Politická ekonomie
2024, Volume 72 (2), Special Issue:
Achieving Energy Transition and Sustainable Development:
The Roles of Political Risk and Energy Technology Investments

PRAGUE UNIVERSITY OF ECONOMICS AND BUSINESS

Understanding the Dynamics of Political Economy in Relation to Energy Transition for G7 Economies

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Abstract

This research covers the literature gap by investigating the factors of economic expansion (*GDP*), total natural resources (*TNRNT*), political risk index (*PRI*) and technological innovation (*TI*) and their impact on the renewable electricity output (*REOT*) in the G7 economies, covering the period 1990–2022. The research utilizes novel MMQREG as the primary method, while BSQR is a non-parametric robustness check method. A pairwise Dumitrescu–Hurlin causality test is employed to find out the causal connection between variables. The diagnostic outcomes show that the modelled variables are static after the first difference while long-run equilibrium is also present. Moreover, the outcomes suggest that *GDP* negatively influences *REOT* across quantiles while *TNRNT* and *PRI* stimulate the use of *REOT* in G7 economies across quantiles. Moreover, *TI* positively influences *REOT* but is inconclusive across quantiles. The robustness check analysis provides similar and valid outcomes. Lowering political risk is also considered important for energy transition in terms of cleaner energy.

Keywords: GDP, total natural resources, political risk index, technological innovation, MMQREG, G7 economies

JEL Classification: O13, O38, Q56

Citation: Qiu, Y, Yan, Y, Badeeb, R. A., Khan, Z., Ageli, M. M.: Understanding the Dynamics of Political Economy in Relation to Energy Transition for G7 Economies. *Politická ekonomie,* 72 (2), Special Issue, 255–277, https://doi.org/10.18267/j.polek.1423

1. Introduction

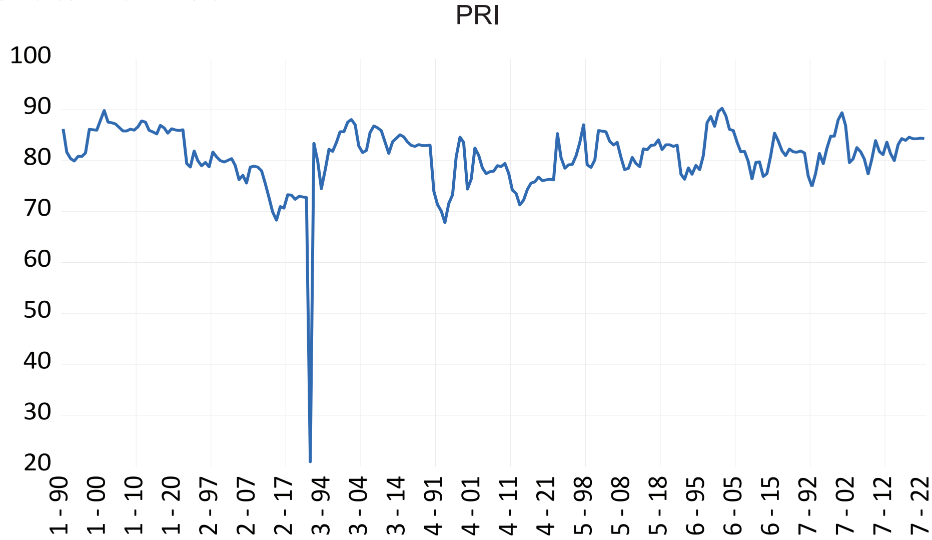
The escalating consumption of fossil fuel energy, leading to a surge in global CO_2 emissions, has become intertwined with nations' pursuit of heightened economic growth. Consequently, this has led to a deterioration in environmental conditions alongside economic expansion, marked by a nearly 50% increase in CO_2 emissions since the onset of the industrial revolution (IEA, 2021) The drive for economic progress has also spurred social modernization and urbanization, culminating in the utilization of coal, gas and oil – known contributors to environmental pollution. This conjunction has given rise to unparalleled emission levels and extreme weather events such as cyclones, heatwaves, floods and droughts in recent times, aligning with the trajectory of global economic growth (M. Ahmad *et al*., 2023) The international community of leaders has united to formulate agreements, commitments and strategies aimed at curbing the escalating global temperature in response to the intensifying impacts of global warming. Evident at the latest UN climate change conference (COP26) held in Glasgow, 120 world leaders convened to deliberate on the multifaceted aspects of climate change. During this pivotal summit, nations collectively resolved to constrain the global temperature rise within 2 °C and expedite efforts to limit it to 1.5 °C further. Additionally, several countries voiced their intent to achieve net zero emissions by the middle of this century (UNFCCC, 2022). However, these aspirations will remain elusive unless there is a reduction in the exploitation of natural resources and a hastening of initiatives to broaden the scope of the energy transition.

The energy transition is a challenging process worldwide because of attracting investments towards renewable energy products and technologies that are costly compared to traditional energy products. The G7 economies which come into the arena of advanced nations face a dilemma in the process of sustainable development which collides with the established economic structures and political paradigms (S. Li *et al*., 2023; S. Zhang *et al*., 2023). Transitioning from fossil fuels towards renewable energy sources involves a complex process of policy interests, the corporate world, international relations, economic expansion and socioeconomic considerations (Vanegas Cantarero, 2020). Hence, it is crucial to determine these factors and evaluate which dynamics change the political considerations of energy transition in the G7 economies.

The relationship between the political risk index of advanced nations and the energy transition of their economies is underpinned by various theoretical frameworks. Some scholars argue that elevated political risk can lead to fluctuations in the availability of natural resources, particularly affecting resource-dependent economies (Wang *et al*., 2023). Consequently, risk-averse investors may be drawn towards investing in renewable energy projects as a more stable alternative. On the contrary, an opposing viewpoint suggests that a decline in the political risk index of the renewable energy market can offer investors reliable and consistent returns. This, in turn, is likely to foster the expansion of renewable energy infrastructure within economies. Conversely, abrupt shifts and uncertainty within governments can potentially curtail the widespread adoption of *REOT* globally (Khan *et al*., 2022). Political hurdles, trade tariffs and grid-related challenges can substantially reduce the electricity output generated through renewable sources within economies. Figure 1 provides a graphical explanation of the G7 economies' political risk index, where the horizontal line represents the period 1990–2022 while the vertical axis explains the level of *PRI* (ICRG, 2023).

