energies

MDPI

Article

Trade Openness, Economic Growth, Capital, and Financial Globalization: Unveiling Their Impact on Renewable Energy Consumption

Bartosz Jóźwik [1,*], Sevgi Sümerli Sarıgül [2], Betül Altay Topcu [2], Murat Çetin [3] and Mesut Doğan [4]

[1] Department of International Economics, Institute of Economics and Finance, The John Paul II Catholic University of Lublin, 20-950 Lublin, Poland
[2] Department of Foreign Trade, Vocational School of Social Sciences, Kayseri University, 38280 Kayseri, Turkey; ssumerli@kayseri.edu.tr (S.S.S.); batopcu@kayseri.edu.tr (B.A.T.)
[3] Faculty of Economics and Administrative Sciences, Tekirdag Namik Kemal Üniversity, 59030 Tekirdag, Turkey; mcetin@nku.edu.tr
[4] Department of Banking and Finance, Vocational School of Bozuyuk, Bilecik Seyh Edebali University, 11100 Bilecik, Turkey; mesut.dogan@bilecik.edu.tr
* Correspondence: bjozwik@kul.pl

Abstract: Renewable energy sources are becoming increasingly popular due to their advantages over fossil fuels, their economic benefits, and growing environmental concerns. Researchers are particularly focused on understanding the factors that affect the efficiency of various energy sources. This paper explores the relationship between renewable energy consumption and trade openness from 1990 to 2018 among the top 15 countries that consume the most renewable energy. The study also considers economic growth, natural resources, capital, and financial globalization as additional factors influencing renewable energy use. To analyze the data, the paper utilizes advanced panel data techniques, including the dynamic Seemingly Unrelated Regression (DSUR) and Dimutrescu–Hurlin panel bootstrap causality methods. The findings reveal cross-sectional dependence and slope heterogeneity in the model. The results show that trade openness, economic growth, and capital investment promote renewable energy consumption, while financial globalization tends to reduce it. Additionally, the study finds one-way causality from trade openness, economic growth, natural resources, capital, and financial globalization to renewable energy consumption. These insights can inform the development of renewable energy policies in the countries examined.

Keywords: trade openness; renewable energy consumption; dynamic SUR; panel bootstrap causality

check for updates

Academic Editor: David Borge-Diez

Received: 3 February 2025
Revised: 23 February 2025
Accepted: 27 February 2025
Published: 4 March 2025

Citation: Jóźwik, B.; Sarıgül, S.S.; Topcu, B.A.; Çetin, M.; Doğan, M. Trade Openness, Economic Growth, Capital, and Financial Globalization: Unveiling Their Impact on Renewable Energy Consumption. *Energies* **2025**, *18*, 1244. https://doi.org/10.3390/en18051244

1. Introduction

Achieving sustainability across various domains presents a significant challenge for contemporary society. Environmental sustainability is a critical aspect of the Sustainable Development Goals (SDGs) and has increasingly garnered scientific interest in recent years [1]. Globally, nations are integrating efforts to develop sustainable industrial practices and enhance living standards, given that environmental degradation poses a substantial threat to human well-being. Effective management of carbon emissions, in particular, is vital for improving public health and advancing the SDGs [2].

Combatting climate change is a central challenge in attaining sustainable development objectives, impacting both developing and developed nations. Recent statistics indicate that carbon dioxide (CO_2) emissions contribute approximately one-third of global greenhouse gas emissions [3]. Remarkably, energy consumption in developed countries has resulted in a 2.5% increase in CO_2 emissions. The Paris Agreement mandates reductions in CO_2 emissions by transitioning to cleaner and more reliable energy sources, as energy plays a fundamental role in ecological sustainability and long-term development.

The global demand for energy is rising due to population growth, economic expansion, financial system changes, and rapid industrialization. Progress in the use of renewable energy is imperative to meet the SDGs. Green energy sources such as hydro, wind, and geothermal energy are essential for achieving sustainable development. Additionally, renewable energy sources offer several benefits, including widespread availability, fair energy costs, enhanced energy efficiency, resource conservation, and reduced dependence on imported energy.

Currently, fossil fuels supply a large portion of countries' energy needs and face a high risk of depletion in the coming decades. In 2020, fossil fuels accounted for 83% of world energy consumption. These energy sources also significantly contribute to environmental degradation [4]. As result of these factors, governments are rapidly shifting their energy policies to prioritize the use of renewable energy sources. For example, Johnstone et al. find that public policy plays a significant role in determining patent applications. They also note that different types of policy instruments are effective for different renewable energy sources [5]. Additionally, in many studies, results indicate that increasing renewable energy consumption has an overall positive effect on economic growth, as seen in the European Union [6] and in developing countries like Ghana [7].

Renewable energy continues to be the main concentration of researchers. Due to their environmental sensitivity, such energy sources can serve the sustainable development of a country by preventing environmental degradation [8]. The use of clean energy sources accelerates growth, encourages technological innovations, and supports financial development [9]. In this context, an improved financial system could allocate funds for the renewable energy sector at a lower cost, thereby encouraging the use of clean energy sources. With financial globalization affecting the financial sector, extra funds may turn to renewable energy investments, and the development of this sector may gain momentum [10]. In addition to these variables, some studies present findings that increases in natural resource rents and fixed capital investments positively affect renewable energy consumption [11].

In our research, we paid special attention to how economic growth and advancements in foreign trade are recognized as significant drivers of increased demand for renewable energy through the expansion of economic activities. Grossman and Krueger [12] elaborate on the effects of trade openness, highlighting its impact on the scale, composition, and technological aspects of production. The scale effect, in particular, suggests that trade openness can boost domestic production and economic growth, leading to higher energy demands. Empirical studies indicate that trade openness may promote the use of renewable energy [13]. Nonetheless, the results from empirical research are often complex and inconsistent. For example, Lin et al. [14] find that trade openness can lead to a reduction in renewable energy consumption, whereas Lu et al. [15] identify a direct positive relationship between trade openness and renewable energy use. These differing findings underscore the need for further research to clarify the relationship between trade openness and renewable energy consumption.

These panel studies discuss how the association between trade openness and renewable energy consumption generally benefit from panel OLS, DOLS, FMOLS, system GMM, PMG, MG, and corrected LSDVC estimators, as well as the Granger panel and Dumitrescu–Hurlin classical causality test. In empirical analyses, it is seen that dynamic SUR (DSUR) estimators and panel bootstrapping causality tests are not preferred. The most important aspect of our study that differs from the literature is the DSUR estimator, which has privileged characteristics over other techniques, and the Dumitrescu–Hurlin panel bootstrapped causality approach.

We examined the top 15 countries that consumed the most renewable energy worldwide in 2018. Table 1 shows that from 1990 to 2018, global renewable energy use increased significantly. The best performances are China, the USA, and Germany, with values of 143.50, 103.80, and 47.33 (million tons of oil equivalent), respectively. The consumption of clean energy has remarkably increased in these economies from 1990 to 2018. In 2018, the worldwide use of clean energy was 561.30 (million tons of oil equivalent), while the total value of 15 countries was 466.07 (million tons of oil equivalent). This figure corresponds to 83% of the global total.

Table 1. Macroeconomic profile in selected countries (1990–2018).

Countries/ Years	1990			2000			2018		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
China	0.02	1027	157	0.71	2770	822	143.50	13,493	5121
United States	13.72	9811	1378	16.50	13,754	3065	103.80	19,479	5520
Germany	0.34	2342	825	3.23	2835	1521	47.33	3562	3240
United Kingdom	0.14	1801	345	1.10	2310	1053	23.90	3139	1834
Sweden	0.44	295	136	1.03	364	261	6.60	539	474
Brazil	0.87	917	109	1.80	1186	230	23.64	1797	517
India	0.02	465	58	0.74	800	194	27.50	2588	1132
Japan	2.57	3509	641	3.74	3986	953	23.40	4580	1718
Spain	0.13	737	212	1.41	971	528	16.00	1297	871
Italy	0.74	1559	511	1.51	1842	842	14.93	1908	1158
France	0.43	1661	514	0.70	2046	985	10.60	2569	1671
Canada	0.90	877	369	2.10	1047	784	10.30	1664	1106
Australia	0.17	630	133	0.24	872	274	7.21	1460	643
Turkiye	0.02	288	68	0.10	413	181	8.53	988	500
Mexico	1.16	626	174	1.44	876	463	4.83	1255	961
Total	20.67	26,545	5630	36.35	36,072	12,156	466.07	60,318	26,466
World	27.30	35,870	12,330	49.32	48,220	22,820	561.30	82,510	47,360
EU	4.24	7973	3194	14.10	9961	6121	159.60	12,427	11,582

Note: This was created by the authors using the British Oil database and World Bank database. Columns (1), (2), and (3) denote total renewable energy consumption (million tons of oil equivalent, total GDP (constant 2015 billion USD), and total trade (constant 2015 billion USD), respectively.

