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Impact of Trade and Financial Globalization on Renewable Energy in EU Transition Economies: A Bootstrap Panel Granger Causality Test

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Abstract: The globalized world has experienced significant environmental degradation together with raising global production and population. In this context, the employment of renewable energy use has become crucial for a sustainable environment and development. In the research, the mutual causality among renewable energy, trade and financial globalization, real GDP per capita, and CO_2 emissions in EU transition economies experiencing the integration with global economy was explored through bootstrap panel Granger causality test for the period of 1995–2015. The causality analysis revealed a unilateral causality from trade globalization to renewable energy in Estonia, Latvia, and Slovenia, and from renewable energy to trade globalization in Croatia and Lithuania. However, no significant causality between financial globalization and renewable energy was revealed. On the other side, a unilateral causality from CO_2 emissions to renewable energy in Lithuania and Slovenia, and from renewable energy to CO_2 emissions in Czechia, Hungary, and Latvia and a reciprocal causality between renewable energy to CO_2 emissions in Romania and Slovakia and a unilateral causality from real GDP per capita to renewable energy in Czechia, Romania, and Slovenia was discovered in the causality analysis.

Keywords: trade globalization; financial globalization; CO_2 emissions; real GDP per capita; renewable energy; bootstrap panel Granger causality; EU transition economies

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1. Introduction

Global production has increased considerably as of the Industrial Revolution. In turn, energy requirements have also increased considerably. The considerable increases in fossil fuel consumption have been experienced due to global production and population growth. However, sustainable economic development, environmental sustainability and health problems have accompanied the rising consumption of fossil fuels [1–3]. The aforementioned developments have directed countries towards renewable energy production regarding its sustainability and clean energy properties.

Renewable energy is a sustainable, replenishable and less carbon-intensive energy type derived from sources like wind, solar, hydropower, geothermal, bioenergy, and the ocean [4]. Although renewable energy production requires a high amount of investment and technology, countries have turned to renewable energy production. Thus the global renewable power production raised to 25.01 exajoules in 2019 from 0.18 exajoules in 1965 [5]. In this context, scholars and policy-makers have tended to explore the factors underlying renewable energy production. The studies have revealed real GDP per capita, financial openness, foreign direct investment inflows, trade openness, energy prices, stock market returns, energy dependence, human development, democracy, population, CO_2 emissions as the institutional, demographic and economic factors underlying the renewable energy [6–11].

The related empirical literature reveals that a few scholars had studied the influence of trade and financial globalization on renewable energy. However, both trade and financial globalization can contribute to renewable energy production and consumption through increases in production, technological transfer and financing provision. The study aims to contribute to the limited literature considering the gap in the relevant literature. In this regard, the paper aims to analyze the causality among trade and financial globalization, renewable energy, CO_2 emissions, real GDP per capita in the sample of eleven EU transition states during the period 1995–2015 through Kónya [12] causality test. The EU transition economies have begun to integrate with the global economy through an institutional and economic transformation as of the late 1980s. Furthermore, the EU transition economies experienced significant increases in share of energy from renewable sources in total energy as seen in Table 1. Therefore, we explore the causality between economic globalization indicators and renewable energy in sample of EU transition economies.

Table 1. Share of energy from renewable sources in total energy (%).

Country	1990 (World Bank, 2020a)	2009 (Eurostat, 2020)	2018 (Eurostat, 2020)
Bulgaria	1.91684851	12.005	20.528
Croatia	21.9231797	23.597	28.024
Czechia	3.57150703	9.978	15.15
Estonia	3.35607862	22.931	29.996
Hungary	3.85666956	11.674	12.489
Latvia	17.5696905	34.318	40.292
Lithuania	3.09677851	19.798	24.448
Poland	2.50148484	8.661	11.284
Romania	3.35576588	22.157	23.875
Slovakia	2.22533593	9.368	11.896
Slovenia	12.3519506	20.147	21.149

Source: Eurostat [13] and World Bank [14].

The paper's remaining sections are structured as follows: the next part briefly summarizes the related literature, the third part introduces the dataset and the methodological approach, and the fourth section conducts the applied analysis and the study ends up with the conclusions.