Furthermore, the influence of *GDP* and *TNRNT* plays a pivotal role in shaping the advancement of renewable electricity output (*REOT*) within G7 economies (Khan *et al*., 2022). Developed nations are driven by the aspiration for sustainable economic growth, often achieved by efficiently utilizing their natural resources. This heightened economic expansion signifies elevated income and consumption patterns, consequently contributing to an increased share of renewable electricity generation (M. Li *et al*., 2023). In addition, robust economic growth fosters the expansion of financial services and enhances financial inclusion. This, in turn, supports the establishment of renewable energy infrastructure, further bolstering the production of renewable electricity within these economies. A visual representation in Figure 2 illustrates the varying levels of *REOT* across G7 nations (Murshed *et al*., 2022). While some advanced economies within the G7 have achieved substantial *REOT* levels, others are progressing along this trajectory. Furthermore, the abundance of natural resources significantly aids in developing renewable energy technologies. Effective resource management, especially within G7 economies, yields access to materials crucial for solar, wind and other technologically efficient renewable energy solutions, thereby propelling the expansion of *REOT* on a global scale (El-Karimi and El-Houjjaji, 2022). Additionally, geographical factors and substantial revenues from the trade in natural resources also act as catalysts in augmenting the prevalence of *REOT* within these economies.

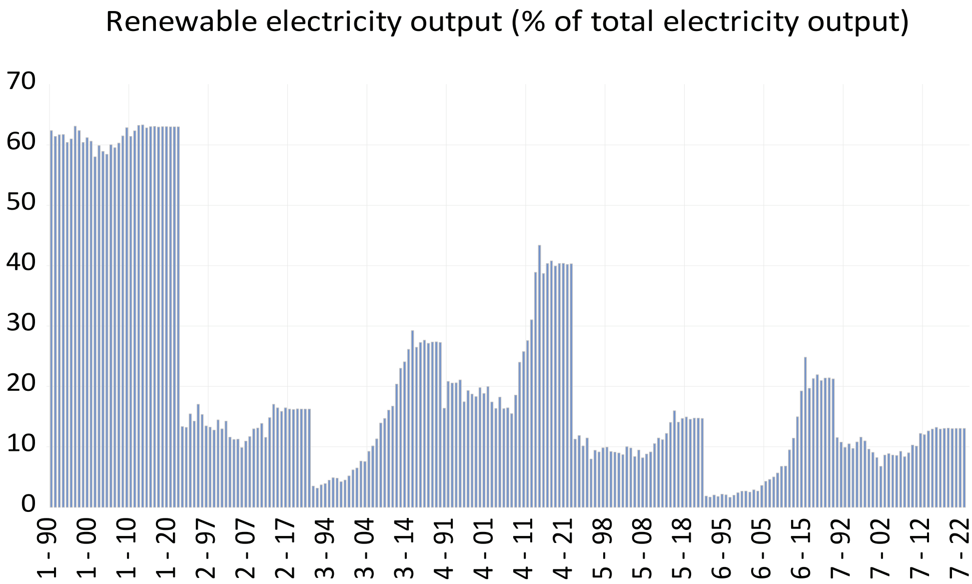
Figure 1: Political risk index



Source: ICRG (2023)

Moreover, technological innovation can potentially influence *REOT*, either amplifying or diminishing it. Given that the G7 economies are characterized by their advanced technological capabilities, they are well-equipped to create novel products and technologies that can augment the utilization of renewable energy sources within their borders (Bai *et al*., 2023). This is further facilitated by the pursuit of research and development initiatives to produce energy-efficient solutions, thereby reducing energy costs and bolstering the renewable energy infrastructure. Conversely, in pursuing rapid economic growth, economies might also channel their technological advancements towards developing technologies geared towards extracting fossil fuels. This path, while contributing to economic expansion, can have detrimental effects on the environment and subsequently undermine the progression of the *REOT* (Gao and Zhang, 2022). Furthermore, if technical advancement results in a drop in the price of fossil fuels, renewable energy may become less competitive. In general, the effect of technical advancement on the generation of renewable power is complicated and relies on several variables. However, technological advancement can greatly increase the quantity of renewable power produced.

Figure 2: Renewable electricity output (REOT)



Source: WB (2023)

Following the background of the study, the research has found several literature gaps, which have provided the objective of the study. The study's main objective is to evaluate the linkage between *REOT* and its covariates *GDP*, *TNRNT*, *PRI* and *TI*. The G7 economies are developed nations that are more focused on achieving sustainable development in renewable energy and electricity output. Hence, it is important to analyse factors that focus more on renewable electricity output because the level of political risk index and volatility in natural resources is increasing due to uncertain events and excessive utilization of resources. Prior literature has examined the impact of *PRI* and *TNRNT* on renewable electricity; however, these investigations have not delved into a comprehensive analysis of these factors. Furthermore, there has been a lack of detailed assessment in previous research. This study addresses these gaps by introducing a thorough evaluation of these variables. In terms of methodology, this research introduces a range of panel data estimation techniques. These techniques encompass diagnostic procedures as well as core methods. Among the former methodologies, consideration is given to slope heterogeneity and cross-sectional dependence. The CIPS panel unit root test is employed to assess the presence of unit roots. The Kao residual cointegration approach is adopted to examine long-term equilibrium. The primary estimations in this study are conducted using an innovative MMQREG method. To verify the robustness of the findings, the study incorporates the BSQR technique. Furthermore, the Dumitrescu–Hurlin causality test is employed to ascertain causal relationships. Finally, this research provides valuable insights for scholars and researchers focusing on this field of study within the G7 economies and analogous advanced nations.