Table 1 also shows the total GDP (constant 2015 billions of USD) figures for the countries sampled in this study. While the total GDP value of 15 countries was 60,318 (constant 2015 billion USD) in 2018, the world's total GDP value was 82,510 (constant 2015 billion USD). In parallel with renewable energy consumption and total GDP figures, the total foreign trade figures of 15 countries constitute an important part of the world total. Similarly, renewable energy usage in these nations increased between 1990 and 2018, and the same trend is felt in total GDP and total foreign trade. These developments provide an important motivation for our research. In this context, it also emphasizes the need for further empirical research on the connection between economic growth, foreign trade, and clean energy in these countries.

Based on the arguments mentioned earlier, this paper raises the following research questions: (1) What is the causal relationship between trade openness and renewable energy consumption (in the top renewable energy-consuming countries)? (2) How do economic growth, natural resources, capital, and financial globalization influence renewable energy consumption? (3) Does financial globalization hinder or promote renewable energy consumption? (4) What policy proposals can be developed in these countries to support the renewable energy sector?

Based on these research questions, two main hypotheses will be empirically tested using panel data techniques to provide insights into policy recommendations for supporting the renewable energy sector. The first hypothesis assumes that trade openness positively influences renewable energy consumption by facilitating the transfer of renewable energy technologies and promoting international cooperation in the energy sector. The second hypothesis assumes that economic growth, capital stock, and financial globalization positively impact renewable energy consumption, while natural resource availability may have a negative effect due to the resource curse hypothesis.

This research makes several notable contributions to the literature. First, it specifically examines the top 15 economies with the highest renewable energy consumption in 2018. Second, the study explores the trade–energy relationship by incorporating natural resources, economic growth, capital, and financial globalization as explanatory variables in the model. This comprehensive approach allows for a nuanced assessment of how these factors influence renewable energy use, enabling more informed recommendations for policymakers. Third, the research employs the dynamic Seemingly Unrelated Regression approach for empirical analysis. This method is particularly effective when cross-sectional units are interdependent and the time dimension of the panel exceeds the number of countries, providing robust estimates. Fourth, while the Dumitrescu–Hurlin panel bootstrap causality test is commonly used in empirical research [16], its bootstrap variant is seldom applied. This study includes this advanced version of the test, adding a novel methodological perspective. Finally, the findings confirm that trade openness, economic growth, and capital investment positively impact renewable energy consumption, whereas financial globalization has a negative effect. These insights can help policymakers design more effective and sustainable renewable energy policies in the long term.

The rest of this study is presented as follows: Section 2 discusses the literature review. Section 3 reveals a methodological framework, an empirical model, and data. Section 4 exhibits empirical results. Section 5 dwells on the discussion. Section 6 presents the conclusion, policy implications, limitations, and future research directions.

2. Literature Review

Many studies focus on examining the key factors underlying renewable energy consumption [17]. For example, Salim and Rafiq [18] demonstrate that economic growth fosters increased renewable energy consumption. Building on this, Okada and Semreth [19] found that the availability of natural resources enhances the use of renewable energy. Sharma et al. [20] provide evidence that capital formation supports the demand for renewable energy within BRICS economies. Additionally, Ozcan et al. [21] show that globalization promotes renewable energy use in Turkey. Collectively, these studies highlight that factors, such as economic growth, trade openness, capital investment, natural resources, and globalization, play crucial roles in influencing renewable energy consumption.

2.1. Trade Openness and Renewable Energy Consumption

Trade openness can accelerate economic growth by causing additional resource and capital accumulation [22]. Energy consumption is affected by trade liberalization in a variety of ways, including scale economies and manufacturing variables. In particular, an increase in export demand accelerates energy consumption by stimulating production growth and economies of scale [23]. Developments in trade openness may cause advanced technologies with high energy efficiency to shift from developed countries to developing countries, affecting both economic activities and energy consumption. For example, ASEAN countries have taken steps to improve energy efficiency and diversify energy supplies, including developing renewable energy sources, with trade and international cooperation playing a key role in advancing clean energy initiatives in certain countries within the region [24]. Latin American countries can also protect the environment by promoting trade and fostering technological innovation [25]. In addition, when used as fuel in the energy transportation sector, it can also affect the export and import of raw materials and manufactured goods.

Also, research conducted by Jóźwik, Topcu, and Dogan [26] confirms these relationships. The study confirms a bidirectional relationship between trade openness and environmental quality. This suggests that while trade openness can lead to increased industrial activities and emissions, it also has the potential to improve environmental outcomes by promoting renewable energy consumption through enhanced technology and standards. Furthermore, Lu et al. [15] conclude that trade openness significantly promotes renewable energy consumption. Contrary to these findings, Lin et al. [14] note that trade openness reduces the consumption of renewable electricity. Jebli and Youssef [27] discovered a bidirectional relationship among variables.

2.2. The Other Determinants of Renewable Energy Consumption

Several factors beyond trade openness influence renewable energy consumption, including economic growth, natural resources, capital stock, and financial globalization. Economic growth has a multifaceted impact on renewable energy consumption, as evidenced by various studies. In many cases, increased economic growth leads to higher renewable energy consumption due to the greater availability of financial resources and technological advancements that accompany economic expansion. For instance, in emerging economies, a rise in GDP is directly linked to an increase in renewable energy consumption, as higher income levels enable more investment in renewable energy infrastructure and technologies [28]. This relationship is also observed in developed countries, where economic growth supports the expansion of renewable energy through increased investments and policy support aimed at sustainable development [29].

We must mention the conservation hypothesis, which suggests economic growth drives energy consumption, while the neutrality hypothesis indicates no causal relationship [7]. Furthermore, the feedback hypothesis suggests a bidirectional relationship, where economic growth not only drives renewable energy consumption but is also supported by it, creating a virtuous cycle of growth and sustainability [30]. This impact of economic growth on renewable energy consumption can vary depending on the country's specific economic and policy context. For example, in some countries, economic growth may initially lead to increased consumption of non-renewable energy sources, which could delay the transition to renewables until economic and policy conditions become more favorable [31]. Overall, while economic growth generally promotes renewable energy consumption, the extent and nature of this effect are influenced by a range of factors, including policy frameworks, economic stability, and the existing energy infrastructure [29].

Natural resources are often associated with the "resource curse", which examines the economic and political impacts of resource wealth, including its links to political instability and economic performance in resource-dependent countries [32]. Despite this stereotype, natural resources are also a crucial factor influencing the utilization of renewable energy. Hossain [33] identified a significant relationship between renewable energy production and the sustainability of natural resources, noting that revenues derived from natural resources can support renewable energy sustainability. Al-Marhubi [34] contends that renewable energy is primarily produced from natural resources, thereby contributing to natural resource rent. However, Shinwari et al. [35], using quantile regression analysis for

China, found that natural resources may actually reduce investments in renewable energy. Conversely, Awijen et al. [36] report an indirect relationship between natural resources and clean energy, while Belaid et al. [37] established a positive link between these variables. These varied findings underscore the complex interplay between natural resources and renewable energy production.

Capital is essential for the adoption and expansion of renewable energy, as clean energy projects require significant financial investment in infrastructure, technology, and operations. Stock market developments and foreign direct investment inflows facilitate access to funding, reducing financial constraints and enabling large-scale investments in green energy [38]. Domestic investments directly and indirectly trigger energy consumption [39]. For instance, Damette et al. [40] state that capital costs negatively influence the likelihood of households switching to renewable energy. As relative capital costs increase, the probability of adopting renewable energy decreases. The significant feature of the renewable energy sector is that it needs more capital due to higher installation and development costs compared to the energy sector using fossil fuels [41]. Additionally, risks such as technological advancements, policy changes, and market dynamics can influence the cost-effectiveness and competitiveness of renewable energy projects [42]. Generally, a capital increase in an economy raises the production and consumption of green energy and also contributes to energy efficiency [20]. Rafindadi and Mikai'lu [43] conclude that capital formation improves clean energy use. Sharma et al. [20] indicated a direct association for the UK among variables that runs from capital formation and growth to energy use.

