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Do Environmental Policy Stringency and Renewable Energy Consumption Mutually Promote Each Other in Emerging Economies?

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Abstract

Environmental awareness is one of the main drivers in the fight against climate change and global warming. The importance attached to environmental policies is an indicator of an economy's environmental awareness. Measures taken in environmental policies also affect companies' energy preferences, and it is theoretically argued that stricter environmental policies will promote clean energy sources. This study examines the causal nexus between environmental policy stringency and renewable energy consumption, grounded in the theoretical relationship between stringent environmental policies and clean energy sources. Covering the period 1990-2020, the study analyses the environmental policy stringency index (EPS) and the share of renewable energy consumption (REC) in total energy consumption for 10 selected emerging economies using panel data methods. The causal relationships between the variables are examined using the Dumitrescu-Hurlin (2012) panel causality test. The analyses conducted reveal a bidirectional causal relationship between environmental policy stringency and renewable energy consumption in the selected countries during the relevant period. This indicates that the two variables mutually promote each other. The study's findings provide policymakers across all economies, particularly emerging economies, with important insights on environmental policies and the use of clean energy for sustainable green growth.

Index-words: *Environmental Policy Stringency, Renewable Energy Consumption, Panel Causality Analysis.*

I. Introduction

Climate change refers to long-term changes in typical meteorological conditions and average temperatures. Climate change is one of the biggest ecological and social challenges of this century [1]. As climate change and the problems it causes or is likely to cause are a common threat to humanity, the measures taken or to be taken in this regard must also be implemented on a global scale. Climate change and temperature increases can also be caused by natural factors, but it is now known that human-induced factors are the most significant. Greenhouse gas emissions are the foremost human-induced cause. The unprecedented temperature increase experienced in the late 20th century provides evidence that the greenhouse effect has settled above the level of natural variability in the climate system [2]. The foundations for combating climate change were laid with the United Nations Framework Convention on Climate Change, adopted at the 1992 Rio Summit. The Convention sets an important goal of stabilizing atmospheric greenhouse gas concentrations at safe levels [3].

The 1997 Kyoto Protocol represents a seminal milestone in international climate governance, establishing the inaugural framework for legally binding emission reduction targets specifically tailored for industrialized nations. While the Protocol's primary aim is to slow global warming and climate change, its success in achieving these goals is debatable. Critics argue that the Protocol's impact was constrained by its narrow jurisdictional scope and the absence of substantive commitments from emerging economies, which ultimately hindered a significant reduction in aggregate global greenhouse gas emissions. The Kyoto Protocol fell short of its objective to curtail the upward trajectory of global greenhouse gas emissions, but the efforts of developed countries are considered a good first step. Therefore, the Kyoto Protocol cannot be considered a complete failure [4]. The Kyoto Protocol was replaced by the Paris Agreement, a more comprehensive agreement signed in 2015.

The most fundamental difference between the Paris Agreement, which came into force in 2016, and the

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Kyoto Protocol is that each country sets its own target, and each signatory country sets an emission reduction target for itself. Parties are obliged to update their emission reduction targets every five years [5]. However, there is no enforcement mechanism in the agreement. The agreement expands the normative framework for compliance, demanding stronger compliance commitments from states [6]. Unlike the limited scope of the Kyoto Protocol, the Paris Agreement is highly inclusive as a universal treaty. The regulatory framework mandates that developed countries provide fiscal support to developing counterparts, aimed at underpining mitigation strategies and enhancing the structural capacity to navigate climate-induced impacts through adaptation.

The extent to which global initiatives to combat climate change have been successful to date is a matter of debate. However, measures to address climate change and global warming have also influenced countries' environmental policies. Many countries have made various policies aimed at protecting the environment and climate as their primary goals, and have shaped their economic policies accordingly. Various indicators measure the stance of economies toward environmental policies. One of these is the Environmental Policy Stringency Index (EPS). EPS does not actually measure a country's environmental conditions, air quality, or carbon emissions; it focuses on policies to reduce climate change and air pollution. Published by the OECD, the index shows how strict countries are regarding environmental policies. The Environmental Policy Stringency (EPS) index is constructed by quantifying and aggregating specific policy instruments related to climate change and air pollution. This composite metric operates on a scale from 0 to 6, where ascending values signify an intensification in the rigor of environmental regulatory frameworks [7].

As the EPS index value increases, it implies that environmental policies are becoming stricter. For example, a high EPS index suggests that the cost of polluting the environment has risen and that companies operating in that country are compelled to adopt technologies that protect the environment. This also implies that companies are turning to cleaner energy sources, such as renewable energy. This situation suggests an incentive relationship between the stringency of environmental policies and the adoption of clean energy sources.