The remaining sections of this paper are structured as follows. In Section 2, an extensive examination of the existing body of literature about theoretical underpinnings and pertinent prior research undertakings is conducted. Moving on to Section 3, the empirical model and comprehensive details regarding data and the adopted methodology are expounded upon. Section 4 encompasses the presentation and analysis of the empirical findings. Concluding the discourse, the final section furnishes both conclusions drawn from the study and novel guidelines for shaping future energy strategies.

2. Literature Review

This research provides an empirical review of the literature in many strands and sections concerning the roles of covariates in renewable electricity output.

2.1 Role of GDP and natural resources in renewable electricity output

Economic growth and renewable electricity have complex linkages in the literature, where most studies treat *GDP* instead of renewable electricity as the dependent variable. However, this research provides the most recent literature on the different regions' different outcomes. One of the early studies (Ohler and Fetters, 2014) inspected the causal linkage between renewable electricity (*REOT*) and *GDP* in the OECD economies. The outcomes suggested that *REOT* and *GDP* have a bidirectional linkage with each other, while sustainable economic expansion enhances the role of *REOT* in OECD economies. In a prevailing debate, Lu *et al*. (2023) scrutinized the link between renewable energy, industrial upgradation, export potential and CO_2 emissions. The study observed that *REOT* significantly reduces CO_2 emissions while the export potential is also the leading factor in the environment. The study confirmed a bidirectional relationship between *REOT* and CO_2 emissions. Additionally, Muhammad *et al*. (2023) evaluated the role of income and technological innovation in renewable energy by employing the augmented mean group panel method in the BRICS economies. The outcomes showed that income (*GDP*) inequality reduces RE in BRICS economies while *TI* will stimulate it in the future. The research further concluded that a bidirectional causal link exists between *GDP* and REC. Similarly Banga *et al*. (2023) inspected the nexus of REC, tourism, *GDP* and CO_2 emissions. The authors found that CO_2 emissions and REC are negatively correlated and predicted that REC would improve sustainable development in the future. Shahzad *et al*. (2023) inspected the nexus of renewable energy, economic progress and the environment in the top tourism economies. The authors recommended that REC products and infrastructure must be improved and investments shall be provided to improve the environment and achieve sustainability in the economies. From the perspective of Vietnam, Bui Minh and Bui Van (2023) concluded a unidirectional effect between renewables and *GDP*.

Moreover, total natural resources are also an important factor in developing and improving renewable electricity infrastructure and production. For example, Yuan *et al*. (2023) investigated the role of natural resources in renewable energy usage and the effects of the stock market and technology in the Next-11 economies. The research found that *TNRNT* increases the usage of renewable energy and electricity output while technology and stock trading influence it negatively. The study recommended that subsidies should be provided to renewable energy projects to enhance the renewable electricity output in the economies. Similarly, U. S. Ahmad *et al*. (2022) also claimed that natural resources are the main determinants of renewable energy in Pakistan and should be utilized sustainably to promote output of renewable energy technologies. Shinwari *et al*. (2022) claimed that natural resources and economic growth reduce the usage of renewable energy products in the upper quantiles of the time series data for China. A unidirectional causal relationship also exists between NRR and REC. Conversely, Shah *et al*. (2023) scrutinized the role of NRR, waste management, quality of life and the moderating role of environmental policy. The authors found that waste management increases the use of renewable electricity while natural resources and quality of life have inconclusive outcomes for renewable electricity output. Furthermore, S. Zhang *et al*. (2023) observed that natural resources have an asymmetric influence on renewable electricity generation in the USA. The authors opined that efficient utilization of NRR could improve electricity use in the economy. Walmsley *et al*. (2018)

also claimed that NRR can be used as an important metric among all renewable energy products and technologies, which could help generate renewable electricity in different regions. In one of the prevailing perspectives, Jin and Huang (2023) evaluated that economic expansion and use of resources improve the load factor of renewable electricity and confirmed a bidirectional linkage between the variables.

2.2 Role of PRI and technological innovation

The body of research on the connection between the political risk index (*PRI*) and renewable electricity is scant, especially in light of the present situation. Additionally, there is a dearth of thorough studies addressing the connection between *PRI* and *REOT*. However, some research has looked at this issue, which we will discuss in this section. Adebayo *et al*. (2023), for instance, studied the relationship between political risk, renewable energy and CO_2 emissions in the MINT economies. The study also looked at how the variables were affected by trade, *GDP* and financial concerns. Their results showed that political and financial risks have a favourable impact on using renewable energy and environmental improvement. Additionally, they found a unidirectional relationship between the variables and verified the environmental Kuznets curve (EKC) theory for these economies. Zhao *et al*. (2023) looked at how geopolitical risk affects the demand for green energy consumption and growth in OECD nations. The CO_2 emissions, net renewable resources, income and globalization were all part of the study's demand function for renewable energy. The researchers discovered that geopolitical risk has a detrimental influence on sustainable environmental policies and dramatically lowers the demand for renewable energy in OECD nations. Another research by Wang *et al*. (2023) used panel techniques such as CUP-FM to assess how political and financial concerns affect the environment and renewable energy (REC) use in the ASEAN economies. According to the study, lowering political and financial risks results in less environmental damage, encouraging the adoption of renewable energy in the ASEAN area. Additionally, they discovered a two-way relationship between political risk and REC, and they recommended minimizing political risks to promote adopting environmentally friendly and effective technology. The impact of country risk, including political, financial and economic hazards, on the environment was looked at by M. Ahmad *et al*. (2023).

Moreover, technological innovation is also one of the key determinants of renewable electricity. For example, Zheng *et al*. (2021) evaluated the nexus of technological innovation in renewable energy and renewable electricity generation in China by utilizing time series data. Their outcomes unearth that technological innovation leads to an increase in *REOT* on the provincial level in China. Del Río and Bleda (2012) provided a review of technological innovation and renewable electricity output. They predicted that different outcomes of technological innovation, including R&D, support the stimulation of renewable electricity. Xia (2023) also found a bidirectional linkage between technological innovation and renewable electricity. Haldar *et al*. (2023) claimed that technological innovation and electricity output increase sustainable development.

