic policy uncertainty index, agriculture output per worker, *FDI*, and *REC*, respectively, whereas *LGHG*, *LEPU*, *LAGRPW*, *LFDI*, and *LREC* are the natural log values of *EPU*, *AGRPW*, *FDI*, and *REC*, respectively. ϵ is the error term and subscripts i and t show the panel group and time (i.e., year), respectively. The expected sign of α_1 is expected to be positive. The expected signs of the coefficients of the independent variables are summarized in Table 2.

Table 2. Expected signs of estimated parameters.

Variable	Symbol	Expected Sign(s)
Economic policy uncertainty	EPU	$\alpha_2 > 0$
Agriculture output per worker	AGRPW	$\alpha_2 > 0$ or $\alpha_2 < 0$
Foreign direct investment	FDI	$\alpha_3 > 0$ or $\alpha_3 < 0$
Renewable energy consumption	REC	$\alpha_4 < 0$

Various previous studies [21,34,38,39] provide strong reasons to expect a positive association between EPU and GHG emissions. For agriculture output, $\alpha_2 > 0$ or $\alpha_2 < 0$ is expected. There is enough evidence of $\alpha_2 > 0$, as the studies such as [42,46–48] show that agricultural sector growth causes an increase in GHG emissions. However, there is also some evidence of $\alpha_2 > 0$, as agricultural growth can reduce GHG emissions [49,50]. The coefficient of FDI can be $\alpha_3 > 0$ or $\alpha_3 < 0$. $\alpha_3 > 0$ implies that FDI inflows are related to higher levels of CO_2 emissions. FDI-CO_2 is acknowledged as the pollution haven hypothesis (PHH) in literature regarding FDI-environmental linkage. It may be due to the motivation of developed economies to maximize profit and invest in developing and emerging economies with less stringent environmental policies, relaxed environmental regulation, or lower environmental tax systems. In such cases, the developed economies shift polluting industries to such economies [51]. There is also an empirical evidence on the confirmation of PHH [44,52]. However, on the other side, some studies put forward the argument that the FDI flows have the potential to be the conduit of cleaner and more efficient technologies to the host economies which are helpful in climate change mitigation. The FDI-GHG association is named the pollution halo hypothesis [53]. When it comes to RE, $\alpha_4 < 0$ is expected. REC has a pivotal role to play and has the potential to add to climate change mitigation efforts by reducing GHG emissions [30,34,35,37].

3.2. Description of Variables and Data Source

The study utilized data from 12 developed economies (Canada, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, Spain, the United Kingdom, the United States, and Sweden) and 12 emerging economies (Brazil, China, Chile, Colombia, India, Russia, and Mexico). The sampled period for data has been collected from 2001 to 2019. The data for all the variables except EPU has been obtained from the World Development Indicators [54]. Moreover, the data for EPU has been taken from economic policy uncertainty [55]. The details and descriptions of the variables are summarized in Table 3.

Table 3. Variables and data source.

Variable	Description	Source
GHG	Total greenhouse gas emissions (kt of CO_2 equivalent)	World Bank [54]
EPU	Environmental Policy Uncertainty Index	EPU [55]
AGRPW	Agriculture, forestry, and fishing, value added per worker (constant 2015 US$)	World Bank [54]
FDI	Foreign direct investment, net inflows (BoP, US$ million)	World Bank [54]
REC	Renewable energy consumption (% of total final energy consumption)	World Bank [54]

3.3. Econometric Methodology

The present study has used pooled regression and quantile regression methods to estimate the model (1). The statistical distribution of data might exhibit uneven variance and shifting interactions between variables at different locations on the conditional distribution of the regression. Estimates based on mean values, such as pooled OLS, might produce inaccurate results [30,31]. Quantile regression is a statistical method used to model the conditional quantile of a response variable, given a set of predictor variables. The method allows for the estimation of the quantile of interest, rather than just the mean or median, making it useful for modeling non-symmetric distributions and exploring the heterogeneity of the response variable [31]. Moreover, quantile regression helps address the heterogeneity problem in panel data by estimating heterogeneous effects across the conditional distribution of the response variable while adjusting for individual and time-specific variables [56]. The average effect produced from pooled regression must adequately capture this diverse effect. Quantile regression can also manage non-normal response variable distributions and resist the impact of outliers [57].