According to Porter's hypothesis, strict environmental policies encourage eco-innovation and improve the environmental and financial efficiency of businesses [8]. There is a prevailing belief that stringent environmental measures, such as high carbon taxes and emission limits, will encourage companies to turn to clean energy sources. However, how consistent is this theoretical relationship with reality? When we look at the measures taken to address climate change, the agreements signed for this purpose, and their outcomes, questions arise about whether strict environmental policies are truly effective. This is where the main motivation for this study arises. Does Environmental Policy Stringency encourage clean energy sources? Or does the use of clean energy sources affect the stringency of environmental policies? This study seeks to answer these questions. In this context, the link between Environmental Policy Stringency and renewable energy is examined, and the existence of reciprocal causality relationships between these two variables is investigated for 10 selected emerging economies.

Emerging economies, while trailing developed nations in terms of income, industrialization, and institutional quality, possess significant potential for rapid development. As these countries often experience higher growth rates, they require intensive energy inputs to sustain their economic expansion. Within this framework, integrating renewable energy sources is essential, as the environmental benefits of this transition are significant. These technologies have the potential to considerably reduce the negative impacts of fossil fuel use, decrease emissions, and minimize environmental remediation costs, thereby supporting the development of a cleaner environment [9, p. 209]. However, the extent to which the relationship between stringent environmental policies and clean energy adoption aligns with theoretical expectations in these rapidly growing economies remains an open question. Therefore, this study aims to examine the link between environmental policy stringency and renewable energy in 10 selected emerging economies, seeking to reveal how these nations navigate the trade-offs between rapid industrial growth and the urgent need for sustainable energy transitions.

The study consists of an introduction, a literature review, a data set, methodology, findings, and a

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conclusion. The literature review section discusses empirical studies on the relevant topic and their findings. The data, methodology, and findings section introduces the data set and sample used in the analyses, explains the econometric methods applied, and presents the analysis results. The conclusion section evaluates the findings in light of theory and literature and presents policy implications.

II. Literature review

Environmental policy stringency is linked to numerous economic, political, and environmental factors. Therefore, it is addressed in the literature using various indicators. However, studies on the relationship between EPS and renewable energy, the subject of this study, are quite limited. These studies are mostly conducted for selected groups of countries.

Wolde-Rufael & Weldemeskel [10], one of the few studies to examine environmental policy stringency and renewable energy consumption together, examines the relationship between EPS, renewable energy, and CO2 emissions for BRIICTS countries using panel data techniques. Utilizing the Panel Pooled Mean Group Autoregressive Distributed Lag (PMG-ARDL) estimation technique, this research identifies an inverted U-shaped nexus between Environmental Policy Stringency (EPS) and CO2 emissions. The empirical evidence further reveals that while renewable energy consumption exerts a mitigating effect on CO2 emissions within the BRIICTS bloc, variables such as income levels, real oil prices, and fossil fuel combustion demonstrate a positive relationship with carbon emissions.

In their analysis of Hungary, Poland, the Czech Republic, and Slovakia for the 1993–2012 period, Godawska & Wyrobek [11] employed the Panel Pooled Mean Group Autoregressive Distributed Lag (PMG-ARDL) model to disentangle the short- and long-term dynamics between environmental policy stringency and renewable energy production. The empirical results suggest that, in the long term, environmental policy stringency positively affects both increases in renewable energy production and the replacement of fossil fuels.

Utilizing a non-linear panel QARDL framework, Alsagr [12] investigates the asymmetric impacts of environmental policy stringency on renewable energy investments within the BRICS economies. The empirical results indicate that renewable energy investments exhibit a positive response across nearly all quantiles in the wake of both short- and long-term positive EPS shocks. On the other hand, long-term negative EPS shocks reduce renewable energy investments only at the low and medium quantiles, whereas short-term negative EPS shocks significantly reduce them across many quantiles.

In their analysis of 32 OECD countries spanning the 1990–2019 period, Hassan et al. [13] explore the causal nexus between the revised EPS index, its components, and renewable energy usage. By employing both static (Driscoll-Kraay standard errors and quantile regression) and dynamic (two-step system GMM and forward-orthogonal deviations-GMM) estimation methods, the authors provide evidence that augmenting environmental policy stringency is associated with the promotion of renewable energy sources.