2.3 Literature summary and gap

Previous studies have indicated that *GDP*, *TNRNT*, *PRI* and *TI* significantly influence *REOT* (renewable electricity output) in various regions. Still, their impact is asymmetric and varies across different areas. However, these studies have mainly focused on developing or emerging economies, leaving a knowledge gap concerning G7 economies. Additionally, there is limited empirical evidence on the factors affecting renewable electricity output in developed regions. This research aims to address this gap by utilizing advanced panel techniques, including the novel MMQR to scrutinize and observe the factors influencing renewable electricity output in developed economies. By examining these factors, this study aims to provide valuable insights into the dynamics of renewable energy production in developed regions.

3. Theoretical Framework, Model Specification and Estimation Techniques

3.1 Theoretical framework

The present research utilizes the nexus of *GDP*, *TNRNT*, *PRI*, *TI* and *REOT* in the G7 economies. Economic expansion (*GDP*) is one of the important predictors of *REOT* in recent research. The influence of *GDP* is observed through different channels. The first channel is the EKC hypothesis by Grossman and Krueger (1991), which asserts an inverted U-shape relationship between *GDP* and CO_2 emissions. As the economy increases in the initial stages, the CO_2 emissions also increase; however, at a later stage, the economic growth leads to a level where the CO_2 emissions decrease and the economies are ready to invest in renewable energy technologies and infrastructures, increasing *REOT* in the long term. Moreover, the Porter theory (Porter, 1990) is also applicable, which suggests that implementing environmental regulations can enhance sustainable economic expansion, which can further lead to innovation and efficient technologies because of the stringent regulations of the environment. A greater economic expansion will increase income and consumption, leading to advancement in energy and renewable electricity. Since G7 economies are developed and have greater economic expansion, we expect a positive relationship between *GDP* and *REOT*.

Total natural resources (*TNRNT*) significantly influence renewable energy infrastructure. One essential aspect is resource endowment, which acts as a crucial channel through which *TNRNT* contributes to developing renewable electricity and infrastructure. Economies with abundant resources are more inclined to share and invest in renewable energy opportunities within other economies. Furthermore, a country's level of technological efficiency and regulatory environment also plays a key role in supporting renewable energy adoption. Nations with advanced technological capabilities and strong regulations are more likely to provide substantial support for expanding renewable energy infrastructure than countries with lax regulations and a preference for energy-intensive technologies. On the other hand, countries characterized by rent-seeking behaviour may hinder investments in renewable energy infrastructure due to corruption and low institutional quality within their economies. These factors discourage potential investors from engaging in renewable energy projects and initiatives. Since the G7 economies are developed and technologically efficient economies, we expect a positive relationship between *TNRNT* and *REOT*.

The political risk index (*PRI*) is of great importance for both developed and emerging countries in the realm of renewable energy and the environment. This index plays a crucial role in shaping policies and objectives related to environmental issues, particularly in advancing green technologies such as renewable energy products. A lower *PRI* signifies a reduced level of political risk, which facilitates advances in technological sectors, especially in green technology, leading to a boost in the renewable energy industry and instilling confidence in investors to channel investments into this sector, consequently benefiting the environment. Additionally, a favourable *PRI* can positively affect international trade, particularly within the renewable energy sector, which may increase *REOT*. Furthermore, a positive *PRI* reinforces environmental policies and enhances awareness regarding green technologies, encouraging the production and consumption of renewable energy products. A conducive *PRI* environment catalyses progress in renewable energy, environmental protection and sustainable development.

3.2 Model specification

The present research hinges on the following baseline model to understand the linkages between our independent modelled variables with predicted variables.

$$REOT_{ti} = \alpha_1 + \beta_2 PRI_{ti} + \beta_3 TI_{ti} + \beta_4 GDP_t + \beta_5 TNRNT_t + M_t \tag{1}$$

The variables above given in Equation (1) represent *REOT* (renewable electricity output) as a dependent variable which is measured as renewable electricity production out of total electricity production. Besides, *PRI* is the political risk index of the G7 economies, while *TI* is the technological innovation taken in the research as the patents filed during the period by residents and non-residents. Moreover, *GDP* is the economic expansion of G7 economies and measured as the residual value of goods and services considered in the US dollars constant in 2015, while *TNRNT* is total natural resources and taken as % of *GDP*. *M* is the error term in the model while

α and β are the slopes and intercepts of the model. The subscripts t and i represent time and cross-sections in the data. The research is based on panel data, extracted from WB (2023) except *PRI*, which is extracted from ICRG (2023). The research is based on the G7 economies, including the United States, Canada, Japan, Germany, Italy, France and the United Kingdom.

3.3 Econometric tools

The research is related to panel data techniques which begin with two diagnostic tests: slope heterogeneity (SH) and cross-section dependence (CD). The SH test (Pesaran and Yamagata, 2008; Pesaran, 2007) explains the process of modelling variables of economies that despite the countries having homogenous properties, the variables should be heterogenous in these economies. SH outcomes are essential for panel data observations because when SH is avoided, the results may provide distortion in the outcomes. Hence, it is necessary to find out whether variables should be heterogeneous. The equation for the SH test is provided as:

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

$$\tilde{\Delta}_{ASH} = (N)^{\frac{1}{2}} \left(2k \left(\frac{T-k-1}{T+1} \right)^{-\frac{1}{2}} \left(\frac{1}{N} \tilde{S} - 2k \right) \right) \tag{3}$$

where $\tilde{\Delta}_{HPY}$ and $\tilde{\Delta}_{ASH}$ represent the null and alternative hypotheses of the model.