2. Literature Review

Renewable energy has become a significant energy source for a sustainable environment and development. Therefore, the determinants of renewable energy production have been widely explored in energy and environment economics. The related empirical literature has generally remained inconclusive, in other words, have reached mixed findings about the impact of institutional and economic variables on renewable energy for different country groups. We evaluate that this can mainly result from the use of samples with different characteristics and methods. Furthermore, the world experienced a considerable improvement in the globalization process. Most of the countries have integrated with global markets and can benefit from the positive aspects of globalization. However, a few researchers have centered on the interaction between globalization, economic globalization, and renewable energy. The scholars have generally used the globalization index in the limited relevant empirical literature, although globalization is a multifaceted process. This research focuses on trade and financial globalization on CO_2 emissions, considering the aforementioned issues.

In the literature about the impact of globalization on CO_2 emissions, Leitão [15] and Yazdi and Shakouri [16] found a reciprocal causality between globalization and renewable

energy. However, Padhan et al. [17] revealed a negative influence of economic globalization on renewable energy consumption, but Gozgor et al. [18] discovered a positive influence of economic globalization on renewable energy.

In this context, Leitão [15] analyzed the causality among globalization, CO_2 emissions, economic growth, and renewable energy in Portugal during the period 1970–2010 and discovered a reciprocal causality between globalization and renewable energy. On the other hand, Yazdi and Shakouri [16] researched the causality among globalization, trade openness, economic growth, and renewable energy consumption in Iran for the period of 1992–2014 through ARDL cointegration test and revealed a reciprocal causality between globalization, renewable energy consumption, and economic growth.

Padhan et al. [17] researched the effect economic globalization and economic growth on renewable energy consumption in OECD member states through quantile regression for the period of 1970–2015 and revealed a negative influence of economic globalization on renewable energy consumption, but a positive influence of real GDP per capita on renewable energy consumption. However, Gozgor et al. [18] reached the opposite conclusion for the nexus of economic globalization and renewable energy in the same sample through cointegration analysis.

In the empirical literature, the relationship between trade liberalization/trade and renewable energy has been explored and different causality directions between two variables have been revealed for the different countries. In this context, Sebri et al. [19] explored the interaction among trade openness, CO_2 emissions, economic growth, and renewable energy consumption in BRICS countries for the duration of 1971–2010 through VECM and a mutual causality between economic growth and renewable energy was discovered. On the other side, Rasoulinezhad and Saboori [9] explored the relationship among financial and trade openness, CO_2 emissions, economic growth, and renewable energy consumption in Commonwealth of Independent States over the 1992–2015 period through causality analysis and no significant causality between trade liberalization and renewable energy consumption, but a unilateral causality from financial openness to renewable energy consumption and a bilateral causality between renewable energy and economic growth was discovered.

Jebli et al. [20] explored the causality among trade openness, CO_2 emissions, economic growth, and renewable energy consumption in 22 Central and Southern American economies throughout 1995–2010 through panel VECM Granger causality and a unilateral causality from renewable energy to trade openness, CO_2 emissions, and economic growth was revealed in the short run, but a bilateral causality among renewable energy, trade openness, and CO_2 emissions in the long run. Zeren and Akkuş [21] examined the causality between trade openness, renewable energy consumption in top Bloomberg emerging economies over 1980–2015 period through the Dumitrescu and Hurlin [22] panel causality test and a mutual causality between trade liberalization and renewable energy was discovered.

On the other side, Murshed [23] researched the influence of trade openness on renewable energy consumption in South Asian Economies for 2000–2017 through causality and regression analyses and discovered that trade openness enhanced renewable energy consumption. Akar [24] reached a similar finding for Balkan countries. Alam and Murad [25] explored the influence of trade openness, economic growth on renewable energy consumption in 25 OECD states over 1970–2012 period through panel ARDL. They discovered a positive influence of trade liberalization and economic growth on renewable energy consumption. However, Lau et al. [26], Kumaran et al. [27], and Zhao et al. [28] reached conclusions suggesting a negative impact of trade openness on renewable energy.