Sohag et al. [14] examine the effectiveness of environmental policies in reducing ecological footprints in OECD countries, considering them alongside innovation and renewable energy sources. Their study, using panel data methods for the period 1990-2018, employs the Cross-Sectional Autoregressive Distributed Lags (CS-ARDL) approach. They conclude that environmental policy in OECD countries significantly reduces ecological footprint through renewable energy and innovation channels. The study also emphasizes that the effectiveness of environmental policy depends on the level of industrialization and the country's biocapacity surplus or deficit.

In another study for OECD countries, Athari [15] examines the effect of environmental policy stringency on renewable energy consumption for the period 2000-2019. Using panel data from 27 OECD countries, the study employed fixed effects and panel quantile estimation methods. The study primarily concludes that EPS has a significant and positive effect on renewable energy consumption, and that stricter green environmental policies in the studied countries encourage renewable energy. The study also emphasizes that EPS reduces the negative impact of global economic policy uncertainty on renewable energy.

In another study, Fatima et al. [16] analyze the relationships between EPS, green investment, and renewable energy use, and their effects on the load capacity factor (LCF) for G11 countries. The study, covering the period 2000-2021, utilizes the Cross-Sectional-Augmented Autoregressive Distributed Lag (CS-ARDL) model and the Common Correlated Effect Mean Group (CCEMG) approach. The authors argue that EPS, green investments, and renewable energy consumption positively influence the load capacity factor.

Dabbous et al. [17] explore the nexus between environmental policy stringency, public environmental consciousness, and energy resilience within the context of 32 OECD economies. The research employs a Principal Component Analysis framework to develop a composite index for energy resilience, which encompasses the critical dimensions of renewable energy, energy efficiency, and access to energy resources. Covering the period 2004-2020, the study primarily emphasizes significant and positive relationships between strict environmental policies, environmental awareness, and energy resilience.

While the nexus between environmental policy stringency and various energy indicators, such as total energy consumption, efficiency, transition, and security, has been extensively documented, existing literature remains fragmented regarding the specific relationship between environmental policy stringency and renewable energy consumption. Empirical evidence concerning this relationship within the context of emerging economies is notably scarce. This study addresses this critical research gap by providing a targeted analysis of ten selected emerging economies. By offering a rigorous econometric examination of the relationship between environmental policy stringency and renewable energy consumption in these emerging economies, this research departs significantly from existing studies and contributes a distinct and original perspective to the energy economics literature. The following sections provide a detailed examination of the data set, methodological framework, empirical analyses, and the resulting findings.

III. Data, Methodology, & Findings

This study investigates the causal linkages between environmental policy stringency and renewable energy consumption across 10[1] selected emerging economies for the period 1990-2020. Detailed descriptions of the variables and their respective data sources are presented in Table 1. The data were utilized in their original form without any transformations. The sample was drawn from emerging markets, with countries excluded based on data unavailability, to ensure a balanced and robust analysis.

Table 1: Dataset and sources.

Variable	Environmental Policy Stringency (EPS)	Renewable Energy Consumption (REC)
Definition	Environmental Policy Stringency Index	Renewable energy consumption (% of total final energy consumption)
Source	OECD	Worldbank

There are various methods for examining causal relationships between variables in panel data analysis. However, the first step in determining the appropriate method is to examine the stationarity of the series and whether the slope coefficients are homogeneous.

In the preliminary stage of the empirical analysis, identifying the presence of cross-sectional dependence is a prerequisite for selecting the appropriate panel unit root test. To this end, this study employs the Breusch-Pagan [18] Lagrange Multiplier (LM) test to examine the null hypothesis of cross-sectional independence among the error terms. The selection of this test is dictated by the dataset's dimensions; specifically, the Breusch-Pagan LM is appropriate for panels where the time dimension (T) exceeds the number of cross-sectional units (N). The standard Breusch-Pagan LM test is not suitable to provide a robust measure for cross-sectional dependence in short panels characterized by a large N and a limited T [19]. The test statistic is calculated as follows:

$$\mathrm{LM} = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T_{ij}\hat{\rho}_{ij}^{2} \rightarrow \chi^2 \frac{N(N-1)}{2} \quad (1)$$

[1] Brazil, China, India, Indonesia, Hungary, Mexico, Poland, Russian Federation, South Africa, Türkiye.

In equation 1, $\hat{\rho}_{ij}^2$ i ve j denotes the correlation coefficient between the residuals of the units. While the Breusch-Pagan LM test is robust for panels with a limited number of units, the test may be inadequate when the cross-sections are large.

