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RETRACTED: A Path Towards Green Revolution: How do Environmental Technologies, Political Risk, and Environmental Taxes Influence Green Energy Consumption?

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RETRACTED

Enhancing green energy consumption is the most important strategy to achieve environmental goals and control global temperature rise. Unquestionably, political intuitions make decisions for developing environmental technologies and imposing environmental taxes for phasing out fossil fuels and achieving energy transition. Therefore, this study explores the role of environmental technologies, political risk, and environmental taxes in green energy consumption considering the potential impacts of population density and economic growth in G7 countries. Second-generation tests are applied for analyzing the long-run equilibrium connection and stationarity features. Finally, the CuP-FM and CuP-BC estimators are applied for assessing long-run linkage and Dumitrescu-Hurlin causal test is applied to reveal causal flow among variables. The estimates uncovered that enhancing environmental technologies and environmental taxes upsurges the consumption of green energy. Reducing political risk in G7 countries also boosts green energy consumption. Economic growth is evidenced to stimulate the consumption of green energy, while population density limits the consumption of green energy. Moreover, environmental technologies and political risk Granger cause green energy utilization, while a feedback relationship exists between environmental taxes and green energy usage. Based on the results, this study suggests that G7 countries should allocate more funds to accelerate innovation in environmental technologies and, at the same time, reduce the political risk to boost green energy consumption.

Keywords: environmental technologies, green energy consumption, economic growth, environmental taxes, G7 countries

INTRODUCTION

Environmental deterioration instigates global warming by interrupting the carbon cycle, and thus, environmental institutions and governments across the world strive to control environmental deterioration (Ahmed et al., 2021a; Awosusi et al., 2022). Scholars have identified energy consumption, mainly gas, oil, and coal, as the leading contributor to environmental deterioration and global warming (Wang et al., 2019; Alvarado et al., 2021; Murshed et al., 2021). Although the negative environmental consequences of energy usage are well documented, such adverse effects do not undermine the importance of energy since energy is a major requirement for sustaining economic activities and accomplishing economic progress (Kanat et al., 2021; Oláh et al., 2021; Štreimikienė, 2021; Can et al., 2022).

The world has apprehended that achieving sustainable growth entails upgrading the energy mix of nations. In this context, reducing fossil fuels combustion and eventually phasing out their usage will be a key strategy to pursue sustainable growth (Mohammed et al., 2021; Xue et al., 2022). In this regard, the Sustainable Development Goal (SDG) 7 sets the target for ensuring global access to sustainable clean energy by 2030 for sustainable growth (UN, 2021). Undeniably, enhancing the supply of sustainable green energy and driving its consumption requires expanding the clean energy infrastructure, which needs technological upgrading (Krzymowski, 2020). Environmental technologies can curb the overall consumption of energy by boosting energy efficiency, which can ultimately decrease the adverse impacts of energy (Hussain et al., 2020; Oláh et al., 2020; Ahmad et al., 2022). In addition, environmental technologies can drive the production of sustainable energy, including wind, bioenergy, solar, geothermal, etc., which will enhance the share of green energy, reduce energy insecurity, and stimulate sustainable growth (Széles et al., 2019; Ahmad et al., 2021b; Buturache and Stancu, 2021). Thus, enhancing environmental technologies can be a practical and effective strategy for realizing energy transition.

Alongside this strategy, environmental taxes levied on energy-related emissions are among critical policy instruments for pollution control, which can discourage fossil fuel combustion and expand green energy consumption. Developed nations introduced environmental taxes in 1980, and since then, various reforms were also introduced to maximize the benefits of such taxes (Shahzad, 2020). Environmental tax is a useful strategy to reduce the economic feasibility of fossil fuels since such tax upsurges the prices of fossil energy making them more expensive for consumers as well as producers. Consequently, individuals and businesses are encouraged to adopt modern technologies and alternative fuels, which in turn reduce emissions (Aydin and Esen, 2018; Sabishchenko et al., 2020).