Furthermore, some researchers have explored the influence of total trade or foreign trade volume on renewable energy. In this context, Aïssa et al. [29] researched the interaction among renewable energy consumption, trade, and output in eleven African countries through panel cointegration analysis. They revealed a positive long-run effect of trade on renewable energy, but no causality between renewable energy consumption and trade or

output. Kim and Kim [30] also explored the relationship between renewable energy and international trade and discovered a positive effect of international trade on renewable energy. Jebli and Youssef [31] also conducted research on the mutual interaction among foreign trade, CO_2 emissions, economic growth, and renewable energy consumption in Tunisia over 1980–2009 period through causality analysis and a unilateral causality from trade, GDP, CO_2 emissions, to renewable energy has been discovered.

Jebli et al. [32] researched the interaction between trade and renewable energy in OECD member states over the duration of 1980–2010 and a unilateral causality from trade to renewable energy was discovered. Tiba et al. [33] also analyzed the interaction among foreign trade, renewable energy, environment, and economic growth in 24 middle and high income countries and a unilateral causality from foreign trade to renewable energy, a mutual causality between CO_2 emissions and economic growth, between CO_2 emissions and renewable energy was discovered in high income countries. Furthermore, a mutual causality between trade/economic growth and renewable energy was discovered in middle-income countries.

Amri [34] explored the relationship among trade, economic growth, and renewable energy in 72 developed and developing countries for the duration of 1990–2012 through dynamic regression analysis and found a mutual causality between trade/income and renewable energy consumption. Liu et al. [35] analyzed the interaction among renewable energy, trade, and output in 15 Asia-Pacific countries over 1994–2014 period through cointegration and causality analyses and a unilateral short run causality from import to renewable energy and output and a mutual causality between renewable energy and output and a unilateral causality from international trade to renewable energy was discovered. Nathaniel and Khan [36] explored the interaction among trade, renewable energy, and ecological footprint in ASEAN countries for the period of 1990–2016 through cointegration and causality analyses, and no significant causality between trade and renewable energy was discovered.

The studies on the impact of GDP per capita and economic growth on renewable energy have reached mixed findings.

Alabi et al. [37] explored the causal interaction between economic growth and renewable energy consumption in Angola, Algeria, and Nigeria over the 1971–2011 period and disclosed a bi-lateral causality between two variables. Caruso et al. [38] reached similar findings for selected EU countries. However, Menyah et al. [39], Ocal and Aslan [40], and Bakirtas et al. [41] reached a significant causality from economic growth to renewable energy.

On the other side, Lin et al. [42] researched the determinants of the renewable electricity share in total electricity consumption in China for the 1980–2011 period and revealed a positive influence of economic growth on renewable electricity consumption. Lau et al. [26] researched the determinants of renewable energy consumption in Malaysia over the 1980–2015 period through ARDL approach and disclosed a positive influence of economic growth on renewable energy. Przychodzen and Przychodzen [43] explored the determinants of renewable energy consumption in 27 transition economies for the period of 1990–2014 and economic growth positively affected renewable energy production.

However, Mehrara et al. [44] explored the factors underlying renewable energy use in Economic Cooperation Organization countries during the period 1992–2011 and revealed a negative impact of economic growth on renewable energy use. Omoju [45] reached the same findings for China. Akar [24] explored the determinants of renewable energy in Balkan countries over the 1998–2011 period through regression analysis and disclosed a negative effect of economic growth on renewable energy consumption. Ergun et al. [10] researched the determinants of renewable energy consumption in Africa from 1990 to 2013 through regression analysis and revealed a negative impact of gross domestic product per capita on renewable energy production.

Some scholars explored the interaction between CO_2 emissions and renewable energy consumption and mainly revealed a positive impact of CO_2 emissions on renewable

energy. In this context, Omri and Nguyen [46] researched the impact of CO_2 emissions on renewable energy consumption in 64 countries during the 1990–2011 period through regression analysis and reached a positive impact of CO_2 emissions on renewable energy consumption. On the other side, Dogan and Seker [47] explored the determinants of CO_2 emissions in the EU and revealed a bilateral causality between CO_2 emissions and renewable energy.