Table 2: Tests of cross-sectional dependence.

	d.f.	EPS	REC
Breusch-Pagan LM	45	834.3031 (0.0000)	810.3102 (0.0000)

The results derived from the cross-sectional dependency tests indicate the presence of cross-sectional dependence among the variables. Accordingly, this study employs the MADF (Multivariate Augmented Dickey-Fuller) panel unit root test, a second-generation procedure specifically designed to account for such dependencies. Developed by Taylor & Sarno [20], the MADF test constitutes a multivariate extension of the standard univariate ADF framework. The estimation process is predicated on the following N×1 stochastic vector:

$$q_{it} = \mu_i + \sum_{j=1}^{k} \rho_{ij} q_{it-j} + u_{it} \tag{2}$$

In equation 2, u_{it} is assumed to follow an independent normal distribution, expressed as $u_t \sim IN(0, \Lambda)$. Within the framework of the single-equation ADF test, the following null hypothesis is tested individually across N distinct equations:

$$H_0 : \sum_{j=1}^{k} \rho_{ij} - 1 = 0 \tag{3}$$

The ADF test proves insufficient when cross-sectional dependence is present. Consequently, Taylor & Sarno [20] employed an alternative approach to accommodate this dependence, establishing the following null hypothesis for N equations:

$$H_0 : \sum_{j=1}^{k} \rho_{ij} - 1 = 0, \quad \forall i = 1, \ldots, N \tag{4}$$

The null hypothesis is evaluated using the MADF test statistic, which functions as a Wald-type test. This approach utilizes the Seemingly Unrelated Regression (SUR) estimator to account for the simultaneous covariance matrices of the error terms [20]. A prerequisite for the MADF test is that the number of cross-sections (N) must be smaller than the time periods (T); this condition is strictly met by the current dataset. The findings of this analysis are detailed in Table 3.

Table 3: MADF panel unit root test.

	Lags	MADF	Approx (%5)
EPS	2	35.071	27.491
REC	2	32.055	27.491

Note: The optimal lag length was selected based on the AIC

The Wald statistic obtained from the MADF test was found to be greater than the critical value at the 5% significance level. According to this result, the null hypothesis, which argues that all of the examined series contain a unit root, is rejected, and it is concluded that the series are I(0).

In addition to cross-sectional dependency, the models must be evaluated for homogeneity. To this end, this section employs the delta (Δ) test introduced by Pesaran & Yamagata [21] to examine the slope coefficients' homogeneity. The procedure utilizes two distinct statistics, Δ and Δ_{adj}, to account for both large and small sample sizes, testing the null hypothesis that the slope coefficients are homogeneous:

$$\tilde{\Delta} = \sqrt{N}\left(\frac{N^{-1}\tilde{S} - k}{\sqrt{2k}}\right) \tag{5}$$

$$\tilde{\Delta}_{adj} = \sqrt{N}\left(\frac{N^{-1}\tilde{S} - E(\tilde{Z}_{iT})}{\sqrt{var(\tilde{Z}_{iT})}}\right) \tag{6}$$

In these expressions, "S" denotes the Swamy test statistic, "N" represents the cross-sectional dimension of the panel, and "k" signifies the number of independent variables, while "E" refers to the expected value. The results of the Pesaran & Yamagata homogeneity test are presented in Table 4. Based on the test statistics, the null hypothesis of homogeneity is rejected, indicating that the slope coefficients are heterogeneous across the panel.

Table 4: Pesaran & Yamagata (2008) homogeneity test.

	Stat.	Prob.
Δ	31.488	0.0000
Δ_{adj}	33.132	0.0000

Up to this stage, it is concluded that the series are I(0) and the slope coefficients are heterogeneous. In this case, the causal relationships between the variables can be examined with the Dimitrescu-Hurlin Panel Causality test. The Dimitrescu-Hurlin panel causality test is a suitable method for heterogeneous slope coefficients and gives effective results when T > N or N > T. The causality test model in which stationary y and x values are defined is given below [22, p. 1456]:

$$Y_{i,t} = a_i + \sum_{k=1}^{K} \gamma_i^{(k)} Y_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(k)} X_{i,t-k} + \varepsilon_{i,t} \quad (7)$$

The model evaluates the causal relationship between variables x and y using an F-test framework. The rejection of the null hypothesis signifies a statistically significant causal effect from x to y. Furthermore, other directions of causality can be examined by transposing the dependent and independent variables in the estimation. The estimation results are shown in Table 5.

Table 5: Dumitrescu - Hurlin panel causality test results.