As mentioned, foreign direct investments also aid in the consumption of renewable energy. In regions with stringent environmental regulations, FDI tends to support renewable energy consumption by aligning with local standards that favor sustainable practices. This is particularly evident in European countries where FDI is directed towards environmentally friendly projects, supporting the pollution halo hypothesis [44].

Globalization influences energy usage, as discussed by Shahbaz et al. [45], who examined its effects through the structure and balance effect, highlighting its role in shaping energy consumption patterns and economic dynamics. According to the scale effect, globalization provides access to large markets in some economies, causing economies of scale, which increase energy consumption, whereas the compositional effect argues that globalization reduces energy consumption because of its effects on the economy. Akadiri et al. [46] revealed no causality between the variables. Ozcan et al. [21] concluded that for Turkey, globalization encourages the consumption of clean energy.

Overall, it should be added that in many cases, government support plays a crucial role in accelerating renewable energy development, particularly by facilitating the import of essential equipment. In the absence of such support, progress can still be achieved through investments in skilled labor training and employment. Tax exemptions are among the most effective policy measures for driving renewable energy project growth, enhancing production, and boosting sales. These findings provided by Hashemizadeh et al. [47] emphasize the importance of strategic governmental involvement in promoting renewable energy, ensuring energy security, and minimizing environmental harm. Additional solutions for skill training may include green leadership and environmental knowledge sharing. Firms can enhance their sustainable performance by adopting green leadership practices and promoting environmental knowledge exchange in the workplace [48].

Despite extensive research on the determinants of renewable energy consumption, several gaps remain. Firstly, the impact of trade openness on renewable energy use is inconclusive, with studies reporting positive, negative, or bidirectional effects, particularly lacking analysis for top renewable energy-consuming countries. Secondly, while economic growth is widely examined, competing hypotheses suggest the need for context-specific analyses. Thirdly, the role of natural resources remains ambiguous, with conflicting findings on whether resource wealth supports or hinders renewable energy adoption. Fourthly, the impact of financial globalization on renewable energy consumption is debated, with limited evidence on whether it facilitates or restricts clean energy investments. Addressing these gaps will enhance understanding and inform more precise policy recommendations.

3. Methods and Data

3.1. Methodological Framework

In this research, a four-step panel data methodology was adopted, as summarized in Figure 1. In the first step, cross-sectional dependence (CSD), slope homogeneity, and unit root analyses were conducted. To detect the presence of CSD, we employed Pesaran's [49] CD test, which is frequently used in panel data research and can be applied to various panel data models. The existence of CSD as an alternate hypothesis was evaluated versus the null hypothesis of no CSD.

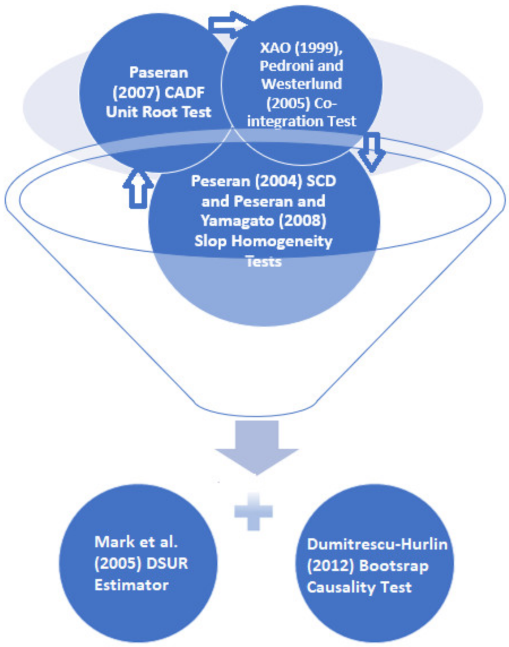

Figure 1. Flow chart of the econometric modeling approach [49–56].

As shown in Figure 1, after the investigation of the CSD, it was tested for the homogeneity of the slope. Since the economic, social, and demographic structures differ in panel data studies, a heterogeneous structure can appear in cross-sectional units. This means that the corresponding parameters change between cross-sectional units. In this context, the assumption that the panel data has a homogeneous slope parameter is not valid and may lead to misleading and inconsistent estimation results [57]. It was investigated whether the slope coefficients are homogeneous or heterogeneous by Δ tests offered by Pesaran and Yamagata [50]. Usman et al. [58] indicate that panel estimates can have deviations and inconsistencies when CSD and heterogeneity are present. Pesaran [51] introduced the cross-sectionally augmented ADF (CADF), which is employed to see if the variables are stationary or not.

The next stage employed the cointegration approaches proposed by Kao [52], Pedroni [59], and Westerlund [53,54]. Although these approaches are called residual-based techniques, in practice they can be given prediction results to consider cross-sectional means. Westerlund [54] suggests two well-defined statistics, as VR_G and VR_P, which are very simple tests to apply. These are expressed as follows:

$$VR_G = \sum_{i=1}^{N}\sum_{t=1}^{T}\hat{E}_{it}^2\left(\sum_{i=1}^{N}\hat{R}_i\right)^{-1} \quad (1)$$

$$VR_P = \sum_{i=1}^{N}\sum_{t=1}^{T}\hat{E}_{it}^2 \quad (2)$$

After cointegration, long-term estimates of coefficients are started in the third step. Here, the DSUR estimator is consulted for long-term forecasts. Since this estimator takes CSD into account, it can offer more effective results than forecasters such as DOLS and FMOLS [60]. This technique can be used in both homogeneous and heterogeneous panels [55]. Mark et al. [55] initially accredit a regression equation as follows:

$$\underline{y}_t = \left(\underline{\beta}', \underline{\delta}'_p\right) W_t + \underline{u}_t \quad (3)$$

The covariance matrix of $\underline{u}_t$ is indicated by Ω_{uu}. This estimator Ω_{uu} is expressed as follows:

$$\begin{bmatrix} \hat{\underline{\beta}}_{dsur} \\ \hat{\underline{\delta}}_{p,dsur} \end{bmatrix} = \left(\sum_{t=p+1}^{T-p} W_t \Omega_{uu}^{-1} y_t\right)^{-1} \quad (4)$$

In applications, Ω_{uu} is replaced with a consistent estimator, $\hat{\Omega}_{uu}\vec{\ }\Omega_{uu}$. Since degrees of freedom are taken into account by the parametric control for endogeneity, *dsur* can be applied where N is much less than T [55].

In the final step in Figure 1, we applied a bootstrap causality procedure proposed by Demutrescu and Hurlin [56] for causality analysis. This causality method is highly compatible in case of CSD and hetoregeneity [61]. This test is a very flexible approach, as it can be used not only in unbalanced panels but also in $T > N$ and $N > T$ cases [62]. Wald statistics ($\overline{W}$) and Z statistics ($\overline{Z}$) are used to evaluate if a causal relationship exists or not in the panel against the null hypothesis. They are expressed as follows:

$$\overline{W} = \frac{1}{N}\sum_{i=1}^{N} W_i \quad (5)$$

$$\overline{Z} = \sqrt{\frac{N}{2K}}\left(\overline{W} - K\right) \quad (6)$$

Here, W_i is individual Wald statistics; the sample size is shown by N, while K is the lag length. This technique employs bootstrapped critical values because CSD is considered.

3.2. Empirical Modeling and Data

The selection of independent variables in the model was based on both theoretical and empirical foundations, reflecting key macroeconomic factors influencing renewable energy consumption. The model incorporates independent variables that are widely used in previous studies. For instance, Bayar et al. [63] focused on how trade openness and financial globalization affect clean energy. Vural [25] examined economic growth and trade openness in selected Latin American countries. Khan et al. [64] incorporated economic growth, trade openness, and fixed capital in an empirical analysis of the G-7. Finally, Ahmadov and van der Borg [65] considered natural resources a key factor influencing renewable energy production in their EU panel data study.

In addition to the above literature, this study also made use of the regression equations offered by Lin et al. [14], Churchill et al. [66], and Baye et al. [13]. Thus, in the analysis of the relationships between variables from 1990 to 2018, a linear regression model was constructed as follows:

$$lnREN_{it} = \gamma_0 + \gamma_1 lnGDP_{it} + \gamma_2 lnTR_{it} + \gamma_3 lnNR_{it} + \gamma_4 lnCAP_{it} + \gamma_5 lnFGL_{it} + \varepsilon_{it} \quad (7)$$

where i is cross-sectional units ($i = 1, \ldots, N$), t denotes time duration ($t = 1, \ldots, T$), and ε_{it} indicates the error terms. $\gamma_1, \ldots, \gamma_6$ show the coefficients that estimate the influence of regressors on clean energy use. REN is an independent variable and indicates aggregate energy consumption expressed as a million tons of oil equivalent. GDP represents total real GDP at constant 2010 USD prices, TR is trade openness (cumulative foreign trade as a percentage of GDP), NR is total natural resource rents (as a percent of GDP), CAP is gross capital formation (as a percentage of GDP), and FGL is the KOF index of financial globalization. Each variable was transformed into a natural log. The natural-log transformation enabled us to realize more efficient long-term estimations and to offer healthier interpretations and policy proposals. The data on financial globalization were obtained from the KOF Swiss Economic Institute. The sources for clean energy were taken from the BP database. All the other data were gained from the WB database.