After the confirmation of variability in the panel data, this research employs the second diagnostic test, which is cross-section dependence (Pesaran, 2004). It shows that there are certain similarities in the entities or specific units. The equation for the CD test is given below.

$$CD_{test} = \sqrt{\frac{2T}{N(N-1)} \left(\sum_{i=1}^{N-1} \sum_{k=i+1}^{N} \hat{\tau}_{ik} \right)} \tag{4}$$

In the above equation, the null hypothesis is represented by H_0 while the alternative is expressed through H_1.

After finding the estimates of the SH and CD tests, we employ the updated version of the ADF (Dickey and Fuller, 1981) unit root test for panel data, that is, the CIPS unit root test (Pesaran, 2007). The CIPS unit root technique takes the lags of panel variables to identify the roots in the unit root circle. CIPS is advantageous over the previous unit roots because it accounts for the SH and CD issues in the method. The equation for the CIPS unit root is given below.

$$\Delta W_{i,t} = \delta_i + \delta_i Z_{i,t-1} + \delta_i \bar{W}_{t-1} + \sum_{l=0}^{p} \delta_{il} \Delta \bar{W}_{t-l} + \sum_{l=1}^{p} \delta_{il} \Delta W_{i,t-1} + \mu_{it} \tag{5}$$

where the test statistics for CIPS are expressed as:

$$CI\hat{P}S = N^{-1} \sum_{i=1}^{n} CDF_i \tag{6}$$

where *CDF* denotes cross-sectionally augmented Dickey-Fuller (CADF).

After the investigation of the CIPS unit root test, this research uses the Kao residual (Kao, 1999), which indicates that two variables have long-run equilibrium if not in the short run. The method is beneficial to observe the long-run correlation between two panel variables. When the long-run equilibrium and other methods are evaluated, this research employs its final method, which is the novel MMQREG (moments and methods of quantile regression) by Machado and Santos Silva (2019). MMQREG is an updated version of simple quantile regression which not only determines the outcomes of the predicted variable on the conditional quantile but also provides robust and heterogenous outcomes. Moreover, the method provides a cushion of scale and location of output variables and distributes the values at each quantile accordingly. The method is advantageous in dealing with non-linear and non-normally distributed data. The equation for MMQREG is given below.

$$Q_H(\tau|R_{it}) = (\gamma + \Psi_i q(\tau)) + R'_{it}\delta + L'_{it}\Omega q(\tau) \tag{7}$$

However, to determine whether the outcomes obtained through MMREG are robust and valid, this research applies bootstrap quantile regression analysis (Hahn, 1995) to observe the robustness of the outcomes of the main methods. The BSQREG method makes repetitive sampling of similar observations and provides robust outcomes of the samplings. The BSQREG technique is also efficient by bootstrapping the variables and finding robust outcomes. The pairwise Dumitrescu–Hurlin panel causality test is employed to find out the causal linkage of panel data variables. The technique is non-conditional and has no specific requirements or conditions of connection between variables.

4. Results and Discussion

Table 1: Descriptive statistics

Variable	*REOT*	*TI*	*PRI*	*GDP*	*TNRNT*
Mean	21.02607	130841.4	80.92157	4.32E+12	0.651519
Median	14.08314	35481.00	81.66667	2.57E+12	0.130095
Maximum	63.29803	621453.0	90.29167	2.10E+13	5.564819
Minimum	1.627480	7453.000	20.83333	8.60E+11	0.012489
Std. dev.	18.49188	174450.0	6.044117	4.74E+12	1.032553
Skewness	1.386483	1.363079	−4.425987	2.166804	2.478619
Kurtosis	3.578456	3.484905	43.55696	6.407099	9.411697
Jarque-Bera	77.23055	73.79555	16586.03	292.4891	632.2091
Probability	0.000000	0.000000	0.000000	0.000000	0.000000

Source: Authors' own calculations

Table 1 explains the descriptive statistics of the research. The average values and median and maximum-minimum range values are positive and escalating smoothly. Moreover, the *TI* has the highest values, while *TNRNT* has the lowest among the variables. The dispersion measurement from the mean values is observed through the SD test, which shows that the values of the SD are near to the mean, showing lesser disparity. Furthermore, skewness and kurtosis show that modelled variables are positively skewed except *PRI*. In contrast, these variables have right-side distribution and some of the variables have heavier tails than expected. Since normality of data is a complex issue, we also employ a Jarque–Bera (JB) test (Jarque and Bera, 1987) to check the linearity and normality distribution of the data. The JB test shows that variables are normally distributed and have linear functions.

Table 2: Slope heterogeneity test

Model	Δ (*p*-values)	$\Delta_{adjusted}$ (*p*-values)
Equation (1)	13.736*** (0.000)	14.912*** (0.000)

Note: The significance level is denoted by *** for 1%, ** for 5% and * for 10%.
Source: Authors' own calculations

Table 2 provides outcomes of the SH test, indicating heterogeneity among cross-section slope coefficients. We also conclude from the estimations that the variables have heterogeneity in the panel data settings and reject the null hypothesis at 1%.

Table 3: Cross-section dependence

Variable	CD test	Correlation
GDP	24.645***	0.94
TNRNT	7.21***	0.43
TI	4.918***	0.51
PRI	6.06***	0.32

Note: The significance level is denoted by *** for 1%, ** for 5% and * for 10%.
Source: Authors' own calculations

Table 3 also confirms that units or entities of the data have cross-section dependence. Hence, we also conclude that variables are cross-sectionally dependent for the second diagnostic test and reject the null hypothesis at 1%.

Table 4: CIPS unit root testing (trend and intercept)

Variable	Level (0)	Difference (1)
REOT	−3.413	–
GDP	−2.721	−5.077***
TNRNT	−3.082**	–
TI	−2.493	−5.495
PRI	−4.941	–

Note: The significance level is denoted by *** for 1%, ** for 5% and * for 10%.
Source: Authors' own calculations

Table 4 shows the unit root outputs of the data. The outcomes suggest that *GDP* and *TI* are static after taking their first difference, while *REOT*, *TNRNT* and *PRI* are static at level. Since not all variables are static at both levels, we accept the alternative hypothesis that variables are static after considering their first difference.