Environmental taxes are among the critical fiscal policy instruments which can influence energy structure and climate targets. Also, the role of environmental technologies cannot be ignored in energy transition strategies. Nevertheless, the effectiveness of both these factors depends on the performance of political institutions, which formulate strategies for energy transition and pollution control. Poor institutional quality with high political risk can lead to corruption and bad governance, which can hinder the implementation of climate-related policies. Producing environmental technologies and making strategies to boost environmental quality are dependent on the quality of institutions in a country (Dasgupta and De Cian, 2018). An effective intuitional framework can ensure persistent growth with less environmental pollution (Rizk and Slimane, 2018).

According to Shahzad (2020), empirical evidence regarding the effectiveness of environmental taxes in energy transition and pollution control is meager. Ahmad et al. (2021c) suggest that past investigations on political institutions' role in pollution control present inconclusive results. This study uncovers the impacts of environmental taxes, environmental technologies, and political risk on green energy utilization in G7 nations due to several reasons. Consumption of energy is closely connected with economic progress, and in this context, G7 countries make a substantial 46% contribution to the total global GDP (Ahmed et al., 2020). These seven nations utilize almost 30% of the total global energy and generate approximately 25% of energy-related emissions. In addition, in G7, green energy constitutes almost 20% of total electricity generation in 2020 (IEA, 2021). The highly developed group of seven strives to raise green energy consumption to limit environmental pollution and boost sustainable growth. Thus, this study will determine the effectiveness of environmental taxes and environmental technologies in green energy utilization by considering the role of political risk.

Unlike previous studies, this research unfolds the influence of environmental taxes, environmental technologies, and political risk on green energy utilization. Previous panel studies have not explored environmental taxes, environmental technologies, political risk, and green energy nexus in G7. In doing so, this study employed the CuP-FM and CuP-BC estimation techniques to estimate the long-run relationship among variables. These methods can tackle the common panel data issues like cross-sectional dependence, residual correlation, heteroscedasticity, fractional integration, and endogeneity. In addition to the long-run investigation, causal associations among selected variables were also investigated.

LITERATURE REVIEW

There is consensus in the economics literature that the development and use of green energy can be a viable way of curtailing environmental degradation. Although green energy is rapidly increasing worldwide, the share in the primary energy mix is still minimal. Technological progress is believed to enhance green energy use, but their association has scarcely been investigated and mostly leans towards their positive side. For instance, Alam and Murad (2020) studied the linkage between technological progress, economic growth, trade openness, and green energy use in OECD economies from 1970 to 2012. Their findings revealed that technological progress, economic growth and trade openness significantly influence green energy use in the long run across OECD countries. However, the short-run results show mixed results. The author concluded that the short-term dynamics vary due to differences in trade openness and technological progress in OECD countries. Likewise, Khan et al. (2020) studied the impact of environmental technologies on total and disaggregated energy use in G-7 countries from 1995 to 2017. Their results revealed that environmental innovation significantly and negatively influences the total energy use while positively related to green energy use in G-7 countries. Vural (2021) also reported the positive impact of technological innovation and economic growth on green energy in selected Latin American countries.

In contrast, Bamati and Raoofi (2020) investigated the impact of technological progress on green energy by using the developing and developed country's data. Their results unveiled that technological progress and economic growth mainly drive green energy in developed countries, while technological progress cannot explain green energy dynamics in developing countries. Khan et al. (2021) concluded that technological progress not only enhances emissions and total energy use but also negatively impacts renewable energy consumption in 69 Belt and Road Initiative countries.

Besides that, political risk factors have gained substantial research interest from the perceptive of green energy consumption. Brunnschweiler (2010) highlighted that green energy projects benefit from effective governance, sound regulatory framework and overall political stability like other investment projects. Moreover, some studies found that political instability and corruption influence environmental policies and green energy investments (Fredriksson and Svensson, 2003; Junxia, 2019; Uzar, 2020). Mahjabeen et al. (2020) suggested institutional stability and technological advancement for the green energy transition and achieving SDGs. Su et al. (2021) studied the impact of political risk and environmental technologies on green energy use in OECD countries from 1990 to 2018. Their outcome disclosed that political risk and environmental technologies significantly stimulate green energy use in OECD countries.