Quantile regressions entail splitting the dependent variable's conditional distribution into quantiles, with the 50th quantile indicating the median [31,58]. Quantile regressions are less susceptible to outliers than mean-based estimate approaches [58]. Moreover, metrics such as GHG and EPU might have significant differences between the median and mean. Due to its capacity to estimate different slopes for different quantiles, quantile regression is an appealing approach for evaluating the EPU-GHG association.

The first step in starting a quantile regression is identifying the target quantile, which is commonly indicated by the parameter $\tau(0 < \tau < 1)$. With the $\tau = 0.5$, the regression concentrates on modeling the response variable's median. With $\tau = 0.9$, the regression attempts to represent the 90th percentile. Similarly, with τ values 0.25 and 0.75, the regression provides the estimates for the lowest and highest quartiles [31,58].

Given X_i, the conditional quantile of Y_i can be estimated as:

$$Q_{Y_{it}}(\tau|X_{it}) = X_{it}^{\tau}\mathrm{B}_{\tau} \quad (2)$$

In Equation (2), $Q_{Y_{it}}(\tau|X_{it})$ indicates the τth quantile of the regressor and X_{it}^{τ} is the vector of dependent variables for each country i at year t for the τth quantile, whereas, B_{τ} indicate the slopes of the response variables at the τth quantile [6,30]. In the present study, the regression coefficients have been estimated at the 10th, 20th, 25th, 30th, 40th, 50th, 60th, 70th, 75th, 80th, and 90th quantiles. Moreover, for the robustness of the estimated results, following [30], we have used balanced panel data. In the present study, the panel quantile method is used to capture the heterogeneous makeup of groups with varying amounts of GHG emissions and EPU.

4. Results

4.1. Summary Statistics and Correlation Matrix

The summary statistics are in Table 4. The mean value of GHG emissions in the total panel is 1,486,568 with mean values of 958,593 and 2,318,148 for a group of developed and emerging economies, respectively. It is notable that on average, GHG emissions are higher in developing economies as compared to those of developed economies. It may be because, in the panel of emerging economies, the major contributors to global GHG such as China, India, and Brazil are included in the model. The highest GHG emissions of 12,700,000 for the Chinese economy is the highest value of GHG emissions in the total panel and the panel of emerging economies. The EPU in the total panel averaged 119.87 as compared to 126.76 and 108.05 in developed and emerging economies respectively. It shows that, on average, developed economies have been experiencing higher levels of policy uncertainty as compared to emerging economies. It can also be observed with the fact that the maximum value of EPU of 497.54 shows the indication of higher levels of EPU in developed economies, whereas in emerging economies, the EPU ranged from a minimum value of 25.23 to a maximum EPU of 350.92. Moreover, the standard deviation of EPU in developed economies is also higher as compared to that in emerging economies. The agriculture output per worker (AGRPW) averaged 30,805.26 in the full panel as compared to 45,522.78 and 5575.23 in developed and emerging economies. It shows that agricultural productivity is higher in developed economies as compared to emerging economies. The FDI levels in developed countries, on average, have been higher with a mean value of 70,108.98 as compared to the mean value of FDI of 47,993.77. When it comes to REC, the developed economies showed an average of 12.81 percent with minimum and maximum levels of REC of 0.85 percent and 52.88 percent, respectively, whereas in emerging economies, the levels of REC are higher with an average of 24.56 percent with minimum and maximum values of 3.18 percent and 48.92 percent, which is also higher than the average of the total panel of countries. The skewness and kurtosis values of the variable show that most of the variables are not normally distributed.

Table 4. Summary statistics.