Table 2 illustrates the definitions of all variables in terms of resources and expected signs.

Table 2. Basic properties of variables.

Variables	Descriptions	Source	Expected Sign
REN	Renewable Energy Consumption (million tons of oil equivalent) [67]	BP	
GDP	Gross Domestic Product (constant 2010 USD) [68]	WB	(+) [69]
TR	Trade Openness (% of GDP) [25]	WB	(+) (−) [70]
NR	Natural Resource Rents (% of GDP) [35]	WB	(+) [35]
CAP	Gross Capital Formation (% of GDP) [71]	WB	(+) [72]
FGL	KOF Index of Financial Globalization [63]	KOF Swiss Economic Institute	(+) (−) [73]

4. Results

4.1. Summary Statistics

The summary statistics are presented in Table 3. The findings suggest that the series with the higher and lower means are lnGDP (28.215) and lnNR (−0.713), respectively. The mean value of lnREN (0.845) is less than the mean value of lnTR (3.775). lnCAP (0.215) has the lowest standard deviation, while the series with the highest is lnNR (1.794). When the maximum values are taken into account, lnREN (4.966) exhibits a higher maximum value than lnTR (4.527). In addition, the series with the highest kurtosis value is lnFGL (7.007), while the series with the lowest is lnNR (1.828). Table 3 also provides the correlation matrix for the series. The findings reveal a direct association among trade openness, economic growth, financial globalization, and clean energy, whereas natural resources and capital demonstrate a negative correlation with clean energy.

Table 3. Summary statistics.

Statistics/ Variables	lnREN	lnGDP	lnTR	lnNR	lnCAP	lnFGL
Mean	0.845	28.215	3.775	−0.713	3.126	4.140
Median	0.916	28.191	3.868	−0.457	3.103	4.265
Std. dev.	1.741	0.891	0.420	1.794	0.215	0.342
Min.	−4.175	26.458	2.718	−4.520	2.683	2.411
Max.	4.966	30.516	4.527	2.272	3.842	4.519

Table 3. *Cont.*

Statistics/ Variables	lnREN	lnGDP	lnTR	lnNR	lnCAP	lnFGL
Skewness	−0.390	0.476	−0.542	−0.291	1.080	−1.721
Kurtosis	3.073	3.025	2.580	1.828	4.739	7.007
Obs.	435	435	435	435	435	435
Correlation matrix						
lnREN	1.000					
lnGDP	0.688	1.000				
lnTR	0.100	−0.318	1.000			
lnNR	−0.073	−0.220	−0.047	1.000		
lnCAP	−0.095	0.079	−0.018	0.056	1.000	
lnFGL	0.338	0.169	0.586	−0.366	−0.156	1.000

4.2. CSD, Slope Homogeneity, and Unit Root Analyses

As Majeed et al. [57] pointed out, most panel data studies apply CSD and slope homogeneity tests as preliminary tests to determine the long-term estimator and causality approach.

Table 4 implies that the Pesaran CD test is applied to determine CSD. The null hypothesis, which refers to no CSD between countries, can be rejected. This shows that a shock in any cross-sectional unit included in the analysis may expand to other cross-sectional units. Table 4 also reveals the findings of the CADF test. The outcomes indicate that the indicators are non-stationary at their level. Furthermore, all the series are stationary at the first difference. This result plays an important role in selecting cointegration, estimation, and causality methods.

Table 4. CD and CADF test results.

Variables	CD-Test	*p*-Value	Corr	Abs (Corr)	CADF Test Statistic	
					L	Δ
lnREN	51.91 ***	0.000	0.941	0.941	0.657	−3.066 ***
lnGDP	52.65 ***	0.000	0.954	0.954	−1.207	−3.096 ***
lnTR	39.66 ***	0.000	0.719	0.720	−1.106	−1.930 **
lnNR	25.29 ***	0.000	0.458	0.488	−0.332	−9.495 ***
lnCAP	4.17 ***	0.000	0.076	0.313	−0.391	−7.072 ***
lnFGL	40.24 ***	0.000	0.729	0.732	−0.591	−4.382 ***

Note: *** and ** denote significance at the 1% and 5% levels, respectively.

On the contrary, Table 5 lists the outcomes of the delta tests, which were carried out to determine if slope homogeneity existed. According to the results, the null hypothesis that slope homogeneity exists can be rejected, so it can be said that our model has heterogeneous panel data.

Table 5. Slope homogeneity analysis.

Tests	Statistics	*p*-Value
Δ	20.355 ***	0.000
Δ-adjusted	23.370 ***	0.000

Note: *** denotes significance at the 1% level.

4.3. Cointegration Analysis

According to the CADF results, since the series are stationary in their first differences, the Pedroni, Kao, and Westerlund tests can be employed to explore the cointegration among variables. Due to the CSD in the series, the results are obtained in a way to reduce the impact of the CSD structure. The outcome, presented in Table 6, demonstrates that the null hypothesis is rejected at various significance levels, which indicates the existence of cointegration among variables.

Table 6. Cointegration analysis.

Cointegration Tests	Statistic	p-Value
Pedroni		
Modified Phillips and Perron t	4.390 ***	0.000
Phillips and Perron t	1.120	0.131
Augmented Dickey & Fuller t	2.008 **	0.022
Kao		
Modified Dickey and Fuller t	−0.486	0.313
Dickey Fuller t	−1.799 **	0.035
Augmented Dickey and Fuller t	−2.033 **	0.021
Unadjusted modified Dickey and Fuller t	0.547	0.291
Unadjusted Dickey and Fuller t	−1.163	0.122
Westerlund		
Variance Ratio	2.763 ***	0.002

Note: *** and ** denote significance at the 1% and 5% levels, respectively.

4.4. Long-Run Estimates

The long-run coefficients were analyzed in the panel data model using the DSUR approach. The results from DSUR estimations are provided in Table 7. Initially, the statistical significance of the Wald χ^2 values indicates the suitability of each model.

Table 7. DSUR analysis.

Regressors	Model 1	Model 2	Model 3	Model 4
lnGDP	0.049 *** (03.12)	0.064 *** (3.92)	0.048 *** (2.86)	0.069 *** (4.04)
lnTR	0.049 ** (2.00)	0.064 ** (2.57)	0.050 ** (2.03)	0.143 *** (4.53)
lnNR		0.015*** (3.13)	0.013 *** (2.69)	0.005 (0.99)
lnCAP			0.135 *** (3.28)	0.091 ** (2.19)
lnFGL				−0.173 *** (−4.60)
Constant	−1.414 *** (−2.82)	−1.871 *** (−3.62)	−1.801 *** (−3.52)	−1.889 *** (−3.78)
R2	0.988	0.989	0.989	0.989
χ^2-statistic	37,133.71	38,011.72	38,993.57	40,975.63
Prob	0.000	0.000	0.000	0.000
RMSE	0.178	0.176	0.174	0.170
Countries	15	15	15	15
Observation	420	420	420	420

Note: *** and ** denote significance at the 1% and 5% levels, respectively.

Long-term forecast results can be evaluated by considering the broadest model (model 4). According to the long-run estimates, the coefficient of economic growth (0.069) implies a positive link between economic growth and clean energy. It can be interpreted as a 1% surge in growth contributing to a 0.069% surge in clean energy usage in the long term. The trade openness coefficient (0.143) shows that trade openness is directly linked with clean energy usage. It can be expressed that a 1% rise in trade openness will boost renewable energy by 0.143% in the long term. It was detected that the natural resources coefficient

(0.005) is not statistically significant. This points to a statistically insignificant association among variables.

The long-run outcomes imply that capital encourages renewable energy consumption. This indicates that a 1% rise in capital contributes to a 0.090% rise in renewable energy. The results also suggest that the coefficient of financial globalization (−0.173) shows an indirect association between financial globalization and clean energy. This indicates that a 1% surge in financial globalization contributes to a 0.173% reduction in clean energy usage.