	Lag	W-Stat.	Zbar-Stat.	Prob.
EPS ↛ REC	1	6.19579	9.96210	0.0000
	2	4.49357	3.05866	0.0022
REC ↛ EPS	1	3.51016	4.73231	0.0000
	2	5.01598	3.74986	0.0002

To ensure the robustness and consistency of the empirical findings, the Dumitrescu-Hurlin panel causality test was conducted using both one and two lag lengths. The estimation results consistently reveal a significant bidirectional causal nexus between environmental policy stringency and renewable energy consumption for the selected 10 emerging economies.

IV. Conclusion

It is difficult to say how successful the signed global agreements have been in combating climate change and global warming. This is because the absence of economies with high production levels from these agreements, or their failure to take action despite being included, indicates that they are not keen on strict environmental policies. So, if economies adopt stringent environmental measures, could this be an incentive in the fight against climate change and global warming? Starting from this question, this study examines the causal links between the stringency of environmental policies and clean energy use in 10 selected emerging economies. The study tests the relationship between the EPS index and REC using panel causality analysis. The analysis results reveal a bidirectional causal relationship between the variables in the selected countries during the relevant period. The findings indicate that environmental policy stringency and energy consumption mutually promote each other in these economies.

The countries covered by the study have relatively high growth rates, high levels of production, and, consequently, high energy needs. It is therefore important to correctly interpret the bidirectional causality relationship determined for these countries. Why is there a bidirectional causality between environmental policy rigidity and renewable energy consumption in these countries? This question must be answered separately in two ways. Firstly, strict environmental policies involve certain mandatory policies. Therefore, companies may be inclined to turn to clean energy sources both to comply with these mandatory policies and to avoid the costs they would otherwise incur. The same applies to investments coming into the country through direct foreign investment. Strict environmental policies in the country can attract green investments and clean energy sources to the country.

The causal link from renewable energy consumption to environmental policy stringency can be evaluated from several perspectives. In economies with high renewable energy consumption, production is also largely based on clean energy sources. Therefore, the economy possesses the necessary knowledge and infrastructure in this area. This situation can encourage policymakers to adopt stricter environmental policies by demonstrating the feasibility of green technology. On the other hand, it may also be a necessity. Economic and geographic characteristics may steer a country towards a green economy, or the economy may lack the financial capacity to cover the costs of alternative technologies. All of these factors can transform clean energy from a choice into a necessity.

When evaluating the study findings, the effects of global agreements should not be overlooked. The countries included in the study are signatory states to global agreements aimed at combating climate change and global warming. Therefore, it is possible to emphasize that commitments to ensure international harmony also affect this situation, and that this is one of the explanations for the causal relationship between the variables. From this perspective, the findings obtained for the selected developing countries appear to be consistent with the Nationally Determined Contributions (NDC) mechanism of the Paris Agreement. The results suggest that such binding agreements can be instrumental in facilitating access to clean energy sources for these nations. Naturally, for this process to become sustainable, it is imperative that all countries, particularly those in the developing world, demonstrate a genuine commitment to fulfilling their pledged obligations and develop coherent policies aligned with these objectives.

The countries studied are high-production-capacity economies. Therefore, their energy choices in production processes are extremely important. The findings confirm that strict environmental policies and renewable energy consumption are mutually reinforcing indicators. The findings imply that a cleaner production process and green growth are possible if planned. However, this is only possible with cooperation and a commitment to action among these countries. In particular, achieving green growth in countries with high production levels, such as those studied, can encourage all other economies. Of course, a global will is needed here. Furthermore, it is essential that international climate accords are designed to bridge the financing gap faced by emerging economies. Strengthening coordination between developed and developing nations is essential to ensure a shared pathway toward an environmentally sustainable future.

Finally, it should be acknowledged that, inherent to the nature of academic inquiry, this study possesses certain limitations. Focusing on 10 emerging economies, the research investigates the specified relationship using appropriate panel data and econometric techniques, contingent on data availability. The analysis primarily centers on the bidirectional causality between the two variables, which is modeled with two lags; consequently, the findings must be interpreted within the parameters of these methodological choices. Future research may expand this scope by incorporating additional variables or by employing alternative econometric frameworks, such as the Panel Vector Autoregression (PVAR) model, to further test the robustness of these relationships. Furthermore, it is essential to emphasize that the heterogeneous nature of emerging economies implies that the EPS-REC nexus may vary significantly depending on countries' income levels, energy structures, or institutional quality. Future research could explicitly explore these heterogeneities by employing threshold regression models or interactive panel frameworks to determine how distinct structural characteristics condition the relationship between environmental policy and renewable energy consumption.

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