Variable	GHG	EPU	AGRPW	FDI	REC
			Total Panel		
Mean	1,486,568.00	119.87	30,805.26	61,961.27	17.14
Std. Dev.	2,529,330.00	63.32	27,115.52	92,569.78	13.78
Min	46,190.00	25.23	964.78	2.00	0.85
Max	12,700,000.00	497.54	113,112.70	733,826.50	52.88
Median	557,230.00	106.36	21,399.15	28,909.42	11.61
Skewness	2.76	2.38	0.85	2.90	0.96
Kurtosis	10.41	11.25	2.81	14.01	2.76
			Developed Economies		
	GHG	EPU	AGRPW	FDI	REC
Mean	958,593.40	126.76	45,522.78	70,108.98	12.81
Std. Dev.	1,669,299.00	66.40	23,864.99	105,724.80	11.24
Min	46,190.00	47.52	12,280.51	2.00	0.85
Max	6,767,470.00	497.54	113,112.70	733,826.50	52.88
Median	461,440.00	110.31	42,708.31	31,375.28	9.03
Skewness	2.81	2.57	0.63	2.66	1.96
Kurtosis	9.38	11.89	2.65	11.79	6.64
			Emerging Economies		
	GHG	EPU	AGRPW	FDI	REC
Mean	2,318,148.00	108.05	5575.23	47,993.77	24.56
Std. Dev.	3,256,567.00	55.94	3207.03	61,942.84	14.60
Min	67,800.00	25.23	964.78	1720.49	3.18
Max	12,700,000.00	350.92	14,201.45	290,928.40	48.92
Median	991,490.00	98.22	5017.53	25,564.94	28.80
Skewness	2.04	1.75	0.62	2.37	−0.03
Kurtosis	6.11	7.20	2.65	8.14	1.69

Note: The number of observations to total panel, developed, and developing economies are 361, 228, and 133, respectively.

4.2. The Pairwise Correlation

The pairwise correlation matrices for the total panel of developed and emerging economies are summarized in Table 5, showing that the correlation coefficients between EPU and GHG are positive in the total panel and group of emerging economies. The EPU-GHG correlation in emerging economies is statistically significant with p-value < 0.01. The AGRPW-GHG correlation is negative but weak for the total panel of countries and a group of emerging economies. However, it is positive in developed economies. The FDI-GHG correlations in all groups of countries are positive and statistically significant with p-value < 0.01. However, this correlation is strong in a group of emerging economies. It is also noteworthy that the REC-GHG correlation has an expected negative sign, and it is statistically significant for all groups of countries. However, the correlation between REC and GHG is weak. The correlation coefficients between the independent variables are lower which rules out the multicollinearity issues. Moreover, it is also confirmed by the mean $VIF < 5$ for all groups of panels (Table 5).

Table 5. Pairwise correlation.

Variable(s)	GHG	EPU	AGRPW	FDI	REC	VIF
			Total Panel			
GHG	1.0000					-
EPU	0.0343	1.0000				1.25
AGRPW	−0.0335	0.2559 ***	1.0000			1.13
FDI	0.5250 ***	0.0601	0.3488 ***	1.0000		1.02
REC	−0.1168 **	−0.0420	−0.1100 **	−0.2471 ***	1.0000	1.12
Mean VIF						1.13
			Developed Economies			
GHG	1.0000					-
EPU	−0.0006	1.0000				1.08
AGRPW	0.4618 ***	0.2389 ***	1.0000			2.09
FDI	0.5445 ***	−0.0034	0.4281 ***	1.0000		1.77
REC	−0.2036 ***	0.0063	0.4306 ***	−0.2409 ***	1.0000	1.37
Mean VIF						1.58
			Emerging Economies			
GHG	1.0000					-
EPU	0.1697 *	1.0000				1.24
AGRPW	−0.3039 ***	0.3982 ***	1.0000			1.42
FDI	0.8952 ***	0.2133 **	−0.1623 *	1.0000		1.09
REC	−0.3034 ***	0.0390	−0.2565 ***	−0.2237 ***	1.0000	1.25
Mean VIF						1.25

* shows p-value(s) < 0.10, ** shows p-value(s) < 0.05, and *** shows p-value(s) < 0.01.

