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Energy Transition in Non-Euro Countries from Central and Eastern Europe: Evidence from Panel Vector Error Correction Model

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Abstract: The countries of Central and Eastern Europe, from the non-euro area, have completed the process of economic transition before joining the European Union. Achieving a certain level of economic development and membership in the European Union have generated their involvement in a new transition process, namely the energy transition. Concerns about promoting the low carbon economy have become increasingly complex for those countries that are interested in the environmental impact of economic activity. This study aims to analyze the process of energy transition in the countries of Central and Eastern Europe on the basis of the causality relationship among specific variables for the period 1990–2018. The study is based on cross-sectional panel data and the panel vector error correction model (PVECM). The efforts made by these countries by joining the European Union have generated economic development, with positive effects being recorded on the protection of the environment, a fact due to the strict regulations adopted and rigorous implementation at the national level. Foreign capital had a positive impact on the transition to a low carbon economy because most of the FDI flows attracted by the non-euro countries in the CEE come from Western Europe, i.e., from EU member countries, located either among the founders or among the countries that joined during the first waves of union expansion. Membership in the European Union facilitates the energy transition process for the non-euro countries of Central and Eastern Europe, but the new geopolitical events generate the reconfiguration of the European strategy of considering the need to ensure energy security.

Keywords: renewable energy transition; non-euro area; panel data; Granger causality; VECM

1. Introduction

After the fall of communism, the countries of Central and Eastern Europe (CEE) were in a complex process of economic, environmental, social, and political metamorphosis, the efforts of the authorities being concentrated on the transition from the centralized economy to the market economy [1–4]. Some of them have succeeded and successfully completed the process of economic transition, with six of them joining the European Union (EU), as they had met the criteria imposed by European documents. The process of economic development is particularly complex, which is why not all CEE countries have joined the EU. In addition, failure to meet the convergence criteria set out in the Maastricht Treaty has led to the inclusion of CEE countries in the non-euro area [5–11]. Membership in the European Union generates challenges not only at the economic and social level but also at the level of environmental protection and promotion of sustainable development, with the energy transition towards a low carbon economy being one of the major objectives of the EU countries.

The opening of the national economies generated foreign capital inflows, differentiated by country, depending on the progress made in the transition to the market economy, the endowment with resources, or the extent of the privatization processes carried out by the public authorities [12–15]. In this way, foreign investors have set up private companies or taken over majority stakes in various companies, especially in the field of industry. Unfortunately, the interests of foreign companies have not always been compatible with the economic policy of the host countries, and the takeover of local companies has, in many cases, led to the deindustrialization of these economies [16,17] or the continuation and development of the activity, except for the lands they owned or for the equipment which was later sold for scrap iron [18].

Attractive sectors for foreign companies are the oil and gas industry as well as the energy industry, given the potential of the energy market. Market liberalization has generated not only the presence of foreign investors in the classical fields of the energy sector but also the emergence of companies involved in the production of renewable energy, which has led to a reduction in the concentration of this market [17,19,20]. Thus, the national industrial landscape in these countries was changed dramatically, and the decomposition and recomposition of industrial structures has been noticed by researchers [21,22]. Currently, these countries are in a process of energy transition, a fact generated by the European authorities' concerns of facilitating the transition to a low carbon economy to manage the challenges imposed by climate change [23–28]. Therefore, the countries of Central and Eastern Europe have completed the process of economic transition by joining the European Union and are currently in energy transition because reaching a certain level of development allows them to focus on concerns of a low carbon economy.

This study aims to analyze the process of energy transition in the countries of CEE that are not members of the euro area, namely Bulgaria, Croatia, Czechia, Hungary, Poland, and Romania. These countries were chosen by taking into account several considerations. All six countries were former communist countries which had a somewhat similar course in the process of transition to the market economy; their rates of economic development were different, and they joined the European Union in waves. In addition, in the period 1990–2020, these countries had similar economic and environmental paths, yet despite the progress made economically, institutionally, and politically, these countries do not meet the convergence criteria imposed by the Maastricht Treaty. As EU members, these countries assumed specific targets regarding sustainable development and are involved in the energy transition, a bold project that takes place through the promotion of the Energy Union launched in 2015. The CEE countries have an important renewable energy potential based on the fact that most of them achieved the targets set at the EU level for the share of renewable energy in consumption (20% until 2020). In order to meet the new targets established by the European Union, the member countries set up an integrated national energy and climate plan (NECP) for the period from 2021 to 2030. These plans have five pillars, namely greenhouse gas emissions reductions, energy efficiency, renewables, interconnections, and research and innovation.