Studies related to environmental taxes mainly focus on their role in carbon emissions mitigations (Shi et al., 2019; Shahzad, 2020; Doğan et al., 2022; Rafique et al., 2022; Yunzhao, 2022), while little attention has been paid to its impact on green energy use. Acemoglu et al. (2016) suggested that environmental regulation can boost the green energy sector growth and lower emission in developed countries, which ultimately leads to the accomplishment of SDGs. Bashir et al. (2021) studied the impact of environmental taxes and regulations on green energy use in 29 OECD countries from 1996 to 2018. They concluded that environmental regulations impede green energy use in these economies. They further propose that OECD countries should focus on implementing their environmental strategies and, at the same time, promoting environmental technologies will be a viable option to promote the green energy industry. Similarly, Carfora et al. (2021) concluded that the environmental tax burden negatively impacts the green energy investment in EU countries.

MATERIAL AND METHODS

Data Specification

This article uses the panel time-series data from 1994 to 2018 to investigate the impact of environmental technologies, political risk, and environmental taxes on green energy consumption in G7 countries. The dependent variable is the green energy consumption (per capita kWh), and the data is obtained from Ritchie and Roser (2020). The explanatory variables include the environmental technologies (patents related to environmental-related technologies) retrieved from the OECD database OECD (2022). Political risk ranking index (based on 12 indicators) accessed from ICRG (2021). Economic growth (per capita constant 2010$) and population density (People per square kilometer square of land) are obtained from WDI (2021). Data on environmental taxes (environmentally related tax revenue) are obtained from the OECD (2022). This study constructed the empirical model as follows:

$$LGR_{it} = \beta_1 LERT_{it} + \beta_2 LPR_{it} + \beta_3 LETA_{it} + \beta_4 LGDP_{it} + \beta_5 LPD_{it} + \varepsilon_{it} \quad (1)$$

Where in **Eq. 1** t is the time dimension, and i represent the cross-sections for OECD economies. The description of the study variables is given in **Table 1**.

Estimation Methods

In recent literature, the analysis of panel data is initiated by performing cross-sectional dependence (CD) estimation because, in recent decades, nations are closely knotted in various trade agreements, and assumptions like cross-sectional independence are far from reality. To reveal CD in G7 data, this work utilized one of the popular methods (CD test) introduced by Pesaran (2004). The test's equation is articulated below.

$$CTD = \sqrt{\frac{2d}{p(p-1)}}\left(\sum_{i=1}^{p-1}\sum_{j=i+1}^{p}\hat{A}_{ij}\right) \quad (2)$$

In **Eq. 2**, CTD refers to the CD test, p indicates sample size, d depicts time and $\hat{A}_{ij}$ signifies pair-wise serial correlation. In addition, the G7 panel has diverse features in terms of variables, such as ERT, GE, PR, ET, and GDP; therefore, overlooking the possibility of heterogeneity may produce misleading conclusions. Hence, to reveal the heterogeneity in the selected panel, the popular test of Pesaran and Yamagata (2008) is applied. This method computes the adjusted delta ($\tilde{\Delta}_{DAD}$) statistics by using the following equation.

$$\tilde{\Delta}_{DAD} = (n)^{\frac{1}{2}}\left(\frac{2K(t-K-1)}{t+1}\right)^{-\frac{1}{2}}\left(\frac{1}{n}\tilde{z} - K\right) \quad (3)$$

In addition, the delta ($\tilde{\Delta}_D$) stat is produced through the following equation.

$$\tilde{\Delta}_D = (n)^{\frac{1}{2}}(2K)^{-\frac{1}{2}}\left(\frac{1}{n}\tilde{z} - K\right) \quad (4)$$

The null hypothesis for both statistics describes slope homogeneity, and thus, heterogeneity of slope entails its rejection. This analysis is meant to assist in choosing the most suitable estimators for further investigation. In this context, tracing independence and homogeneity of slope parameters requires adopting the first-generation tests; however, this was not the case in our analysis. Thus, this work made use of the second-generation techniques.

TABLE 1 | Variables, data source, and measurement.