Omri et al. [48] analyzed the determinants of renewable energy consumption in 64 countries through regression analysis and revealed the CO_2 emissions as a significant driver of renewable energy consumption. However, Paweenawat and Plyngam [49] researched the causality among CO_2 emissions, energy consumption, income, and renewable energy in Thailand over the 1986–2012 period through ARDL approach. They revealed no significant causality between CO_2 emissions and renewable energy in the short run.

3. Data and Econometric Methodology

The study explores the causal interaction among renewable energy, trade globalization, financial globalization, CO_2 emission, and real GDP per capita in EU transition economies for the duration of 1995–2015. Renewable energy is proxied by share of energy from renewable sources, trade globalization and financial globalization are respectively represented by indexes of trade globalization and financial globalization calculated on an annual basis by [50]. Trade globalization index is calculated based on exports and imports of goods and services, trade regulations, trade partner diversity, trade agreements, trade taxes, and tariffs. On the other side, the financial globalization index is calculated based on international investments in foreign direct investments, portfolio investments, international debt, international income payments, international reserves, international investment agreements, investment restrictions, and capital account openness [51]. Real GDP per capita is proxied by GDP per capita (constant 2010 US$) and CO_2 emissions are represented by CO_2 emissions (metric tons per capita) as seen in Table 2. The renewable energy data existed for the period of 1990–2015 in the database of World Bank and the period of 2009–2018 in Eurostat database. Therefore, the study period was specified as 1995–2015 regarding World Bank data [14] and all the variables were annual.

Table 2. Dataset definition.

Variables	Definition	Source
RNW	Share of energy from renewable sources (%)	World Bank [14]
TRGI	Trade globalization index	KOF Swiss Economic Institute [50]
FINGI	Financial globalization index	KOF Swiss Economic Institute [50]
GDP	GDP per capita (constant 2010 US$)	World Bank [52]
CO	CO_2 emissions (metric tons per capita)	World Bank [53]

The study sample consists of eleven transition states of EU. The programs Gauss 10.0 (APTECH Systems, Higley, Arizona, USA), EViews 10.0 (HIS Global, Irvine, California, USA), and Stata 14.0 (StataCorp LLC, TA, USA) were used for the empirical analysis. The average share of energy from renewable sources of the sample in the study duration was 16.35%. The average of trade and financial globalization indexes in the sample were 73.76 and 65.63, but three variables considerably varied among the cross-sections. On the other side, the average of real GDP per capita was 12,097 USD, but it varied very considerably among the countries. Lastly, the average CO_2 emissions were about 6.75 metric tons per capita as seen in Table 3.

Table 3. Main characteristics of the series.

Variables	Mean	Std. Dev.	Min	Max
RNW	16.34636	9.542929	3.106707	40.36562
TRGI	73.76266	10.54052	42.95188	91.06991
FINGI	65.6343	12.83061	33.496	87.16071
GDP	12097.59	4950.488	3784.204	25430.35
CO	6.755519	2.850889	2.682623	14.66803

In a selection of the panel causality tests, the presence of cross-sectional dependency and heterogeneity in the panel exhibits importance to obtain relatively more reliable results. In this context, disregarding the cross-sectional dependence would probably produce size and bias distortions in the analyses [54,55]. Furthermore, seemingly unrelated regression (SUR) would exceed ordinary least squares (OLS) by estimating the equation sets one by one [56] and in turn transforms the model in a way that the error terms become uncorrelated [56]. On the other side, the slope coefficients' heterogeneity is essential for causality analysis. The causality between two series by putting the panel's joint constraint is a robust null hypothesis [57]. Homogeneity presumption for panel parameters cannot include heterogeneity among the countries because of country-specific features [58].