Compared with other studies published in the international literature, the present research is differentiated because it is focused on a group of countries with a similar past economic development and, especially for the communist ones, the same concerns regarding the energy transition, considering the quality of members of the European Union (more precisely of the Energy Union). The energy transition process has certain specificities in these countries considering the deindustrialization process that these economies are going through after the fall of communism [17,18], the efforts to align with the standards promoted by the EU regarding sustainable development [27,29], impact of COVID-19 on economic activity [30] (Wang et al., 2022), the geopolitical context generated by the invasion of Ukraine by Russia, and the position of these countries taking into account the geographical location and dependence on energy resources in Russia. The need to ensure energy security will generate the reconfiguration of the energy transition process.

2. Literature Review

Given the economic, social, technological, and environmental challenges posed by the new energy transition, increasingly more studies are focusing on national, regional, and international efforts to move from fossil fuels to renewable energy [26,28,31,32]. Numerous researchers have focused on analyzing the impact of economic activity on environmental pollution, with multiple studies focusing on validating the Kuznets curve for different regions/countries/areas for different periods of time [33–43]. Lately, given the concerns of international political leaders regarding facilitating the energy transition, increasingly more scientific studies are using independent variables, such as conventional energy consumption, renewable energy consumption, energy intensity, energy efficiency, or energy innovation. Energy has, thus, become a common thread not only in human activity but also in scientific research, given the need for specialists and public authorities to find measures to help reduce the negative impact of energy production and consumption on the environment. The impact of the development of economic activity (under different aspects, such as the intensification of international trade, the change in the structure of foreign trade, urbanization, and the expansion of foreign capital) on energy consumption has been the subject of interesting studies that have been reported for certain groups of countries [44,45]. Therefore, the countries of CEE have completed the process of economic transition by joining the European Union and are currently in energy transition because reaching a specific level of development allows them to focus on concerns about low carbon economy [46].

In the literature, only a few studies have been identified that focus on the process of energy transition in which the countries of CEE are involved. Armeanu et al. (2019) developed research for eleven states from CEE over the period from 2000 to 2016 [47]. The results of the panel data estimations advocate for a non-linear relationship between renewable energy and economic growth and a long-run unidirectional causal relation from non-renewable energy to economic growth.

The study of Przychodzen and Przychodzen (2019) focused on 27 transition economies, from CEE and the Caucasus and Central Asia, for the period 1990–2014 [48]. A specific regression model was developed by Polish researchers in order to analyse the effects of different economic and political factors on renewable energy production. The reserchers concluded that renewable energy generation is positively influenced by factors such as higher economic growth, size of general government debt, rising level of unemployment, and implementation of the Kyoto protocol.

In order to analyse the relationship between economic growth and renewable energy consumption, Marinaș et al., 2019 focused their study on ten countries from CEE members of the European Union [49]. Specific statistical data were selected for the period 1990–2014, and the researchers used the auto-regressive and distributed lag (ARDL) modeling procedure. Despite some similarities among the selected countries, the results obtained revealed significant differences. For Romania and Bulgaria, gross domestic product and renewable energy consumption dynamics are independent, but for countries such as Lithuania, Hungary, and Slovenia, increasing renewable energy consumption generated economic growth.