Variable	Symbol	Measurement	Source
Green energy	LGR	Green energy is measured by Renewable energy consumption per capita (kWh)	Ritchie and Roser, (2020)
Environmental technologies	LERT	Environmental related technologies patents	OECD, (2022)
Political risk	LPR	Political risk rating index based on 12 indicators	ICRG, (2021)
Environmental taxes	LETA	Environmentally related tax revenue	OECD, (2022)
Economic growth	LGDP	Economic growth per capita (constant 2010$)	WDI, (2021)
Population density	LPD	People per square kilometer (km^2) of land	WDI, (2021)

The investigation for apprehending the order of integration is performed by utilizing the CADF and CIPS tests. These two tests familiarized by Pesaran (2007) are applied considering the rejection of homogeneity and independence in the previous tests.

$$\Delta m_{i,t} = \alpha_i + \varphi_i m_{i,t-1} + \varphi_i \overline{CZ}_{t-1} + \sum_{l=0}^{p} \varphi_{il} \Delta \overline{CZ}_{t-1} + \sum_{l=0}^{p} \varphi_{il} \Delta m_{i,t-1} + \mu_{it} \quad (5)$$

Where α symbolizes the intercept, m shows the calculated variable, p symbolizes lag length, and $\overline{CZ}_{t-1}$& $\Delta\overline{CZ}_{t-1}$ describes the cross-sectional average. The $\overline{CZ}_{t-1}$& $\Delta\overline{CZ}_{t-1}$ presented in **Eq. 5** is utilized further for computing the CIPS stat. These renowned test are considered robust in the absence of homogeneity and independence.

Afterward, the long-run equilibrium connection is estimated by using the Westerlund (2008) approach that produces a group stat (DH_g) along with a panel stat (DH_p) through the use of the Durbin–Hausman principle. The investigation of cointegration under this test requires a non-stationary response variable along with stationary or non-stationary regressors. This test is popular for datasets with independence and heterogeneity concerns.

Bai et al. (2009) familiarized the CuP-FM & BC tests with the striking features of handling autocorrelation, CSD, endogeneity, and mixed integration levels. Consequently, scholars in environmental economies literature prefer these two tests over many other available tests. As the dataset of G7 exhibits long-run equilibrium association, the coefficients for the long-run are computed by using these two tests. Additionally, the FMOLS test is also utilized owing to the fact that it counters issues like autocorrelation and endogeneity in panel datasets using the lags and leads options.

In the end, the analysis for calculating the long-run elasticities is aided with Granger causality analysis by using the test of Dumitrescu and Hurlin (2012). The long-run estimation alone is not enough for practical policy suggestions. Thus, the knowledge of the direction of causal flow is important to suggest policy implications.

RESULTS AND DISCUSSION

This study uses the CD test proposed by Pesaran (2004) to evaluate the independence or dependence among selected variables in OECD countries. The result is shown in **Table 2**, which supports the existence of a cross-section within our dataset.

TABLE 2 | CD test results.

	Stat	Prob	Abs (Corr)
LGR	8.794***	0.000	0.665
LERT	21.556***	0.000	0.941
LPR	8.380***	0.000	0.370
LETA	8.008***	0.000	0.494
LGDP	17.979***	0.000	0.785
LPD	12.361***	0.000	0.630

**** <1%.*

TABLE 3 | slope heterogeneity test results.

Test	Value	*p*-Value
$\tilde{\Delta}$	9.972***	0.000
$\tilde{\Delta}_{adjusted}$	12.093***	0.000

**** <1%.*

TABLE 4 | Unit root test results.

Variable	CIPS		CADF	
	Level	First-difference	Level	First-difference
LGE	−1.935	−5.365***	−1.466	−4.073***
LERT	−3.616***	−4.685***	−3.655***	−3.844***
LPR	−2.949***	−4.935***	−1.892	−3.288***
LETA	−1.194	−4.051***	−1.386	−2.581**
LGDP	−1.300	−2.942***	−1.682	−3.641***
LPD	−1.197	−3.520***	−1.507	−3.730***

**** <1%, **<5%.*

Considering the issue of slope homogeneity, this study used Pesaran and Yamagata (2008) estimation method. The results in **Table 3** show that the model has a heterogeneous slope and ignoring this can affect the consistency of the estimator.