4.3. Economic Policy Uncertainty-GHG Model Results

Table 6 summarizes the results of the pooled regression and quantile regression analyses. They show that the EPU coefficient is positive and statistically significant (p-value < 0.01) for all groups of countries—total panel, developed economies, and emerging economies. This is consistent with the results of [5]. The quantile regression results also show positive LEPU elasticities of LGHG emissions for all panels and quantiles. However, the LEPU coefficients are only significant at higher quantiles in the total panel. The LEPU coefficients vary across different quantiles, indicating that EPU affects GHG emission changes at different levels. The LEPU coefficients are insignificant at higher quantiles in the total panel and developed economies. The LEPU coefficients generally increase and are significant at higher quantiles in emerging economies. EPU can affect ES through various direct and indirect pathways. An important channel through which EPU impacts ES is investment [8] and innovation [33]. Moreover, EPU also has negative impacts on energy efficiency [36]. EPU can reduce investment and innovation in ES. Companies may delay investment in environmentally sustainable practices and technologies, as they may be uncertain about the future economic policy environment [8,32]. Another channel is policy coordination as EPU can result in a lack of coordination between policies and ambiguity in environmental policy, which makes it challenging for businesses to make long-term investment choices and prepare for the future. Pirgaip et al. [7] showed that EPU has negative impacts on energy conservation policies. The extended prevalence of EPU also has its impacts on consumer behavior regarding the use of eco-friendly goods and services. Uncertainty in economic policy can influence consumer behavior, with customers potentially limiting their desire for environmentally friendly products and services. However, a reduction in EPU can help increase REC [35]. Moreover, EPU might cause governments to reverse or reduce environmental restrictions to support economic development, which could result in environmental deterioration.

Table 6. Econometric analyses results.