The study of Simonescu (2021) focused on several new members of EU, such as Bulgaria, Slovakia, Slovenia, Czech Republic, Hungary, Romania and Poland [29]. The researcher used panel threshold and dynamic panel models, as well as vector error correction models, with data that was available for the period 1990–2019. The study used GHG emissions, GDP per capita, renewable energy consumption, foreign direct investment, gross inland energy consumption per capita, control of corruption index of economic freedom (corruption), human development index, and labour productivity. The author identified certain differences among the analyzed countries regarding the impact of different indicators on greenhouse gas emissions. An inverted N-shaped curve was detected between GDP and GHG, and a U-shaped renewable Kuznet curve was observed for selected countries, except for Poland.

Using parametric and semiparametric methods, the study of Butnaru et al., 2020 was developed for EU countries for the period 1960–2015 [50]. The research demonstrated the convergence of renewable energy consumption per capita for the selected countries, with fossil fuels being the most used energy in the short and medium run.

An interesting study run by Ćetković and Buzogány, 2019 focused on the position of the six countries from CEE (Hungary, Poland, Czech Republic, Bulgaria, Slovakia, and Romania) on EU energy-related legislation in the period of 2007–2018 [51]. The research is based on the position of the national officials in the Council of Ministers. No common regional positioning was detected for these countries. Even these countries are considered to be climate and energy policy laggards in the European Union, and the lack of regional coherence and the exclusive promotion of national interests has led to the adoption of bold goals for decarbonization at the EU level.

The interest on renewable energy transition has increased over time, and this is reflected in the large number of papers on this field. Filtering from the Web of Science platform regarding the studies on this theme, we found 15,026 papers published from 1981 until the present day. As shown in Figure 1, the number of published papers in the area illustrates a hyperbolical progression; there is a jump in the number of publications after 2013. Thus, there is a growing interest in the field, the main interest being on renewable energy.