Table 5: Kao residual test

	T-statistics	Prob.
ADF	−1.557610***	0.0597

Note: The significance level is denoted by *** for 1%, ** for 5% and * for 10%.

Source: Authors' own calculations

Table 5 suggests from the estimated outcomes that long-run equilibrium exists among *REOT* and its covariates *GDP*, *TI*, *PRI* and *TNRNT* at 5% and 10% significance levels. Hence, we conclude that the alternative hypothesis is to be accepted.

Table 6: MMQREG (Methods of moments of quantile regression)

Dependent variable: *REOT*

Variables	**Location**	**Scale**	***Q* = 0.25**	***Q* = 0.50**	***Q* = 0.75**	***Q* = 0.90**
	Coefficient [SE] *p*-values	**Coefficient [SE] *p*-values**	**Coefficient [SE] *p*-values**	**Coefficient [SE] *p*-values**	**Coefficient [SE] *p*-values**	**Coefficient [SE] *p*-values**
GDP	−0.47907*** [0.1228782]	−0.186526** [0.0920067]	−0.404563*** [0.1502651]	−0.525251*** [0.1107213]	−0.632363*** [0.1015647]	−0.78134*** [0.1305744]
TNRNT	0.121375*** [0.0372482]	0.1011292*** [0.0278901]	0.0809783*** [0.0472273]	0.1464119*** [0.0333357]	0.2044846*** [0.0311205]	0.285261*** [0.0409951]
TI	0.046874 [0.0578638]	−0.022195 [0.0433263]	0.0557405 [0.0691869]	0.0413797 [0.0525371]	0.0286344 [0.0475908]	0.0109063 [0.0603506]
PRI	0.67618** [0.3402215]	0.2072925 [0.2547454]	0.5933753 [0.4080386]	0.7274998** [0.308506]	0.846536*** [0.2799733]	1.01211*** [0.3556543]
C	5.721814*** [1.529927]	2.345309** [1.145553]	4.78496*** [1.869424]	6.302446*** [1.379724]	7.649225*** [1.264611]	9.522527*** [1.625412]

Note: $p < 0.01$, 0.05 and 0.1 shows significance at 1%, 5% and 10%.

Source: Authors' own calculations

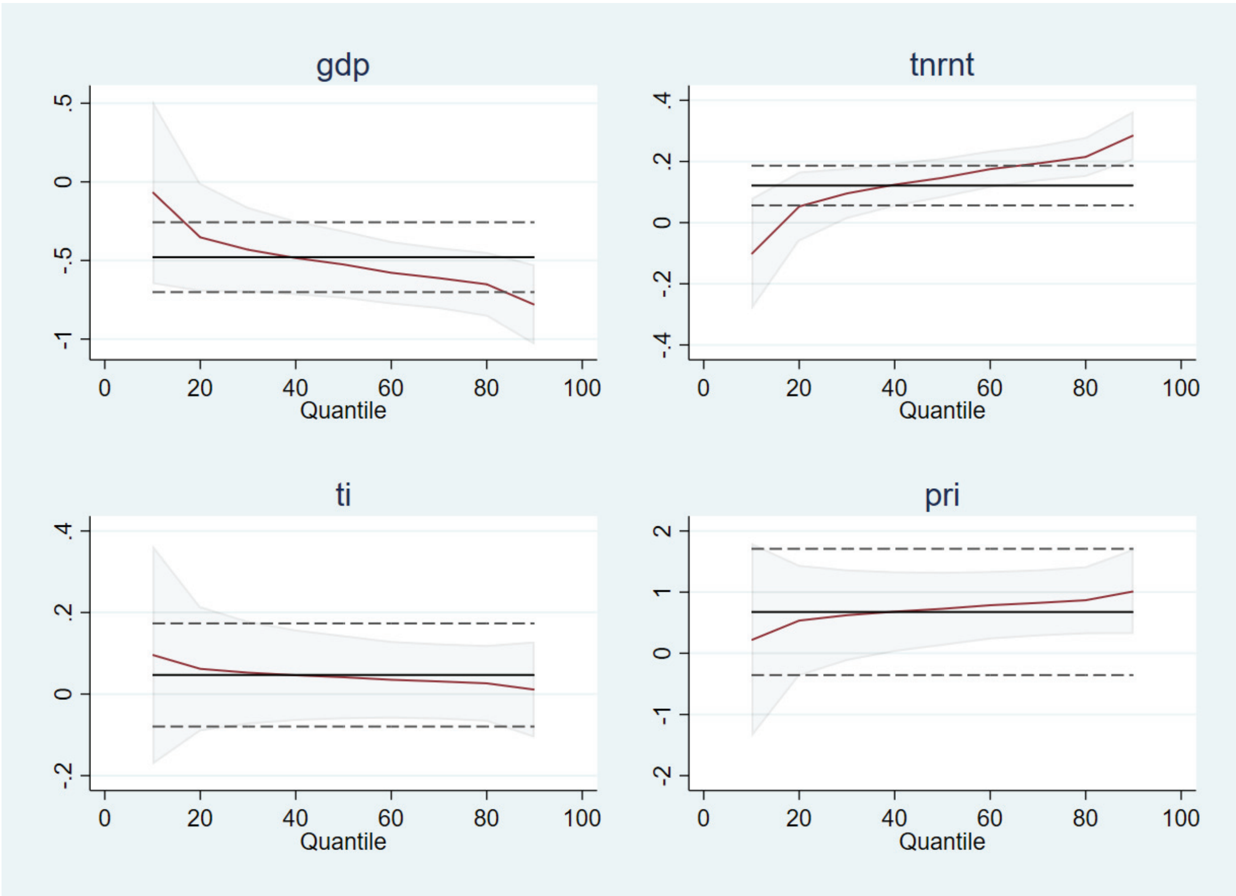
Thus, confirming the panel data diagnostics issues and considering the unit root and equilibrium, this research implicates the main methods which are given in Table 6, through the novel MMQREG. Our empirical estimations show that *GDP* negatively influences renewable electricity output (*REOT*). A one-percent increase in *GDP* leads to a decrease in *REOT* by −0.40%, −0.52%, −0.63% and −0.78% across quantiles. It should be noted that negative *GDP* intensity is increasing progressively in the upper quantiles. The outcomes are statistically significant in each quantile at 1%. Since G7 economies are developed, they mostly focus on higher economic growth, which demands intensive energy. The energy demand can be fulfilled through nonrenewable or renewable energy. However, nonrenewable energy is cost-effective and economically efficient, which discourages the use of renewable energy products and decreases the renewable electricity output. In advanced economies, the need for transportation is also on top, which increases the usage of fossil fuels and thus ignores the use of renewables. Policymakers should devise plans to incentivize the use of renewable energy products, introduce tax rebates and focus on environmental regulations such as COP 27 to achieve its targets, leading to meeting the SDGs. The outcomes of the study are analogous to the implications of Azam *et al*. (2021) and Ohler and Fetters (2014).