Variables	Pooled OLS	Quantiles										
		10th	20th	25th	30th	40th	50th	60th	70th	75th	80th	90th
Total Panel												
LEPU	0.5345 ***	0.6019 ***	0.8370 ***	0.8686 ***	0.7061 ***	0.6879 ***	0.6669 ***	0.5378 **	0.2324	0.2071	0.1045	−0.0018
	(0.1303)	(0.1746)	(0.2210)	(0.1725)	(0.1573)	(0.1506)	(0.1793)	(0.2675)	(0.2786)	(0.2439)	(0.2078)	(0.1514)
LAGRPW	−0.5228 ***	−0.4104 ***	−0.4635 ***	−0.5856 ***	−0.6216 ***	−0.6285 ***	−0.6416 ***	−0.6625 ***	−0.5343 ***	−0.5052 ***	−0.4636 ***	−0.3425 ***
	(0.5054)	(0.0564)	(0.0791)	(0.0997)	(0.0833)	(0.0781)	(0.07820	(0.0884)	(0.0728)	(0.0723)	(0.0720)	(0.0693)
LFDI	0.4667 ***	0.3197 ***	0.4234 ***	0.4971 ***	0.5470 ***	0.5549 ***	0.5680 ***	0.5374 ***	0.5814 ***	0.5581 ***	0.5345 ***	0.5095 ***
	(0.0309)	(0.0418)	(0.0682)	(0.0648)	(0.0469)	(0.0441)	(0.0628)	(0.0788	(0.0931)	(0.0909)	(0.0820)	(0.0697)
LREC	−0.3891 ***	−0.2378 ***	−0.4119 ***	−0.4316 ***	−0.4051 ***	−0.4005 ***	−0.4147 ***	−0.4267 ***	−0.3572 ***	−0.4169 ***	−0.5106 ***	−0.5457 ***
	(0.0638)	(0.0661)	(0.0784)	(0.0795)	(0.0875)	(0.0851)	(0.0794)	(0.0926)	(0.1048)	(0.0967)	(−0.0922)	(0.1459)
Constant	12.1097 ***	10.4118 ***	9.6658 ***	10.2709 ***	10.9888 ***	11.2572 ***	11.6126 ***	12.9885 ***	12.9674 ***	13.3482 ***	14.1299 ***	14.2076 ***
	(0.7240)	(1.1346)	(1.2589)	(1.0033)	(0.7574)	(1.2179)	(1.2179)	(1.6494)	(1.6002)	(1.3380)	(1.1515)	(1.1093)
Developed Economies												
		10th	20th	25th	30th	40th	50th	60th	70th	75th	80th	90th
LEPU	0.5024 ***	0.5611 **	1.0473 ***	1.0200 ***	0.8244 ***	0.4596	0.2237	0.3237	−0.0017	0.0764	−0.0295	0.0764
	(0.0640)	(0.2438)	(0.1757)	(0.2222)	(0.2709)	(0.3148)	(0.4942)	(0.2778)	(0.2115)	(0.1893)	(0.1849)	(0.1810)
LAGRPW	0.3484 **	−0.0835	−0.2129	−0.3083 *	−0.1969	0.0762	0.3956	0.4917	0.9920 ***	1.1023 ***	1.1549 ***	1.2207 ***
	(0.1370)	(0.2344)	(0.1567)	(0.1716)	(0.2149)	(0.2739)	(0.2714)	(0.3121)	(0.2548)	(0.1972)	(0.1836)	(0.1667)
LFDI	0.2659 ***	0.2311 ***	0.2965 ***	0.3339 ***	0.3823 ***	0.3851 ***	0.3574 ***	0.3387	0.2841 ***	0.2112 **	0.2064 ***	0.1535 ***
	(0.0376)	(0.0621)	(0.0584)	(0.0723)	(0.0715)	(0.0649)	(0.0812)	(0.0974)	(0.0919)	(0.0810)	(0.0695)	(0.0510)
LREC	−0.4585 ***	−0.2581 ***	−0.2092 ***	−0.2172 ***	−0.3330 ***	−0.1969 *	−0.3368 *	−0.5834	−1.2950 ***	−1.3905 ***	−1.4018 ***	−1.5522 ***
	(0.0728)	(0.8169)	(0.0798)	(0.0989)	(0.1081)	(0.1163)	(0.2022)	(0.3401)	(0.2932)	(0.1682)	(0.1282)	(0.1406)
Constant	5.2172 ***	8.1146 ***	6.7682 ***	7.6800 ***	7.4622 ***	6.2396 ***	4.8533 ***	4.3087	3.2142 **	2.7627 *	2.8755 *	2.7844 *
	(0.9952))	(1.4294)	(1.4294)	(1.4740)	(1.6333	(1.8310)	(1.5495)	(1.5672	(1.6197)	(1.6017)	(1.6689)	(1.6233)
Emerging Economies												
		10th	20th	25th	30th	40th	50th	60th	70th	75th	80th	90th
LEPU	0.6637 ***	0.2979	0.3400 *	0.3176	0.5900 ***	0.5747 ***	0.6994 ***	0.7899 ***	0.7677 ***	0.7612 ***	0.7424 ***	0.5934 **
	(0.1263)	(0.1731)	(0.1986	(0.2061)	(0.2010)	(0.1667)	(0.1531)	(0.1335)	(0.1248)	(0.1452)	(0.1756)	(0.2312)
LAGRPW	−1.4845 ***	−1.4381 ***	−1.4539 ***	−1.5266 ***	−1.4701 ***	−1.4807 ***	−1.4863 ***	−1.5479 ***	−1.4644 ***	−1.4708 ***	−1.5012 ***	−1.2059 ***
	(0.0941)	(0.1240)	(0.1448)	(0.1530)	(0.1565)	(0.1356)	(0.1225)	(0.1110)	(0.1136)	(0.1272)	(0.1564)	(0.1917)
LFDI	0.7254 ***	0.9229 ***	0.8534 ***	0.8284 ***	0.8266 ***	0.8374 ***	0.8499 ***	0.7706 ***	0.7439 ***	0.7344 ***	0.6451 ***	0.5168 ***
	(0.0491)	(0.0921)	(0.1017)	(0.1054)	(0.1031)	(0.0905)	(0.0769)	(0.0672)	(0.0724)	(0.0809)	(0.0917)	(0.0701)
LREC	−0.8769 ***	−0.7924 ***	−0.7797 ***	−0.7778 ***	−0.8081 ***	−0.6995 ***	−0.7081 ***	−0.7145 ***	−0.7885 ***	−0.7847 ***	−0.8114 ***	−0.9214 ***
	(0.0693)	(0.1200)	(0.1635)	(0.1710)	(0.1662)	(0.1387)	(0.1208)	(0.1232)	(0.1020)	(0.0948)	(0.0978)	(0.1097)
Constant	18.3751 ***	16.6849 ***	17.4592 ***	18.4865 ***	17.0086 ***	16.9400 ***	16.4346 ***	17.5282 ***	17.6311 ***	17.8228 ***	19.3118 ***	19.4755 ***
	(1.0147)	(1.8315)	(2.2572)	(2.4303)	(2.4533)	(2.1827)	(1.8217)	(1.4783)	(1.3517)	(1.3539)	(1.2824)	(1.1476)