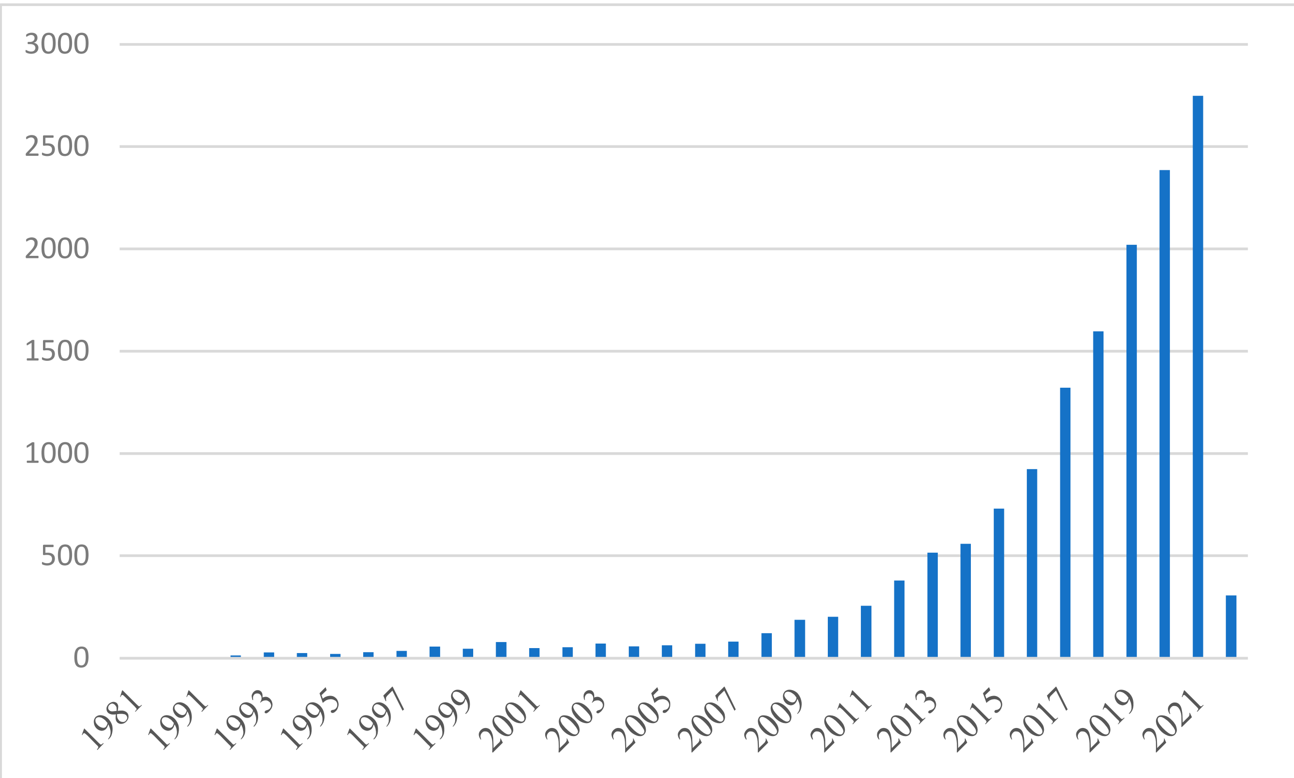


Figure 1. Dynamics on publications regarding renewable energy transition. Source: Authors' projection.

The studies conducted to analyze the impact of renewable resources on the energy transition process are increasingly more complex, both from the point of view of the statistical methods used as well as the variables used. Given the growing interdependencies among national economies as a result of globalization, increasingly more studies on the energy transition also take into account the impact generated by the intensification of trade and international capital flows. Foreign direct investment (FDI) has a significant impact on energy use both through the consumption it generates in the host countries as well as through the transfer of technology that transnational companies can make, which can determine a more rational use of fossil fuels and the promotion of renewable energy [52–55]. The intensification of international trade has generated an increase in national production and, thus, energy consumption, which is why many studies analyze the impact of trade on the use of conventional fuels and renewable energy for different periods and different levels (national, regional, or international) [56–60].

Taking in account the theoretical considerations presented by an in-depth literature review, carbon dioxide emission per capita is considered to be a proxy variable for renewable energy transition. Thus, the following research hypothesis has been defined in order to reach significant answers to our research aims:

Hypothesis 1. *GDP/capita, renewable energy consumption as percentage of total energy consumption, trade openness, FDI, and human development index cause carbon dioxide emission per capita in the CEE countries from the non-euro area over time.*

3. Data and Methodology

3.1. Methodology

To investigate the relationship among variables reflecting renewable energy transition over the time in the countries in the non-euro area, a panel VAR/VEC model was adopted. The vector autoregression (VAR) model was developed by Sims (1980) in order to analyze the dynamic response of the system as a result of shocks [61]. Its advantage does not depend on "incredible identification restrictions" inherent in structural models [62].

The VAR model represents a dynamic multivariate model aiming to treat a simultaneous set of variables equally, the endogenous variable being regressed on its own lags and the lags of all other variables considering a finite-order system.

In this study, the VAR (k) is modeled as:

$$y_t = \varphi + A_1 y_{t-1} + \ldots + A_i y_{t-k} + u_t \quad (1)$$

where y_t is a 6 × 1 vector including the variables of y_t, which are cointegrated as $y_t = [p_t, x_t, \ldots, b_t]$. A_i is a 6 × 6 parameter matrix, i = 1, ..., k. φ is an intercept vector. u_t is a 6 × 1 vector containing six error terms.

3.1.1. Testing Stationarity for Panel Data

Before beginning the estimation process, it is mandatory to pre-test the stationarity. For stationarity checking, the augmented Dickey–Fuller test (ADF) [63] can be used, but it registers a low power for rejecting the hypothesis of no stationarity, especially in the case of short-spanned data [64]. (Costantini and Martini, 2010). Recent panel unit root tests were introduced by Levin et al. (2002); LLC tests were introduced by Im et al. (2003); IPS tests by Breitung (2000); and BRT tests by Maddala and Wu (1999), Choi (2001), and Hadri (2000) [65–70].

The most popular tests used for checking stationarity are LLC and IPS; LLC considers homogeneity, and IPS considers heterogeneity of the autoregressive coefficients for all panel members, allowing for different orders of serial correlation through averaging the augmented Dickey–Fuller results [64].