Conversely, total natural resources (*TNRNT*) have blessings in the G7 economies and lead to increased renewable electricity output (*REOT*) production. In a certain outcome, a one-percent increase in the *TNRNT* will significantly increase *REOT* by 0.080% to 0.28% from the lower to upper quantiles. This estimated outcome suggests that G7 economies are resource-rich and efficiently utilize these resources mostly towards renewable energy mechanisms and materials such as solar, wind and turbine energies, leading to an increase in the use of *REOT*. Moreover, G7 economies have enough resources and are more technologically advanced, hence focusing on the production of renewables, decreasing the costs of RE products and increasing the *REOT*. Since the G7 economies are resource-abundant, they should attract more investment in renewable energy projects because they have gained confidence of investors. The outputs of the research are analogous with those of Shinwari *et al*. (2022).

Furthermore, *TI* supports *REOT* in G7 economies across quantiles, but inconclusively and insignificantly. This suggests that technological innovation is a stronger factor for renewable energy and electricity output. However, the outcomes are insignificant in G7 economies because the impact of *TI* may vary in these economies. Moreover, the *TI* is supportive and insignificant in economies where the *REOT* is still growing, such as Africa and India (Iqbal *et al*., 2023).

In contrast, the influence of the political risk index on *REOT* is significant and positive in G7 economies. However, the impact of *PRI* is stronger in the upper quantiles than in the lower ones. A one-percent increase in *PRI* will lead to more than one percent (1.014%), which indicates that increasing *PRI* in the G7 economies will soar the energy prices, which are more subjected to volatility and fluctuations. However, the investment in renewable electricity will increase because of the stable market and lower volatility. Authorities may also support renewable energy products because of the higher political risk and to reduce the over-reliance on obtaining fossil fuels. Investment in technological support also increases when the *REOT* prices fall after increasing demand for fossil fuels, making the economy's R&D efficient and performing better for the production and development of *REOT*. The outcomes of the research are analogous to the output of W. Zhang *et al*. (2022).