In the pretests, the presence of cross-sectional dependency and heterogeneity for the series was discovered. Therefore, we investigated the causal interaction among the series through Kónya [12] bootstrap panel Granger causality test regarding cross-sectional dependency and heterogeneity. Konya [12] bootstrap causality test rests on SUR and critical values are calculated for each cross-section through bootstrapping. Therefore, stationarity of the series is not required and Granger causality test can be employed for each country in the panel through Konya [12] causality test. The test rests on the following SUR estimation of two equation sets:

$$\begin{aligned} y_{i,t} &= \alpha_{1,1} + \sum_{i=1}^{ty_1} \beta_{1,1,i} y_{1,t-i} + \sum_{i=1}^{lx_1} \gamma_{1,1,i} \chi_{1,t-i} + \varepsilon_{1,1,t} \\ y_{2,t} &= \alpha_{1,2} + \sum_{i=1}^{ly_1} \beta_{1,2,i} y_{2,t-i} + \sum_{i=1}^{lx_1} \gamma_{1,2,i} \chi_{2,t-i} + \varepsilon_{1,2,t} \\ y_{N,t} &= \alpha_{1,N} + \sum_{i=1}^{ly_1} \beta_{1,N,i} y_{N,t-i} + \sum_{i=1}^{lx_1} \gamma_{1,N,i} \chi_{N,t-i} + \varepsilon_{1,N,t} \end{aligned} \quad (1)$$

and:

$$\begin{aligned} \chi_{1,t} &= \alpha_{2,1} + \sum_{i=1}^{ly_2} \beta_{2,1,i} y_{1,t-i} + \sum_{i=1}^{lx_2} \gamma_{2,1,i} \chi_{1,t-i} + \varepsilon_{2,1,t} \\ \chi_{2,t} &= \alpha_{2,2} + \sum_{i=1}^{ly_2} \beta_{2,2,i} y_{2,t-i} + \sum_{i=1}^{lx_2} \gamma_{2,2,i} \chi_{2,t-i} + \varepsilon_{2,2,t} \\ \chi_{N,t} &= \alpha_{2,N} + \sum_{i=1}^{ly_2} \beta_{2,N,i} y_{N,t-i} + \sum_{i=1}^{lx_2} \gamma_{2,N,i} \chi_{N,t-i} + \varepsilon_{2,N,t} \end{aligned} \quad (2)$$

where the renewable energy is proxied y, trade globalization index is proxied by x in system 1; y denotes the renewable energy, x denotes the financial globalization index in system 2; y denotes the renewable energy, x denotes the CO_2 emissions in system 3; y denotes the renewable energy, x denotes the real GDP per capita in system 4. l is the length. In this context, a unilateral significant causality from x to y is revealed if not all the $\gamma_{1,j,i}$s are zero, but all $\beta_{2,j,i}$s are zero. On the other side, a significant unilateral causality from y to x is revealed if all $\gamma_{1,j,i}$s are zero, but not all $\beta_{2,j,i}$s are zero. Furthermore, a reciprocal

significant causality between x and y is revealed if neither $\gamma_{1,j,i}$s nor $\beta_{2,j,i}$s are zero. Lastly, no significant causality between x and y is revealed if all $\gamma_{1,j,i}$s and $\beta_{2,j,i}$s are zero.

4. Empirical Analysis

In the empirical analysis part of the study, first presence of cross-sectional dependency and heterogeneity were explored through relevant econometric tests. For this reason, the cross-sectional dependency test of LM, LM CD, and $LM_{adj.}$), which are respectively developed by [59–61] were conducted to question the cross-section independence, and the test results were introduced in Table 4. The null hypothesis (H_0 = cross-sectional independence) declined at a 5% significance level, and cross-sectional dependency among the series was discovered.

Table 4. Cross-sectional dependence tests' results.

Test	Test Statistic	Prob.
LM	76.23	0.0306
LM adj *	2.381	0.0173
LM CD *	4.248	0.0000

* two-sided test.

The homogeneity presence was explored through [62] homogeneity tests, and the results were introduced in Table 5. The null hypothesis asserting the presence of homogeneity was declined at 1% significance level, and the existence of heterogeneity was discovered. The results of both tests directed us to employ a causality test regarding cross-sectional dependency and heterogeneity.

Table 5. Homogeneity tests' results.