4.5. Bootstrap Causality Analysis

The causal relations between variables were detected by utilizing the Demutrescu–Hurlin panel bootstrap causality technique, and the results are exhibited in Table 8 as well as Figure 2. The outcome for GDP shows that the null hypothesis is rejected, which demonstrates that economic growth does not cause increased clean energy usage. However, the null hypothesis that the use of renewable energy does not cause economic growth cannot be rejected. This means that the causality exists between economic growth and the use of clean energy.

Table 8. Bootstrap causality analysis.

Hypotheses	W-Stat.	Zbar-Stat.	*p*-Value	Causality
lnGDP ≠> lnREN	4.472	9.510	0.026 **	Unidirectional
lnREN ≠> lnGDP	2.160	3.178	0.576	
lnTR ≠> lnREN	2.126	3.083	0.068 *	Unidirectional
lnREN ≠> lnTR	2.679	4.600	0.350	
lnNR ≠> lnREN	2.140	3.124	0.024 **	Unidirectional
lnREN ≠> lnNR	2.614	4.422	0.198	
lnCAP ≠> lnREN	2.118	3.062	0.024 **	Unidirectional
lnREN ≠> lnCAP	2.650	4.519	0.164	
lnFGL ≠> lnREN	5.039	11.062	0.000 ***	Unidirectional
lnREN ≠> lnFGL	1.322	0.882	0.842	

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

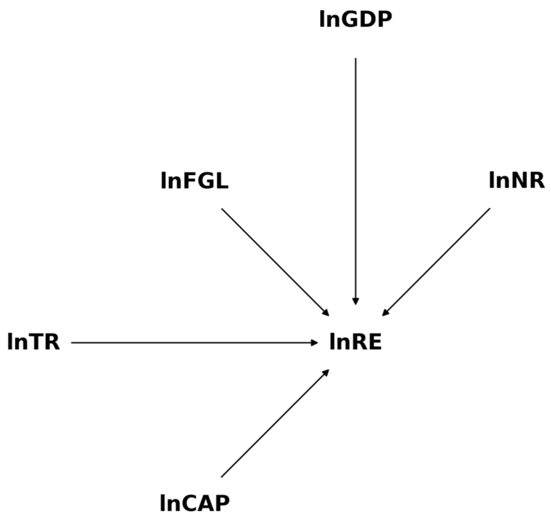

Figure 2. Graphical demonstration of empirical findings.

The null hypothesis that trade openness does not cause increased renewable energy use can be rejected. This suggests the existence of a causal linkage between trade and renewable energy use. We also found that the null hypothesis that natural resources are not the cause of renewable energy use can be rejected, which indicates a causal association between natural resources and renewable energy use.

The empirical results show a causality between capital and clean energy use, because the null hypothesis that capital is not a cause of clean energy use can be rejected. Finally, the null hypothesis that financial globalization is not a cause of increased renewable energy use can be rejected. Thus, according to the causality findings, all independent variables cause renewable energy consumption.

The summary of these results is presented in Figure 2, which represents the hypothesis that each variable exerts a direct unidirectional positive influence on renewable energy usage.

5. Discussion

The empirical analysis conducted made it possible to obtain a number of statistically significant results. First, economic growth influences renewable energy consumption. The long-run outcomes of our study indicate that a 1% increase in GDP is associated with a 0.069% increase in renewable energy consumption. In this context, Vural [25] emphasizes that real GDP is a crucial indicator of clean energy consumption, highlighting its role as an economic driver. Similarly, Sadorsky [69] and Rahman and Sultana [41] found that real GDP per capita is a significant determinant of long-term energy consumption, suggesting that economic growth influences energy demand. Our results support the conservation hypothesis, which suggests that economic growth drives energy consumption [7]. Economic growth can promote clean energy consumption by expanding the energy market; however, a balanced approach is necessary to ensure that growth does not exacerbate environmental challenges. In these situations, supporting renewable energy investments becomes crucial for managing the increased energy demand driven by economic expansion while mitigating adverse environmental impacts [28]. Our DSUR findings are consistent with the results of Mohamed et al. [74]. Using the ARDL model for France, they demonstrate that long-term economic growth positively influences clean energy consumption.

In contrast, our findings diverge from those of Uzar [75], who identified an indirect linkage between economic growth and clean energy usage across 43 countries. Similarly, Shahbaz et al. [76] suggest that economic growth may actually reduce clean energy usage, highlighting a more complex relationship than that observed in our study. In other studies, like Gyimah [7], who examined the relationship between economic growth and clean energy use in Ghana using time-series techniques, there is no causal linkage between these variables, which also differs from our findings. These variations underscore the nuanced nature of the relationship between economic growth and clean energy consumption, suggesting that the impact of economic growth on renewable energy use can vary depending on regional, methodological, and contextual factors.

Second, trade openness positively affects renewable energy consumption. A 1% increase in trade openness leads to a 0.143% rise in renewable energy consumption. This is the strongest positive effect among the independent variables, highlighting the role of trade in facilitating the transition to renewable energy sources, possibly through technology transfer and investment (Table 7). Our findings align with the research of Jebli and Youssef [27], who suggested that trade liberalization fosters the growth of green energy. Similarly, Baye et al. [13] demonstrated that trade increases green energy output in sub-Saharan Africa, reinforcing the idea that trade openness significantly influences renewable energy consumption [24]. Omri and Nguyen [70] argue that the movement of goods and services facilitates access to green technologies, thereby boosting the demand for renewable energy. Furthermore, trade openness is widely recognized as a key channel for the international transfer of clean technologies [77]. This perspective underscores the importance of trade in advancing the adoption and development of green energy technologies on a global scale.

The positive link determined among trade openness and clean energy usage is similar to the findings of Vural [25], who focused on selected Latin American countries. This study's outcomes coincide with the results provided by Alam and Murad [78]. On the other hand, contrary to these studies, our analysis does not match the outcomes of Baye et al. [13] for 32 SSA regions. The aforementioned studies indicate that trade openness decreases renewable energy use.

Third, natural resources are not significant. The findings indicate no significant linkage between natural resources and clean energy use. This situation occurs despite the fact that in many of the countries analyzed, there is a risk of resource depletion that needs to transition from non-renewable to renewable energy sources, as Sadorsky points out [79]. Another factor that can be taken into consideration is natural resource rent. Extremely high levels of these rents can potentially hinder investments in renewable energy. This is because substantial revenues from natural resources might reduce the immediate economic incentives to invest in cleaner alternatives [32]. Additionally, Canh [80] supports the notion that wealth, which is often linked to natural resources, can enhance the use of renewable energy. By facilitating access to capital for investments, wealth derived from natural resources can potentially promote the expansion of renewable energy usage. These perspectives highlight the complex relationship between natural resources and renewable energy, suggesting that while natural resource wealth might offer capital for investment, it can also present barriers if not managed with a focus on sustainability.

Fourth, capital positively and slightly affects renewable energy consumption. In the long run, we determined a direct association between capital and renewable energy consumption. Discussing the situation where environmental factors exceed the cost of consumption in the preference of energy sources, Damette et al. [40] emphasize that relative capital costs and income level are critical in choosing renewable energy consumption. As a matter of fact, it is certain that directing and encouraging a significant part of capital investments in the renewable energy sector and projects will develop this sector faster [35]. Our findings are also consistent with the results of Paramati et al. [38]. Their study investigated how both domestic and foreign capital influence clean energy consumption in developed countries. They found that both types of capital contribute to an increase in renewable energy use. Similarly, Islam et al. [39] reached comparable conclusions in their analysis of renewable and non-renewable energy use in Bangladesh. Our results also align with the results of Riti et al. [81], who explored the relationship between renewable energy consumption and its determinants in sub-Saharan African countries and found that capital investment positively influences clean energy use, as identified using the Dumitrescu–Hurlin panel causality technique. Also, Rahman and Sultana [41] observed a positive relationship between capital investment and clean energy consumption in emerging economies. These variations underscore the context-dependent nature of the relationship between capital investment and clean energy use.

Finally, we determined that financial globalization decreases the utilization of green energy. A 1% increase in financial globalization is associated with a 0.173% decrease in renewable energy consumption. This demonstrates that the share of fossil fuels in investments might be considerably higher than the share of clean energy sources [13]. It can also be interpreted as a large part of the financial investments and capital arising from globalization flowing into the fossil fuel sector. Our finding is consistent with the results of Majeed et al. [57], who found that economic globalization adversely affects clean energy consumption. In contrast, Koengkan et al. [82] demonstrated a direct positive relationship between globalization and the use of clean energy in Latin American countries. Similarly, Ozcan et al. [21] explored the linkages between globalization, human capital, and clean energy use in Turkey. Their study indicates that social, political, and economic globalization have a direct positive effect on clean energy consumption. These differing results suggest that the impact of financial globalization on renewable energy can vary significantly depending on regional and contextual factors.