Figure 3: MMQREG coefficients



Source: Authors' own calculation

Table 7: Robustness check analysis via BSQR approach

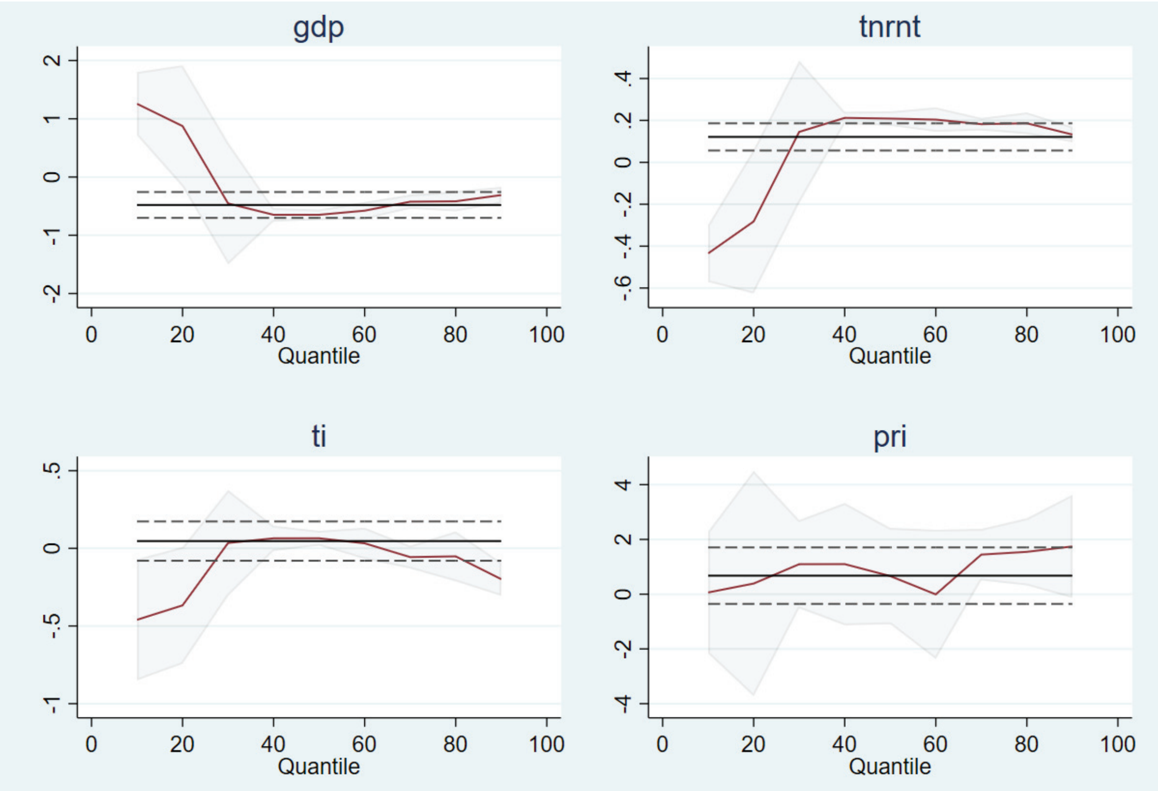
Dependent variable: *REOT*

Variables	***Q* = 0.25**	***Q* = 0.50**	***Q* = 0.75**	***Q* = 0.90**
	Coefficient [SE] ***p*-values**	**Coefficient [SE]** ***p*-values**	**Coefficient [SE]** ***p*-values**	**Coefficient [SE]** ***p*-values**
GDP	0.0162974 [0.6317055]	−0.6481152*** [0.04859]	−0.3737918*** [0.1117017]	−0.3099875*** [0.056434]
TNRNT	−0.0141642 [0.205881]	0.2087589*** [0.0168859]	0.1908915*** [0.0230317]	0.1326123*** [0.0166242]
TI	−0.1242936 [0.2071209]	0.06502** [0.0292616]	−0.0695051 [0.064647]	−0.1983529*** [0.048466]
PRI	0.8655797 [1.454312]	0.6620091 [0.794468]	1.509106** [0.6245493]	1.743481* [1.007416]
C	−0.2386359 [7.414409]	7.901627*** [1.679611]	3.616768** [1.866196]	3.073366 [2.297671]

Note: $p < 0.01$, 0.05 and 0.1 shows significance at 1%, 5% and 10%.
Source: Authors' own calculations

The research conducted a robustness check of the primary outcomes using the non-parametric method BSQR, which is given in Table 7. The estimated outcomes suggest that *GDP*, *TNRNT*, *TI* and *PRI* have significant and similar outcomes to the estimates of MMQREG. Moreover, the study found that *TI* is also significant in lower and upper quantiles and insignificant in median quantiles, indicating that after taking repetitive samplings of the data, the *TI* is found to support *REOT* in the region.

Figure 4: BSQREG coefficients



Authors' own calculation

Table 8: Pairwise Dumitrescu–Hurlin panel causality test

Null hypothesis	*F*-statistics	*p*-value(s)	Prob.
GDP* → *REOT	5.87104	4.31169	0.0016
REOT* → *GDP	0.97701	−0.15976	0.8731
TNRNT* → *REOT	6.33746	5.43349	0.0007
REOT* → *TNRNT	2.69515	2.66805	0.0076
TI* → *REOT	2.82919	2.88866	0.0039
REOT* → *TI	1.56420	0.80668	0.4199
PRI* → *REOT	8.46092	7.63669	0.0043
REOT* → *PRI	0.53083	−0.89409	0.3713

Note: $p < 0.01$, 0.05 and 0.1 shows significance at 1%, 5% and 10%.

Source: Authors' own calculations

The research employs the pairwise Dumitrescu–Hurlin causality test, which is reported in Table 8. The outcomes reveal that *GDP* and *TNRNT* bidirectionally lead to *REOT* while *TI* and *PRI* have a unidirectional causal linkage. This also suggests that any changes concerning policy level in the explanatory variables will cause changes in *REOT*.

5. Conclusion and Policy Implications

Research efforts have maintained their emphasis on attaining environmental sustainability and the crucial goal of capping the temperature rise below 2 degrees Celsius. This necessitates a shift in energy sources from nonrenewable to renewable. Still, this transition encounters challenges such as resource depletion, political instability and rapid economic expansion in developed and emerging economies. To cover this literature gap, this study utilized the role of *GDP*, total natural resources (*TNRNT*), political risk (*PRI*) and technological innovation (*TI*) in renewable electricity output (*REOT*) in G7 economies in the period 1990−2022. The research employed panel data methods, which included slope heterogeneity and cross-section dependence as diagnostic tests, CIPS panel unit root and Kao residual cointegration to investigate stationarity and equilibrium in the variables. Moreover, the research utilized novel MMQREG as the primary method, while BSQR is a non-parametric robustness check method. A pairwise Dumitrescu–Hurlin causality test was employed to find the causal connection between variables. The diagnostic outcomes show that modelled variables are static after the first difference while long-run equilibrium is also present. Moreover, the outcomes suggest that *GDP* negatively influences *REOT* across quantiles while *TNRNT* and *PRI* stimulate the use of *REOT* in G7 economies across quantiles. Moreover, *TI* positively influences *REOT* but is inconclusive across quantiles. The robustness check analysis provides similar and valid outcomes. At the same time, the causality test indicates that *GDP* and *TNRNT* have bidirectional linkage, which leads to *REOT*, while *PRI* and *TI* have been found to have a one-way connection and linkage towards *REOT* in G7 economies. It is recommended that authorities encourage *TNRNT* and *TI* to promote *REOT* in the G7 economies and manage the economic expansion and *PRI* to attract investments towards renewable energy projects in the G7 economies.

The study's estimations lead to several policy implications. Firstly, to stimulate economic expansion, authorities should encourage the adoption of efficient and renewable technologies by offering tax incentives and financial support. This will help renewables compete with fossil fuels and boost renewable electricity usage. Secondly, it is crucial to utilize natural resource sustainably, avoiding wasteful practices and encouraging support for renewable energy projects. This will further enhance the adoption of renewable energy electricity output (*REOT*) in economies. Thirdly, while the impact of technological innovation on the renewable energy industry is uncertain, there is significant potential for growth. Therefore, authorities should attract investments in research and development, promoting energy-efficient technologies to bolster the renewable electricity infrastructure. Lastly, an increasing political risk index positively affects renewable electricity output. Tax breaks and incentives should be offered to risk-averse investors to capitalize on this. This will discourage reliance on fluctuating nonrenewable energy sources and drive greater utilization of renewable energies and *REOT*.

Acknowledgement

Funding: 2023: General Research Project for Teachers of Ideological and Political Theory Courses in Higher Education Institutions by the Ministry of Education (Project No:23JDSZK063).

Conflicts of interest: The authors hereby declare that this article was not submitted nor published elsewhere.

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