In this study we have considered three unit root tests, namely LLC, ADF, and the Phillips–Perron test (PP) [71]. In order to investigate the existence of structural breaks, the robustness was checked both on single cross-sectional units and on the whole panel dataset.

3.1.2. Panel Cointegration

The cointegration analysis in the case of a single spatial series was significantly improved by the Pedroni panel cointegration technique (1999, 2000), allowing interdependence in the case of cross-sectional data with individual effects in the intercepts and slopes of the cointegrating equation [72,73]. According to Pedroni (1999), the time series panel regression can be written as follows [72]:

$$y_{i,t} = \alpha_t + \delta_i t + \beta_{1i}x_{1i,t} + \beta_{2i}x_{2i,t} + \ldots + \beta_{Mi}x_{Mi,t} + e_{i,t} \tag{2}$$

where t = 1, . . . , T; I = 1, . . . , N; and m = 1, . . . , M. T represents the number of observations over time, N represents the number of individual cases in the panel, and M represents the number of regression variables. According to Pedroni, there are seven statistics for testing the cointegration in case of panel data. Four statistics consider the within-dimension cointegration, and three statistics consider the between-dimension cointegration [74]. Another test used in case of panel cointegration is that of Kao (1999), namely the panel cointegration test [75]. Other tests used in the case of residual-based panel cointegration were introduced by Westerlund (2005), Persyn and Westerlund (2008), and Westerlund and Edgerton (2008) [76–78]. The Westerlund (2005) test refers to the variance ratio statistics, and does not require corrections for the residual serial correlations [77]. The Persyn and Westerlund (2008) test presents an error correction based on the cointegration test [76]. Westerlund and Edgerton (2008) considered the presence of structural breaks within the panel [78].

3.1.3. Granger Causality

The implementation of the panel VAR/VEC model is the result of both the cointegration test [79] and the fact that VAR/VEC considers all the variables as a priori endogenous, controlling the interactions between dependent and independent variables [80]. In this regard, Granger (1988) presented the causal effect of one variable on another, known as Granger causality, and it exists when an independent variable conduces predictions of the dependent variable [80,81].

In order to identify whether a cointegration exists and whether a long-run relationship exists among variables, Johansen's VAR procedure [82] and Pedroni's heterogeneous panel cointegration test were used. Using VECM, the causality is tested considering the procedure of Engle–Granger causality [83]. In our study, a panel-VECM with 5 independent variables was proposed for examining the causality between the variables, which can be written as follows:

$$\begin{aligned} CDE_{it} = c_{1i} + \textstyle\sum_{i=1}^{k} \alpha_{1ik} FDI_{it-k} + \sum_{i=1}^{k} \beta_{1ik} \Delta GDP_{it-k} + \sum_{i=1}^{k} \gamma_{1ik} \Delta RE_{it-k} + \\ \textstyle\sum_{i=1}^{k} \delta_{1ik} \Delta TO_{it-k} + \sum_{i=1}^{k} \varphi_{1ik} \Delta HDI_{it-k} + \varepsilon_{it} \end{aligned} \tag{3}$$

$$\begin{aligned} FDI_{it} = c_{2i} + \textstyle\sum_{i=1}^{k} \alpha_{1ik} CDE_{it-k} + \sum_{i=1}^{k} \beta_{1ik} \Delta GDP_{it-k} + \sum_{i=1}^{k} \gamma_{1ik} \Delta RE_{it-k} + \\ \textstyle\sum_{i=1}^{k} \delta_{1ik} \Delta TO_{it-k} + \sum_{i=1}^{k} \varphi_{1ik} \Delta HDI_{it-k} + \varepsilon_{it} \end{aligned} \tag{4}$$

$$\begin{aligned} \Delta GDP_{it} = c_{3i} + \textstyle\sum_{i=1}^{k} \alpha_{1ik} FDI_{it-k} + \sum_{i=1}^{k} \beta_{1ik} \mathrm{CDE}_{it-k} + \sum_{i=1}^{k} \gamma_{1ik} \Delta RE_{it-k} + \\ \textstyle\sum_{i=1}^{k} \delta_{1ik} \Delta TO_{it-k} + \sum_{i=1}^{k} \varphi_{1ik} \Delta HDI_{it-k} + \varepsilon_{it} \end{aligned} \tag{5}$$