6. Conclusions and Policy Recommendations

The inclusion of many of the world's leading renewable energy-capacity economies in our analysis underscores the significance of investing in and supporting the renewable energy sector. Additionally, the focus on macroeconomic factors is crucial for developing effective policies and strategies to enhance renewable energy use and achieve sustainable energy goals.

The DSUR results confirm the first hypothesis, which assumes that trade openness positively influences renewable energy consumption. Additional literature analysis suggests that this might occur by facilitating the transfer of renewable energy technologies and promoting international cooperation in the energy sector. The second hypothesis was only partially confirmed. Economic growth and capital investment positively influence the use of green energy sources. In contrast, financial globalization appears to discourage the use of green energy. The relationship between natural resources and green energy consumption was found to be statistically insignificant. The causality analysis identifies unidirectional causal linkages from all the regressors to green energy consumption, suggesting that these factors play a significant role in shaping the use of renewable energy.

Based on the empirical findings of the study, several recommendations can be made to advance the renewable energy sector in the sampled economies. In the first place, expanding trade openness can enhance energy efficiency policies by fostering the production and adoption of renewable energy technologies and facilitating access to advanced technological products. Moreover, strengthening trade relationships with countries that excel in renewable energy can help reduce dependence on imported fossil fuels, such as oil and gas, thereby contributing to a more sustainable and self-reliant energy strategy.

In addition, the study's results indicate that economic growth is a significant factor influencing the adoption of clean energy sources. Thus, fostering economic development can enhance environmental awareness and positively impact the use of renewable energy. Policies aimed at stimulating economic growth should, therefore, be a central component of strategies to increase renewable energy utilization. Furthermore, given that capital promotes the use of renewable energy in the long term, investments in renewable energy technologies and infrastructure are essential. Governments and financial institutions should foster favorable conditions for such investments through incentives and supportive regulatory frameworks.

As a final point, given the finding that financial globalization appears to diminish the use of green energy, as suggested by Padhan et al. [73], globalization can enhance a country's economic performance and influence energy consumption in diverse ways. For instance, according to the Pollution Haven Hypothesis, the impact of globalization on energy use is often mediated through direct investments. If foreign capital, channeled through multinational companies, preferentially supports traditional energy sectors rather than renewable energy, it could negatively impact the latter. To address this, it is recommended that governments refocus efforts on the renewable energy sector by implementing more effective incentives to attract foreign direct investment into green energy projects. Additionally, the empirical evidence indicates that the financial sector, which has expanded through financial globalization, has largely allocated its investments to fossil fuel-based energy production rather than renewable energy. To counter this trend, policymakers should consider strategies to encourage the financial sector to redirect its investments towards renewable energy initiatives, thereby supporting the transition to a more sustainable energy system.

We acknowledge several limitations of this study. It primarily examines total trade openness without analyzing the distinct effects of exports and imports on renewable energy consumption. Another limitation is the lack of comparative empirical findings, as economies with minimal renewable energy use were not included in the analysis. Additionally, the study does not differentiate between specific renewable energy sources, such as solar, wind, and bioenergy. Moreover, it does not provide country-specific insights, since estimation techniques like AMG and CCEMG were not employed. Addressing these limitations in future research could lead to more nuanced policy recommendations and a deeper understanding of the factors influencing renewable energy consumption.

Author Contributions: Conceptualization, B.J., S.S.S., B.A.T., M.Ç. and M.D.; methodology, M.Ç. and B.A.T.; software, B.A.T.; validation, M.Ç.; formal analysis, M.Ç.; resources, B.A.T. and M.D.; data curation, B.A.T. and M.D.; writing—original draft preparation, B.J. and S.S.S.; writing—review and editing, B.J. and S.S.S.; visualization, B.J.; supervision, B.J. and M.D.; and project administration, M.Ç., S.S.S. and B.A.T. All authors have read and agreed to the published version of the manuscript.

Funding: The APC was funded by The John Paul II Catholic University of Lublin, Poland.

Data Availability Statement: The data (variables) can be found at World Bank Open Data, https://data.worldbank.org, date of access: 10 September 2024; British Petroleum BP, https://www.bp.com/en/global/corporate/sustainability/data-and-how-we-report.html, date of access: 10 September 2024; KOF Swiss Economic Institute, https://kof.ethz.ch/en/forecasts-and-indicators/indicators/kof-globalisation-index.html, date of access: 10 September 2024.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

AMG	Average Marginal Gains
CADF	Cross-Sectionally Augmented Dickey–Fuller
CCEMG	Common Correlated Effects Mean Group
CSD	Cross-Sectional Dependence
DOLS	Dynamic Ordinary Least Squares
FMOLS	Fully Modified Ordinary Least Squares
GMM	Generalized Method of Moments
LSDVC	Least Squares Dummy Variable
OLS	Ordinary Least Squares
PMG	Pooled Mean Group
SDG	Sustainable Development Goals
SUR	Seemingly Unrelated Regression

References

1. Mishra, M.; Desul, S.; Santos, C.A.G.; Mishra, S.K.; Kamal, A.H.M.; Goswami, S.; Kalumba, A.M.; Biswal, R.; da Silva, R.M.; dos Santos, C.A.C.; et al. A Bibliometric Analysis of Sustainable Development Goals (SDGs): A Review of Progress, Challenges, and Opportunities. *Environ. Dev. Sustain.* **2023**, *26*, 11101–11143. [CrossRef] [PubMed]
2. Mensah, J. Sustainable Development: Meaning, History, Principles, Pillars, and Implications for Human Action: Literature Review. *Cogent Soc. Sci.* **2019**, *5*, 1653531. [CrossRef]
3. Figueres, C.; Le Quéré, C.; Mahindra, A.; Bäte, O.; Whiteman, G.; Peters, G.; Guan, D. Emissions Are Still Rising: Ramp up the Cuts. *Nature* **2018**, *564*, 27–30. [CrossRef]
4. Holechek, J.L.; Geli, H.M.E.; Sawalhah, M.N.; Valdez, R. A Global Assessment: Can Renewable Energy Replace Fossil Fuels by 2050? *Sustainability* **2022**, *14*, 4792. [CrossRef]
5. Johnstone, N.; Haščič, I.; Popp, D. Renewable Energy Policies and Technological Innovation: Evidence Based on Patent Counts. *Environ. Resour. Econ.* **2009**, *45*, 133–155. [CrossRef]