The values in ( ) are bootstrap standard errors. * shows p-value(s) < 0.10, ** shows p-value(s) < 0.05, and *** shows p-value(s) < 0.01.

The coefficients of agricultural output per worker are negative and significant in the total panel and emerging economies. In developed economies, they are negative and significant from the 10th to 25th quantiles but insignificant at the 30th quantile (Table 6). However, they become positive and significant from the 40th to 90th quantile. The coefficient values increase at higher quantiles, indicating that agricultural output per worker adversely affects ES in developed economies at higher distribution levels. This GHG emission increasing impact on agriculture output in developed economies might be due to the reliance of these economies on fossil fuels to meet the energy demands in the agriculture sector [46]. Moreover, increased agriculture production warrants extended land use, more use of fertilizers and aquaculture production, and investments in road infrastructures. These factors cause an increase in the carbon footprints of the agriculture sector growth. The findings are supported by the findings of [42] who find a negative impact of non-organic agricultural output growth in the European region. However, the same study asserted that organic agriculture contributes to a reduction in the carbon footprints of the agriculture sector. Interestingly, our results show that agriculture sector output growth has negative and highly significant signs in pooled regression and quantile regressions and the value of coefficients for a group of emerging economies is higher than that for the total group of countries. Depending on the methods and technology used, the increasing agricultural output can have various implications on GHG emissions in developing nations. While certain agricultural methods can result in higher emissions, others can help to mitigate and reduce emissions. Sustainable agricultural intensification can reduce GHG emissions in emerging economies. According to the study, sustainable intensification may enhance crop yields while decreasing the amount of land required for agriculture, lowering deforestation and emissions related to land-use change [47]. Smallholder farmers in developing nations may cut emissions while increasing output by adopting climate-smart farming techniques. According to the research, various approaches, such as agroforestry and conservation agriculture, can contribute to sustainable intensification by reducing the demand for fertilizers and pesticides, both of which can cause emissions [48]. Moreover, the use of RE also reduces the carbon footprints of the agriculture sector [49]. For instance, developing solar irrigation systems can help reduce carbon emissions in agricultural production [50].