The results of CIPS in **Table 4** show that data of environmental technologies and political risk have unit root problems at the level, while green energy, environmental taxes, economic growth, and population density are significant at first difference. The results from CADF indicate that only environmental technologies suffer from stationarity issues at the level, but all the variables show stationarity at first difference.

The results from the Westerlund (2008) panel cointegration test in **Table 5** indicate that the study variables have a long-run equilibrium relationship, which is evident from of DH_g and DH_p

TABLE 5 | Westerlund (2008) panel cointegration test.

	Value	*p*-Value
DH_g	−2.045**	0.022
DH_P	−1.590*	0.056

** <5%, *<10%.

TABLE 6 | Long-run estimation results.

Variables	CuP-FM		CuP-BC	
	Coefficients	T Stats	Coefficients	T Stats
LERT	0.012***	5.083	0.011***	5.144
LPR	0.008***	3.678	0.009***	3.867
LETA	0.024***	9.686	0.022***	9.516
LGDP	0.050***	20.456	0.052***	21.183
LPD	−0.050***	−20.345	−0.049***	−20.739

*** <1%.

values. This enables us to estimate the long-run cointegration relationship.

Table 6 represents the CuP-FM and CuP-BC results, indicating that the coefficient value of environmental technologies is statistically significant and positive at a 1% significance level. This indicates that environmental technologies increase green energy consumption in G7 countries. The findings portray that the environmental technologies support the renewable energy transition. The results can be justified on the ground that G7 countries are among the high-income countries and the leading player in innovation related to environmental technologies. The result of our study coincides with Alam and Murad (2020) for OECD and Vural (2021) for selected Latin American countries but opposes the findings of Khan et al. (2021), who concluded that innovation leads to impeding green energy in BRI countries.

The results further indicate that the improvement of the political risk rating index leads to enhance green energy consumption in G7 countries. These results indicate that green energy consumption increases due to investment profile upgradation, socio-economic, maintaining democratic accountability, and most importantly, the governance stability conditions in G7 countries. These factors positively contribute to boosting green energy consumption. The result of our study coincides with Mahjabeen et al. (2020), and Su et al. (2021).

On the other hand, the coefficient value of environmental taxes is statistically significant and positive at a 1% significance level. This implies that increases in environmental taxes boost the green energy consumption in G7 countries. These results are justifiable because environmental taxation discourages fossil fuel combustion and encourages individuals and businesses to adopt energy-efficient technologies and expand green energy consumption in G7 countries. Many economists agree that environmental tax is a key tool for fighting climate change. Environmental taxes discourage anti-ecological behavior, internalize the negative externalities, motivate companies to innovate technologies, promote energy-saving, and expand the use of green energy sources. Our results coincide with Acemoglu et al. (2016), who concluded that environmental regulation and taxes could boost green energy sector growth and curtail environmental degradation. However, our results are similar to the findings of Bashir et al. (2021), and Carfora et al. (2021), who found that environmental tax not only impedes green energy consumption but also negatively impacts green energy investment.

The results further unveiled that the coefficient value of economic growth is statistically significant and positive at a 1% significance level. This implies that an increase in GDP increases the green energy use in G7 countries. Since these economies are high-income countries, they can allocate more financial resources for green energy projects. Hamburger and Harangozó (2018) highlighted that high-income countries could offer more opportunities to enhance green energy than low-income countries. Burke (2010) also disclosed that countries move toward green energy sources with the increase in their income level. Our results oppose the findings of Godawska (2021), who concluded that economic growth adversely affects green energy production in Visegrad countries.

The coefficient value of population density is statistically significant and negative at a 1% significance level. The transformation from fossil fuel to green energy is linked to the availability of land and population density. However, the land use aspects differ in G7 countries. For instance, Japan has a high population density per square kilometer of land with 347.13, following the United Kingdon with 274.71 people per square kilometer. Canada has large land with a low density of 4.13 people per square kilometer, but the challenges vary greatly, like the sun does not always shine, and the wind does not always blow.