Test	Test Statistic	Prob.
$\widetilde{\Delta}$	9.015	0.000
$\widetilde{\Delta}_{adj.}$	10.571	0.000

The causal interaction among renewable energy, trade globalization, financial globalization, CO_2 emissions, and real GDP per capita in eleven EU transition economies for 1995–2015 was explored through bootstrap causality test and test results reported in Tables 6–9. The causality analysis between trade globalization and renewable energy presented in Table 6 and a unilateral causality from trade globalization to renewable energy in Estonia, Latvia, and Slovenia, and unilateral causality from renewable energy to trade globalization in Croatia and Lithuania was discovered. In theoretical terms, a significant causality between trade globalization and renewable energy is expected, considering the increases in the output and technological transfer resulting from trade globalization. Still, the causality direction can be changed depending on the countries' potential and approach towards renewable energy. In this context, Aïssa et al. [29], Rasoulinezhad and Saboori [9], and Nathaniel and Khan [36] revealed no significant causality between trade and renewable energy, but Sebri et al. [19], Amri [34], and Zeren and Akkuş [21] discovered a two-way causality between two variables. On the other side, Jebli and Youssef [31], Jebli et al. [32], Tiba et al. [33], and Liu et al. [35] revealed a unilateral causality from trade to renewable energy. Still, Jebli et al. [20] showed a unilateral causality from renewable energy to trade. Our findings revealed that trade globalization had a significant effect on the renewable energy in Estonia, Latvia, and Slovenia incompatible with Jebli and Youssef [31], Jebli et al. [32], Tiba et al. [33], and Liu et al. [35]. On the other side, a significant causality from renewable energy to trade globalization was revealed in Croatia and Lithuania incompatible with Jebli et al. [20].

Table 6. Causality analysis between renewable energy and trade globalization.

Countries	H_0: TRGI Is Not the Cause of RNW				H_0: RNW Is Not the Cause of TRGI			
	Wald St.	Bootstrap Critic Value			Wald St.	Bootstrap Critic Values		
		1%	5%	10%		1%	5%	10%
Bulgaria	8.8464	44.7627	24.2052	17.1286	7.3971	32.0311	16.2259	10.7983
Croatia	0.4123	32.8062	15.8140	10.7433	34.8960 **	37.9527	19.3220	12.9013
Czechia	0.7446	42.9621	20.6403	14.3989	5.4331	44.3254	23.2376	15.5162
Estonia	12.9861 *	35.4443	17.5990	11.6910	0.1451	30.4781	15.2729	10.5094
Hungary	7.8702	6.9005	26.1133	18.9257	0.1856	44.7453	22.4945	15.2530
Latvia	16.3657 **	22.5088	12.3336	8.2503	0.1588	35.5174	18.4655	12.3581
Lithuania	1.8563	40.3328	20.7102	14.1074	27.2157 **	30.5951	16.2497	11.0971
Poland	7.0130	55.5188	30.9381	22.0181	9.2569	47.9452	24.0374	16.7736
Romania	4.8904	32.9063	17.7028	12.0731	4.3656	42.0022	20.0110	13.4153
Slovakia	7.4813	45.3693	23.6163	16.0807	0.2603	40.0041	21.8501	15.0193
Slovenia	13.3336 *	36.0687	17.6316	12.1915	3.9083	39.0535	19.7149	13.3175

**, * indicates that it is respectively significant at 5%, 10%.

Table 7. Causality analysis between renewable energy and financial globalization.

Countries	H_0: FINGI Is Not the Cause of RNW				H_0: RNW Is Not the Cause of FINGI			
	Wald St.	Bootstrap Critic Value			Wald St.	Bootstrap Critic Value		
		1%	5%	10%		1%	5%	10%
Bulgaria	2.4116	41.7844	22.5821	5.4261	1.6362	32.3546	16.4587	11.0447
Croatia	0.3166	29.4784	15.6118	10.7328	0.3302	41.3339	21.2784	14.4160
Czechia	6.0159	30.6188	15.7428	10.8004	4.3581	34.3406	18.8492	12.7182
Estonia	0.4498	27.8959	13.8942	9.5116	0.9312	39.6911	20.1473	13.6960
Hungary	7.8604	37.6044	20.2577	14.3526	7.7433	36.3349	18.9620	12.7462
Latvia	3.2370	23.7755	12.1965	8.1950	0.5179	37.1669	18.8811	12.3706
Lithuania	0.1824	30.5119	15.4894	10.4238	2.3816	29.6871	15.8014	10.7737
Poland	4.9238	48.5862	25.8412	17.9884	1.4323	40.4925	22.3914	15.3243
Romania	2.2956	29.4947	16.6234	11.4730	0.2762	47.2754	24.9916	17.5495
Slovakia	3.4114	48.2462	24.2063	16.9555	0.4606	44.7273	23.7293	16.2438
Slovenia	4.6394	31.7152	16.2565	11.3121	0.5743	33.5498	17.9570	12.3690