6. Jóźwik, B.; Tiwari, A.K.; Gavryshkiv, A.V.; Galewska, K.; Taş, B. Energy–Growth Nexus in European Union Countries During the Green Transition. *Sustainability* **2024**, *16*, 10990. [CrossRef]
7. Gyimah, J.; Yao, X.; Tachega, M.A.; Hayford, I.S.; Opoku-Mensah, E. Renewable Energy Consumption and Economic Growth: New Evidence from Ghana. *Energy* **2022**, *248*, 123559. [CrossRef]
8. Hassan, Q.; Viktor, P.; Al-Musawi, T.J.; Ali, B.M.; Algburi, S.; Alzoubi, H.M.; Al-Jiboory, A.K.; Sameen, A.Z.; Salman, H.M.; Jaszczur, M. The Renewable Energy Role in the Global Energy Transformations. *Renew. Energy Focus* **2024**, *48*, 100545. [CrossRef]
9. Vo, D.H.; Tran, Q.; Tran, T. Economic Growth, Renewable Energy and Financial Development in the CPTPP Countries. *PLoS ONE* **2022**, *17*, e0268631. [CrossRef]
10. Chen, Y.; Zhang, X. Does Financial Globalization Promote Renewable Energy Investment? Empirical Insights from China. *Environ. Sci. Pollut. Res.* **2023**, *30*, 101366–101378. [CrossRef]
11. Han, Z.; Zakari, A.; Youn, I.J.; Tawiah, V. The Impact of Natural Resources on Renewable Energy Consumption. *Resour. Policy* **2023**, *83*, 103692. [CrossRef]
12. Grossman, G.M.; Krueger, A.B. *Environmental Impacts of a North American Free Trade Agreement*; NBER Working Paper No. 3914; National Bureau of Economic Research: Cambridge, MA, USA, 1991; pp. 1–39.
13. Baye, R.S.; Olper, A.; Ahenkan, A.; Musah-Surugu, I.J.; Anuga, S.W.; Darkwah, S. Renewable Energy Consumption in Africa: Evidence from a Bias Corrected Dynamic Panel. *Sci. Total Environ.* **2021**, *766*, 142583. [CrossRef] [PubMed]
14. Lin, B.; Omoju, O.E.; Okonkwo, J.U. Factors Influencing Renewable Electricity Consumption in China. *Renew. Sustain. Energy Rev.* **2016**, *55*, 687–696. [CrossRef]
15. Lu, Z.; Gozgor, G.; Mahalik, M.K.; Padhan, H.; Yan, C. Welfare Gains from International Trade and Renewable Energy Demand: Evidence from the OECD Countries. *Energy Econ.* **2022**, *112*, 106153. [CrossRef]
16. Li, R.; Leung, G.C.K. The Relationship between Energy Prices, Economic Growth and Renewable Energy Consumption: Evidence from Europe. *Energy Rep.* **2021**, *7*, 1712–1719. [CrossRef]
17. Hoa, P.X.; Xuan, V.N.; Thu, N.T.P. Determinants of the Renewable Energy Consumption: The Case of Asian Countries. *Heliyon* **2023**, *9*, e22696. [CrossRef] [PubMed]
18. Salim, R.A.; Rafiq, S. Why Do Some Emerging Economies Proactively Accelerate the Adoption of Renewable Energy? *Energy Econ.* **2012**, *34*, 1051–1057. [CrossRef]
19. Okada, K.; Samreth, S. Corruption and Natural Resource Rents: Evidence from Quantile Regression. *Appl. Econ. Lett.* **2017**, *24*, 1490–1493. [CrossRef]
20. Sharma, R.; Shahbaz, M.; Kautish, P.; Vo, X.V. Analyzing the Impact of Export Diversification and Technological Innovation on Renewable Energy Consumption: Evidences from BRICS Nations. *Renew. Energy* **2021**, *178*, 1034–1045. [CrossRef]
21. Ozcan, B.; Danish; Temiz, M. An Empirical Investigation between Renewable Energy Consumption, Globalization and Human Capital: A Dynamic Auto-Regressive Distributive Lag Simulation. *Renew. Energy* **2022**, *193*, 195–203. [CrossRef]
22. Bahmani-Oskooee, M.; Niroomand, F. Openness and Economic Growth: An Empirical Investigation. *Appl. Econ. Lett.* **1999**, *6*, 557–561. [CrossRef]
23. Cole, M.A. Does Trade Liberalization Increase National Energy Use? *Econ. Lett.* **2006**, *92*, 108–112. [CrossRef]
24. Lean, H.H.; Smyth, R. CO_2 Emissions, Electricity Consumption and Output in ASEAN. *Appl. Energy* **2010**, *87*, 1858–1864. [CrossRef]
25. Vural, G. Analyzing the Impacts of Economic Growth, Pollution, Technological Innovation and Trade on Renewable Energy Production in Selected Latin American Countries. *Renew. Energy* **2021**, *171*, 210–216. [CrossRef]
26. Jóźwik, B.; Topcu, B.A.; Doğan, M. The Impact of Nuclear Energy Consumption, Green Technological Innovation, and Trade Openness on the Sustainable Environment in the USA. *Energies* **2024**, *17*, 3810. [CrossRef]
27. Jebli, M.B.; Youssef, S.B. Output, Renewable and Non-Renewable Energy Consumption and International Trade: Evidence from a Panel of 69 Countries. *Renew. Energy* **2015**, *83*, 799–808. [CrossRef]
28. Ntanos, S.; Skordoulis, M.; Kyriakopoulos, G.; Arabatzis, G.; Chalikias, M.; Galatsidas, S.; Batzios, A.; Katsarou, A. Renewable Energy and Economic Growth: Evidence from European Countries. *Sustainability* **2018**, *10*, 2626. [CrossRef]
29. Bhattacharya, M.; Paramati, S.R.; Ozturk, I.; Bhattacharya, S. The Effect of Renewable Energy Consumption on Economic Growth: Evidence from Top 38 Countries. *Appl. Energy* **2016**, *162*, 733–741. [CrossRef]
30. Wang, Q.; Dong, Z.; Li, R.; Wang, L. Renewable Energy and Economic Growth: New Insight from Country Risks. *Energy* **2022**, *238*, 122018. [CrossRef]
31. Asiedu, B.A.; Hassan, A.A.; Bein, M.A. Renewable Energy, Non-Renewable Energy, and Economic Growth: Evidence from 26 European Countries. *Environ. Sci. Pollut. Res.* **2021**, *28*, 11119–11128. [CrossRef]
32. Dunning, T. Resource Dependence, Economic Performance, and Political Stability. *J. Confl. Resolut.* **2005**, *49*, 451–482. [CrossRef]
33. Hossain, F. Production of Clean Energy from Cyanobacterial Biochemical Products. *Strat. Plan. Energy Environ.* **2016**, *36*, 6–23. [CrossRef]

34. Al-Marhubi, F. Do Natural Resource Rents Reduce Labour Shares? Evidence from Panel Data. *Appl. Econ. Lett.* **2021**, *28*, 1754–1757. [CrossRef]
35. Shinwari, R.; Yangjie, W.; Payab, A.H.; Kubiczek, J.; Dördüncü, H. What Drives Investment in Renewable Energy Resources? Evaluating the Role of Natural Resources Volatility and Economic Performance for China. *Resour. Policy* **2022**, *77*, 102712. [CrossRef]
36. Awijen, H.; Belaïd, F.; Zaied, Y.B.; Hussain, N.; Lahouel, B.B. Renewable Energy Deployment in the MENA Region: Does Innovation Matter? *Technol. Forecast. Soc. Chang.* **2022**, *179*, 121633. [CrossRef]
37. Belaïd, F.; Elsayed, A.H.; Omri, A. Key Drivers of Renewable Energy Deployment in the MENA Region: Empirical Evidence Using Panel Quantile Regression. *Struct. Chang. Econ. Dyn.* **2021**, *57*, 225–238. [CrossRef]
38. Paramati, S.R.; Apergis, N.; Ummalla, M. Financing Clean Energy Projects through Domestic and Foreign Capital: The Role of Political Cooperation among the EU, the G20 and OECD Countries. *Energy Econ.* **2017**, *61*, 62–71. [CrossRef]
39. Islam, M.M.; Irfan, M.; Shahbaz, M.; Vo, X.V. Renewable and Non-Renewable Energy Consumption in Bangladesh: The Relative Influencing Profiles of Economic Factors, Urbanization, Physical Infrastructure and Institutional Quality. *Renew. Energy* **2022**, *184*, 1130–1149. [CrossRef]
40. Damette, O.; Delacote, P.; Del Lo, G. Households Energy Consumption and Transition toward Cleaner Energy Sources. *Energy Polic.* **2018**, *113*, 751–764. [CrossRef]
41. Rahman, M.M.; Sultana, N. Impacts of Institutional Quality, Economic Growth, and Exports on Renewable Energy: Emerging Countries Perspective. *Renew. Energy* **2022**, *189*, 938–951. [CrossRef]
42. Mikhaylov, A. Understanding the Risks Associated with Wallets, Depository Services, Trading, Lending, and Borrowing in the Crypto Space. *J. Infrastruct. Policy. Dev.* **2023**, *7*, 2223. [CrossRef]
43. Rafindadi, A.A.; Mika'Ilu, A.S. Sustainable Energy Consumption and Capital Formation: Empirical Evidence from the Developed Financial Market of the United Kingdom. *Sustain. Energy Technol. Assess.* **2019**, *35*, 265–277. [CrossRef]
44. Liu, P.; Rahman, Z.U.; Jóźwik, B.; Doğan, M. Determining the Environmental Effect of Chinese FDI on the Belt and Road Countries CO_2 Emissions: An EKC-Based Assessment in the Context of Pollution Haven and Halo Hypotheses. *Environ. Sci. Eur.* **2024**, *36*, 48. [CrossRef]
45. Shahbaz, M.; Lahiani, A.; Abosedra, S.; Hammoudeh, S. The Role of Globalization in Energy Consumption: A Quantile Cointegrating Regression Approach. *Energy Econ.* **2018**, *71*, 161–170. [CrossRef]
46. Akadiri, S.S.; Alkawfi, M.M.; Uğural, S.; Akadiri, A.C. Towards Achieving Environmental Sustainability Target in Italy. The Role of Energy, Real Income and Globalization. *Sci. Total Environ.* **2019**, *671*, 1293–1301. [CrossRef]
47. Hashemizadeh, A.; Ju, Y.; Abadi, F.Z.B. Policy Design for Renewable Energy Development Based on Government Support: A System Dynamics Model. *Appl. Energy* **2024**, *376*, 124331. [CrossRef]
48. Khan, R.U.; Saqib, A.; Abbasi, M.A.; Mikhaylov, A.; Pinter, G. Green Leadership, Environmental Knowledge Sharing, and Sustainable Performance in Manufacturing Industry: Application from Upper Echelon Theory. *Sustain. Energy Technol. Assess.* **2023**, *60*, 103540. [CrossRef]
49. Pesaran, M.H. General Diagnostic Tests for Cross Sectional Dependence in Panels. *SSRN Electron. J.* **2021**, *60*, 13–50. [CrossRef]
50. Pesaran, M.H.; Yamagata, T. Testing Slope Homogeneity in Large Panels. *J. Econ.* **2008**, *142*, 50–93. [CrossRef]
51. Pesaran, M.H. A Simple Panel Unit Root Test in the Presence of Cross-section Dependence. *J. Appl. Econ.* **2007**, *22*, 265–312. [CrossRef]
52. Kao, C. Spurious Regression and Residual-Based Tests for Cointegration in Panel Data. *J. Econ.* **1999**, *90*, 1–44. [CrossRef]
53. Westerlund, J.; Edgerton, D.L. A Panel Bootstrap Cointegration Test. *Econ. Lett.* **2007**, *97*, 185–190. [CrossRef]
54. Westerlund, J. New Simple Tests for Panel Cointegration. *Econ. Rev.* **2005**, *24*, 297–316. [CrossRef]
55. Mark, N.C.; Ogaki, M.; Sul, D. Dynamic Seemingly Unrelated Cointegrating Regressions. *Rev. Econ. Stud.* **2005**, *72*, 797–820. [CrossRef]
56. Dumitrescu, E.-I.; Hurlin, C. Testing for Granger Non-Causality in Heterogeneous Panels. *Econ. Model.* **2012**, *29*, 1450–1460. [CrossRef]
57. Majeed, A.; Wang, L.; Zhang, X.; Muniba; Kirikkaleli, D. Modeling the Dynamic Links among Natural Resources, Economic Globalization, Disaggregated Energy Consumption, and Environmental Quality: Fresh Evidence from GCC Economies. *Resour. Policy* **2021**, *73*, 102204. [CrossRef]
58. Usman, M.; Khalid, K.; Mehdi, M.A. What Determines Environmental Deficit in Asia? Embossing the Role of Renewable and Non-Renewable Energy Utilization. *Renew. Energy* **2021**, *168*, 1165–1176. [CrossRef]
59. Pedroni, P. Panel Cointegration: Asymptotic and Finite Sample Properties of Pooled Time Series Tests with an Application to the PPP Hypothesis. *Econom. Theory* **2004**, *20*, 597–625. Available online: https://www.jstor.org/stable/3533533 (accessed on 10 September 2024). [CrossRef]
60. Kim, J. Real Exchange Rates and Real Interest Differentials for Sectoral Data: A Dynamic SUR Approach. *Econ. Lett.* **2007**, *97*, 247–252. [CrossRef]