The pooled and quantile regressions support the PHH for all the groups of countries. FDI elasticities of GHG emissions are significant at 0.01 level and are 0.4667, 0.2659, and 0.7254 (Table 6) for the total panel, developed, and emerging economies, respectively. The FDI elasticity is higher in emerging economies than in the total panel and developed economies, indicating a more substantial FDI impact on GHG in emerging economies. The quantile regression analysis also shows higher FDI elasticities for emerging economies than for the total panel and developed countries. The elasticity values decrease at higher distribution quantiles for developed and emerging economies. The results of the present analyses corroborate with the findings in previous studies including [44,51,52]. FDI can raise greenhouse gas (GHG) emissions in developed economies via a variety of avenues, including increased industrial activity, energy consumption, and transportation. FDI inflows can stimulate economic activity and output, leading to a rise in GHG emissions. However, there may be multiple source reasons for this positive association between FDI and GHG emissions in developed economies. It might be due to the reason that FDI in the duration of EPU has a negative impact on environmental quality due to relaxed environmental standards. Cole [59] provides strong reasons to believe that FDI inflows might enhance the production of carbon-intensive commodities as well as energy consumption. It is also notable that FDI inflows increase economic growth which in turn enhances energy consumption and thereby GHG emissions. This might be one of the reasons for GHG emissions increasing the impact of FDI in developed economies. Huang et al. [43] also explored the positive association between FDI and carbon emission in G20 economies. Another reason for a positive association between FDI and GHG could be the role of the former in stimulating industrial activity and the surge in energy consumption leading to an increase in the latter. FDI has an adverse effect on ES by affecting carbon emission efficiency [60,61].

REC affects GHG emissions in different economies at different stages. According to a study, REC has a negative and significant impact on GHG emissions for all panel groups, meaning that more REC leads to less GHG emissions. However, the strength of this impact varies across different quantiles, representing different levels of GHG emissions. The study found that REC elasticities, which measure the responsiveness of GHG emissions to changes in REC, are higher for emerging economies than for the total panel from the 10th to 60th quantile. REC reduces GHG emissions more effectively in emerging economies at lower GHG emissions than in developed economies. However, the study also found that REC elasticities are higher for developed economies than for emerging economies from the 70th to 90th quantile. REC reduces GHG emissions more effectively in developed economies at higher GHG emissions than in emerging economies. The study suggests that REC has a more significant role in lowering GHG emissions in developed economies at higher stages than in emerging economies. Different degrees of development result in various effects of RE on GHG emissions. Contrary to fossil fuels, the leading cause of global climate change, RE sources, including wind and solar, release little to no GHGs or other air pollutants. In addition to being more affordable and available than fossil fuels, RE sources may assist nations in diversifying their economy and lowering their reliance on imports. Nevertheless, depending on the area and economic level, different RE sources have varying effects on GHG emissions. The results of our analyses corroborate with the results of Allard et al. [30], who show that the coefficients of RE are higher for lower-middle-income countries as compared to those for upper-middle and high-income countries. This confirms that in lower-middle-income countries, RE plays a pivotal role in the reduction of CO_2 emissions. The positive role of RE in reducing GHG emissions and promoting ES has been asserted in [34,35,37].

5. Conclusions

This study aims to conduct a comparative analysis of the impact of EPU on ES measured by GHG emissions in 19 developed emerging economies. For this analysis, the study employed pooled OLS and quantile regression to scrutinize the insinuations of EPU on GHG emissions across the different panels of developed and emerging economies. Moreover, it also examined these impacts at different quantiles of EPU, GHG, and other variables in the model. The findings reveal that EPU has a significant positive impact on GHG emissions. The quantile regression analysis reinforces these results by demonstrating positive elasticities of GHG emissions in all panels and quantiles. However, the influence of EPU on GHG emissions varies at different quantiles. In the overall panel, the EPU coefficients decrease and become insignificant at higher quantiles, indicating a diminishing impact on GHG emissions. Similarly, for developed economies, the EPU coefficients decline at higher quantiles. Conversely, in emerging economies, the impact of EPU increases up to the 80th quantile but declines at the 90th quantile. Importantly, the EPU coefficients in quantile regression estimates are higher for emerging economies compared to the total panel and developed economies, indicating a stronger GHG emission-increasing effect in these economies. These findings highlight the negative impact of EPU on ES through increased GHG emissions. Therefore, it is crucial to prioritize clarity and stability in policy-making to reduce EPU. Policymakers should focus on implementing clear, transparent, and stable policy-making procedures and standards. Businesses and investors can contribute by providing clear guidance and long-term planning, enabling them to better understand the consequences of policy choices and reducing uncertainty related to economic policy changes. Furthermore, policymakers and governments should encourage openness and information sharing to minimize the uncertainty and unexpected nature of policy decisions. By promoting transparency and facilitating knowledge dissemination, they can foster an environment conducive to sustainable decision-making and reduce the adverse environmental effects associated with policy uncertainty.