Table 8. Causality analysis between renewable energy and CO_2 emissions.

Countries	H_0: CO_2 Emission Is Not the Cause of RNW				H_0: RNW Is Not the Cause of CO_2 Emission			
	Wald St.	Bootstrap Critic Value			Wald St.	Bootstrap Critic Value		
		1%	5%	10%		1%	5%	10%
Bulgaria	4.2209	28.3144	14.5398	9.6870	4.1849	27.78286	14.6908	0.1074
Croatia	2.3197	38.3059	20.2272	13.7559	0.5236	42.24757	20.1602	13.2400
Czechia	5.6996	34.8510	17.9577	12.1791	78.5323 ***	37.90574	21.2318	14.4659
Estonia	2.9785	30.7269	16.0333	10.4784	4.7461	30.11468	14.8927	9.8172
Hungary	1.5115	51.1984	26.7677	18.3740	16.4136 *	44.07672	23.8917	16.3845
Latvia	0.6672	29.4360	14.8573	9.6784	12.9507 *	36.25140	19.0939	12.5903
Lithuania	14.4073 **	26.7428	13.3773	8.7281	2.7378	28.31456	15.3157	10.0500
Poland	0.33374	28.9642	15.0131	10.1679	3.6145	43.67226	22.8993	15.7815
Romania	17.2924 **	27.7321	14.0219	9.7921	33.5551 **	38.07972	20.0294	13.6791
Slovakia	22.0571 *	43.8053	22.5734	15.8978	19.4469 *	39.57048	23.2065	16.4650
Slovenia	12.2983 *	32.5947	17.6888	11.5974	10.4034	44.19843	22.9981	16.2071

***, **, * indicates that it is respectively significant at 1%, 5%, 10%.

Table 9. Causality analysis between real GDP per capita and renewable energy.

Countries	H_0: GDP Is Not the Cause of RNW				H_0: RNW Is Not the Cause of GDP			
	Wald St.	Bootstrap Critic Value			Wald St.	Bootstrap Critic Value		
		1%	5%	10%		1%	5%	10%
Bulgaria	2.0464	50.8993	29.1946	20.1993	7.1154	53.3875	29.44463	20.8589
Croatia	0.4233	35.0795	18.5855	12.2062	0.4570	45.3903	22.44310	14.7866
Czechia	16.2285 *	37.6513	22.2228	15.8881	6.3666	51.3260	26.75393	18.8187
Estonia	3.4169	28.8198	14.9741	9.97130	10.5094	53.1987	28.49377	19.3129
Hungary	5.9984	57.1728	32.3425	22.8146	5.3495	31.1988	17.01013	11.6173
Latvia	4.6993	20.6217	10.4578	7.1282	0.8446	50.9055	25.71107	17.2067
Lithuania	1.8078	52.7100	30.2212	21.8787	6.9219	62.2689	35.59382	25.7880
Poland	24.0955	74.0902	43.6008	33.4240	2.8522	31.0150	15.81786	10.4976
Romania	23.5227 **	34.1308	18.6578	12.8874	3.9612	49.2939	7.18408	18.5251
Slovakia	16.0550	61.6467	35.6302	26.1593	10.8854	72.1978	39.51884	28.4645
Slovenia	14.2667 *	38.4524	19.4535	13.4619	0.4506	47.6993	24.63181	17.3053

**, * indicates that it is respectively significant at 1%, 5%, 10%.

The causality analysis between financial globalization and renewable energy presented in Table 7 revealed no significant causality between financial globalization and renewable energy. A significant causality from financial globalization to renewable energy is expected because it facilitates the countries to provide the funds in the international markets. Furthermore, Leitão [15] and Yazdi and Shakouri [16] revealed a reciprocal interaction between globalization and renewable energy.