61. Danish; Baloch, M.A.; Mahmood, N.; Zhang, J.W. Effect of Natural Resources, Renewable Energy and Economic Development on CO_2 Emissions in BRICS Countries. *Sci. Total Environ.* **2019**, *678*, 632–638. [CrossRef]
62. Wang, Z.; Bui, Q.; Zhang, B. The Relationship between Biomass Energy Consumption and Human Development: Empirical Evidence from BRICS Countries. *Energy* **2020**, *194*, 116906. [CrossRef]
63. Bayar, Y.; Sasmaz, M.U.; Ozkaya, M.H. Impact of Trade and Financial Globalization on Renewable Energy in EU Transition Economies: A Bootstrap Panel Granger Causality Test. *Energies* **2020**, *14*, 19. [CrossRef]
64. Khan, Z.; Malik, M.Y.; Latif, K.; Jiao, Z. Heterogeneous Effect of Eco-Innovation and Human Capital on Renewable & Non-Renewable Energy Consumption: Disaggregate Analysis for G-7 Countries. *Energy* **2020**, *209*, 118405. [CrossRef]
65. Ahmadov, A.K.; van der Borg, C. Do Natural Resources Impede Renewable Energy Production in the EU? A Mixed-Methods Analysis. *Energy Policy* **2019**, *126*, 361–369. [CrossRef]
66. Churchill, S.A.; Inekwe, J.; Ivanovski, K.; Smyth, R. The Environmental Kuznets Curve in the OECD: 1870–2014. *Energy Econ.* **2018**, *75*, 389–399. [CrossRef]
67. Ulucak, R.; Danish; Ozcan, B. Relationship between Energy Consumption and Environmental Sustainability in OECD Countries: The Role of Natural Resources Rents. *Resour. Policy* **2020**, *69*, 101803. [CrossRef]
68. Bekun, F.V.; Alola, A.A.; Sarkodie, S.A. Toward a Sustainable Environment: Nexus between CO_2 Emissions, Resource Rent, Renewable and Nonrenewable Energy in 16-EU Countries. *Sci. Total Environ.* **2019**, *657*, 1023–1029. [CrossRef]
69. Sadorsky, P. Renewable Energy Consumption and Income in Emerging Economies. *Energy Policy* **2009**, *37*, 4021–4028. [CrossRef]
70. Omri, A.; Nguyen, D.K. On the Determinants of Renewable Energy Consumption: International Evidence. *Energy* **2014**, *72*, 554–560. [CrossRef]
71. Topcu, E.; Altinoz, B.; Aslan, A. Global Evidence from the Link between Economic Growth, Natural Resources, Energy Consumption, and Gross Capital Formation. *Resour. Policy* **2020**, *66*, 101622. [CrossRef]
72. Amri, F. Renewable and Non-Renewable Categories of Energy Consumption and Trade: Do the Development Degree and the Industrialization Degree Matter? *Energy* **2019**, *173*, 374–383. [CrossRef]
73. Padhan, H.; Padhang, P.C.; Tiwari, A.K.; Ahmed, R.; Hammoudeh, S. Renewable Energy Consumption and Robust Globalization(s) in OECD Countries: Do Oil, Carbon Emissions and Economic Activity Matter? *Energy Strat. Rev.* **2020**, *32*, 100535. [CrossRef]
74. Mohamed, H.; Jebli, M.B.; Youssef, S.B. Renewable and Fossil Energy, Terrorism, Economic Growth, and Trade: Evidence from France. *Renew. Energy* **2019**, *139*, 459–467. [CrossRef]
75. Uzar, U. Political Economy of Renewable Energy: Does Institutional Quality Make a Difference in Renewable Energy Consumption? *Renew. Energy* **2020**, *155*, 591–603. [CrossRef]
76. Shahbaz, M.; Topcu, B.A.; Sarıgül, S.S.; Vo, X.V. The Effect of Financial Development on Renewable Energy Demand: The Case of Developing Countries. *Renew. Energy* **2021**, *178*, 1370–1380. [CrossRef]
77. Hussain, J.; Khan, A.; Zhou, K. The Impact of Natural Resource Depletion on Energy Use and CO_2 Emission in Belt & Road Initiative Countries: A Cross-Country Analysis. *Energy* **2020**, *199*, 117409. [CrossRef]
78. Alam, M.M.; Murad, M.W. The Impacts of Economic Growth, Trade Openness and Technological Progress on Renewable Energy Use in Organization for Economic Co-Operation and Development Countries. *Renew. Energy* **2020**, *145*, 382–390. [CrossRef]
79. Sadorsky, P. Do Urbanization and Industrialization Affect Energy Intensity in Developing Countries? *Energy Econ.* **2013**, *37*, 52–59. [CrossRef]
80. Canh, N.P.; Schinckus, C.; Thanh, S.D. The Natural Resources Rents: Is Economic Complexity a Solution for Resource Curse? *Resour. Policy* **2020**, *69*, 101800. [CrossRef]
81. Riti, J.S.; Riti, M.-K.J.; Oji-Okoro, I. Renewable Energy Consumption in Sub-Saharan Africa (SSA): Implications on Economic and Environmental Sustainability. *Curr. Res. Environ. Sustain.* **2022**, *4*, 100129. [CrossRef]
82. Koengkan, M.; Poveda, Y.E.; Fuinhas, J.A. Globalisation as a Motor of Renewable Energy Development in Latin America Countries. *GeoJournal* **2019**, *85*, 1591–1602. [CrossRef]