The coefficients of agricultural output are negative and significant for the entire panel and emerging economies. In developed economies, the coefficients are negative and significant from the 10th to 25th quantiles, shifting to positive and significant between the 40th and 90th quantiles. It suggests that agricultural output per worker negatively influences developed countries at higher quantiles. To address this, policymakers in developed nations should promote sustainable farming methods such as soil carbon sequestration, reduced animal protein use, and optimized crop management. Conservation initiatives should incentivize carbon sinks, lower methane emissions, and boost RE in the agricultural sector. Livestock and manure management strategies, including improved feed quality and biogas collection, are also essential. Quantifying and reducing emissions from fertilizers, pesticides, and animal manure using nuclear and isotopic methods is crucial for environmental sustainability. Both pooled and quantile regression analyses support the PHH across all panels. The FDI elasticities of GHG emissions are significant. Notably, the FDI elasticity is higher in emerging economies than in the total panel and developed economies, indicating a more substantial impact of FDI on GHG emissions in emerging economies. The quantile regression analysis also reveals higher FDI elasticity values for emerging economies than developed ones. However, these values decrease at higher quantiles for developed and emerging economies. The study provides substantial evidence supporting the notion that FDI significantly affects GHG emissions, aligning with the PHH. To address this, emerging economies should develop policy frameworks that attract low-carbon technology transfers and enhance the environmental performance of businesses. Additionally, attracting FDIs for energy-efficient and low-carbon footprint Greenfield projects is crucial. The governments in host economies should prioritize implementing emission reduction policies and programs. For example, FDI can contribute to ES by promoting RE use, phasing out coal, implementing carbon pricing, and electrifying transportation sectors.

The results indicate that REC significantly negatively impacts GHG emissions across all panel groups. The REC elasticities are higher for emerging economies from the 10th to 60th quantiles than the total panel, suggesting a more significant contribution of REC to GHG emissions reduction in emerging economies within this range. However, from the 70th to 90th quantiles, the coefficients of REC are higher for developed economies, indicating a more vital role in reducing GHG emissions at higher quantiles in developed economies. Policymakers should prioritize efforts to decrease energy output and consumption per unit of GDP, particularly in emerging economies where EPU significantly influences GHG emissions. It can be achieved by implementing laws and regulations that promote the adoption of cleaner and more efficient technologies and supporting RE sources. The findings suggest that REC can help reduce GHG emissions, particularly in developing countries. Governments should encourage using REC in all nations, focusing on emerging economies with the most significant impact. Similarly, efforts should be directed towards boosting REC in developed economies, with a more significant potential to cut GHG emissions. Given the increased economic globalization, international collaboration is essential in dealing with policy uncertainty. Governments should open avenues for international collaboration to address policy uncertainty and ES challenges. Adopting innovative and evidence-based approaches, such as circular economy models that minimize waste and encourage reuse and recycling, can reduce uncertainty and foster sustainable economic growth. Policymakers should prioritize sustainability and avoid conventional models contributing to policy uncertainty.

Current comparative analysis of the linkage between EPU, agriculture output, FDI, and RE provides a foundation for future research. Future research can look into additional variables, such as technical innovation, and trade dynamics, to thoroughly understand the complicated interaction between policy uncertainty, agricultural output, RE, and ES. Furthermore, longitudinal studies can give insights into the dynamics and trends, providing a more in-depth knowledge of the connections under consideration. Longitudinal research can capture the effects of policy changes and technical advances on environmental sustainability in industrialized and emerging economies. The findings may be used to assess the efficacy of current policies and indicate areas for improvement. Future studies would also contribute to the continuing policy debate on environmental sustainability by directing policymakers to develop evidence-based solutions and promoting a continuous feedback loop between research and policy implementation.

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