TABLE 7 | Robustness test - FMOLS.

Statistic	Coefficient	Standard error	T-Value	*p*-Value
LERT	1.003***	0.034	29.039	0.000
LPR	0.077***	0.023	3.392	0.000
LETA	1.805***	0.017	103.273	0.000
LGDP	3.669***	0.035	103.374	0.000
LPD	−4.232***	0.006	−635.909	0.000
R-squared	0.912			
Adjusted R-squared	0.905			

*** <1%.

In order to reconfirm the results of CuP-FM and CuP-BC, this study adopted the FMOLS method, and the results are shown in **Table 7**. The results validate the earlier findings as environmental technologies, political risk, environmental tax, and economic growth have a positive impact on green energy consumption, while population density negatively impacts green energy consumption in G7 countries.

This study employed the panel Granger causality test to examine the causal flow between variables. The findings shown in **Table 8** indicate the unidirectional causality from environmental technologies and political risk to green energy. In contrast, bidirectional causality exists between environmental taxes and green energy use. Economic growth granger causes

TABLE 8 | Dumitrescu-Hurlin panel causality tests.

Null hypothesis	W-Stat	Zbar-Stat	Prob	Conclusion
LNET does not homogeneously cause LGE	4.023***	4.553	0.000	LNET→LGE
LGE does not homogeneously cause LNET	7.067	1.335	0.181	
LPR does not homogeneously cause LGE	2.681**	2.459	0.014	LPR→LGE
LGE does not homogeneously cause LPR	1.590	0.757	0.449	
LETA does not homogeneously cause LGE	4.106***	4.683	0.000	LETA↔LGE
LGE does not homogeneously cause LETA	2.706**	2.498	0.013	
LGDP does not homogeneously cause LGE	2.587**	2.313	0.021	LGDP↔LGE
LGE does not homogeneously cause LGDP	2.655**	2.418	0.016	
LPD does not homogeneously cause LGE	4.702***	5.614	0.000	LPD→LGE
LRE does not homogeneously cause LPD	2.067	−0.189	0.849	

**** <1%, **<5%.*

green energy use and the other way round. Population density granger causes green energy use but not the other way round.

CONCLUSION AND POLICY IMPLICATIONS

This study investigates the impact of environmental technologies, political risk, and environmental taxes on green energy consumption, considering the potential impacts of population density and economic growth in G7 countries from 1994 to 2018. This study employed second-generation tests for analyzing the long-run equilibrium connection and stationarity features. The findings from CuP-FM and CuP-BC unveiled that environmental technologies and environmental taxes promote green energy consumption in G7 countries. The improvement in the political risk index and economic growth stimulates green energy consumption, while population density negatively affects the green energy use in these countries. The panel causality test indicates the unidirectional causality from environmental technologies, political risk, and population density to green energy use. Environmental taxes and economic growth have bidirectional causality with green energy use.

Our results have substantial policy implications for the G7 countries in terms of green energy transition and environmental sustainability policies. Our findings conclude that raising innovation in environmental technologies boosts renewable energy use. Thus, G7 countries should allocate more financial resources to research and development of environmentally friendly technologies. The government should provide subsidies for environmental innovation and discourage fossil fuel usage. The policymakers should provide easy access to credit at a lower rate to businesses engaged in research and development activities. At the same time, they should facilitate industries to switch from traditional to eco-friendly technologies and motivate them to use green energy rather than fossil fuel. The political risk rating index positively impacts green energy use in G7 countries. Thus the policymaker should further promote the investment profile up-gradation, and improve democratic accountability and governance to boost green energy consumption in G7 countries.

This study is limited to the G7 countries and a limited number of variables are considered for a short period of 1994–2018. In future investigations, one may conduct similar studies in developing countries by introducing the role of fiscal decentralization and human capital.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

GP: Conceptualization, methodology, data collection, empirical analysis, writing original draft. FM: Writing—review, and editing, Supervision. ZA: Conceptualization, writing original draft. JO: writing—review, and editing, Funding acquisition. EH: Writing—review, and editing.

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