The causality analysis between CO_2 emissions and renewable energy presented in Table 8 a unilateral causality from CO_2 emissions to renewable energy in Lithuania and Slovenia, and unilateral causality from renewable energy to CO_2 emissions in Czechia, Hungary, and Latvia and a reciprocal causality between renewable energy to CO_2 emissions in Romania and Slovakia. Theoretically, rising CO_2 emissions is one of the countries'

motivations to make renewable energy investments because renewable energy is a relatively more environmentally friendly energy type. Therefore, the use of renewable energy is expected to decrease CO_2 emissions. In this context, a significant causality between renewable energy and CO_2 emissions in Czechia, Hungary, Latvia, Romania, and Slovakia was compatible with the theoretical considerations and Jebli and Youssef [31], Tiba et al. [33], and Jebli et al. [20].

Lastly, the causality analysis between real GDP per capita and renewable energy introduced in Table 9 denoted a unilateral causality from real GDP per capita to renewable energy in Czechia, Romania, and Slovenia. A significant causality between real GDP per capita and renewable energy is expected because renewable energy development requires substantial investments, and increasing GDP raises the countries' energy requirement. However, significant causality from real GDP per capita to renewable energy was revealed for Czechia, Romania, and Slovenia incompatible with Jebli and Youssef [31], and Padhan et al. [17]. However, Sebri et al. [19], Jebli et al. [32], Yazdi and Shakouri [16], Amri [34], Rasoulinezhad and Saboori [9] revealed a mutual causality between economic growth and renewable energy consumption.

5. Conclusions

The serious environmental degradation and decreasing fossil fuel supplies have led policy-makers and scholars to seek alternative solutions for sustainable economic growth and the environment. In this context, renewable energy resources have become a critical option for decarbonization, together with the technological developments in renewable energy production and the countries head for renewable energy production. For example, the EU aims to meet 32% of energy requirements from renewable energy by 2030 to achieve the first climate-neutral continent by 2050. Therefore, the specification of the factors underlying renewable energy production has become crucial. In turn, determinants of renewable energy production/consumption have been extensively researched in the related literature. The scholars have generally reached conflicting findings of institutional and economic determinants of renewable energy production or consumption. However, the impact of economic globalization indicators on renewable energy has been explored by a limited number of scholars. Therefore, we researched the causality among economic globalization indicators, real GDP per capita, CO_2 emissions, and renewable energy in a sample of EU transition economies through bootstrap panel Granger causality test of Kónya [12] taking notice of heterogeneity and cross-section independence among the series.

The causality analysis revealed that trade globalization significantly influenced renewable energy in Estonia, Latvia, and Slovenia, which experienced significant renewable energy production progress. Still, no significant causality between financial globalization and renewable energy was revealed. The relevant theoretical considerations and empirical findings indicated that both trade and financial globalization significantly influence renewable energy and, in turn, renewable energy has a significant influence on trade. On the other side, a unilateral causality from CO_2 emissions to renewable energy was revealed in Lithuania and Slovenia, and unilateral causality from renewable energy to CO_2 emissions was discovered in Czechia, Hungary, and Latvia and a mutual causality between renewable energy and CO_2 emissions in Romania and Slovakia in compatible with relevant theoretical and empirical literature. Lastly, a unilateral causality from real GDP per capita to renewable energy in Czechia, Romania, and Slovenia was discovered.

The EU aims to meet 32% of energy requirements from renewable energy by 2030. The Czechia, Hungary, Poland, and Slovakia in EU transition economies especially should make a significant improvement to catch the target. However, renewable energy production needs relatively high investments. Therefore, all the EU countries, especially the countries in the question above, should benefit from trade and financial globalization to improve renewable energy production through technology and financing transfer. Future studies can focus on the mechanisms through which trade and financial globalization affect renewable energy production.

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