$$\begin{aligned} \Delta RE_{it} = c_{4i} + \textstyle\sum_{i=1}^{k} \alpha_{1ik} FDI_{it-k} + \sum_{i=1}^{k} \beta_{1ik} \mathrm{CDE}_{it-k} + \sum_{i=1}^{k} \gamma_{1ik} \Delta GDP_{it-k} + \\ \textstyle\sum_{i=1}^{k} \delta_{1ik} \Delta TO_{it-k} + \sum_{i=1}^{k} \varphi_{1ik} \Delta HDI_{it-k} + \varepsilon_{it} \end{aligned} \tag{6}$$

$$\begin{aligned} \Delta TO_{it} = c_{5i} + \textstyle\sum_{i=1}^{k} \alpha_{1ik} FDI_{it-k} + \sum_{i=1}^{k} \beta_{1ik} \mathrm{CDE}_{it-k} + \sum_{i=1}^{k} \gamma_{1ik} \Delta RE_{it-k} + \\ \textstyle\sum_{i=1}^{k} \delta_{1ik} \mathrm{CDE}_{it-k} + \sum_{i=1}^{k} \varphi_{1ik} \Delta HDI_{it-k} + \varepsilon_{it} \end{aligned} \tag{7}$$

$$\begin{aligned} \Delta HDI_{it} = c_{6i} + \textstyle\sum_{i=1}^{k} \alpha_{1ik} FDI_{it-k} + \sum_{i=1}^{k} \beta_{1ik} \mathrm{CDE}_{it-k} + \sum_{i=1}^{k} \gamma_{1ik} \Delta RE_{it-k} + \\ \textstyle\sum_{i=1}^{k} \delta_{1ik} \Delta TO_{it-k} + \sum_{i=1}^{k} \varphi_{1ik} \Delta CDE_{it-k} + \varepsilon_{it} \end{aligned} \tag{8}$$

where Δ represents the first difference; $ECT_{\mathrm{t-1}}$ represents the lagged ECT; k represents the lag length; and $\varepsilon_{\mathrm{it}}$, υ_{it}, and $\varepsilon_{\mathrm{it}}$ represent the serially uncorrelated error terms. The direction of panel causations can be identified by testing the coefficients' significance of dependent variables in Equations (3)–(8) [74].

The panel data VECM methodology represents a mix between the traditional VAR approach and the panel-data approach. The VAR model considers all the variables in the system as endogenous, and panel data permits unobserved individual heterogeneity.

In the case where the variables of y_t are cointegrated, according to the cointegrating methodology of Johansen and Juselius (1992), a VECM can be estimated as [84]:

$$\Delta y_t = \prod y_{t-1} + \sum_{j=1}^{k-1} \Gamma_j \Delta y_{t-j} + \varepsilon_t \tag{9}$$

where Δy_t is a 6×1 vector that includes GDP, renewable energy consumption, trade openess, FDI, human development index, and carbon dioxide emission as $[\Delta p_t, \Delta x_t, \ldots, \Delta b_t]$. Γj represents the adjustment on short-run, and Πy_{t-1} represents the error correction term.

The error term ε_t is a vector of innovations that are independent and identically distributed [62]. The error correction term must be significant and negative to highlight the long-run causality [79]. Thus, error correction relates to the last period deviation from long-run equilibrium, influencing the short-run dynamics of the dependent variable [85]. To examine whether the variables are cointegrated, we used the likelihood ratio of maximal eigenvalue test and the trace test [86].

3.1.4. Panel DOLS Estimates

To estimate the regression equation, we considered FMOLS (fully modified OLS) [73], DOLS (dynamic OLS) [87], PMG (pooled mean group estimator) [88], GMM (generalized method of moments) or QML (quasi maximum likelihood). In the case of cointegration, the relationship on the long run can be estimated using the DOLS estimator [74,89,90].

3.2. Data

The variables reflecting renewable energy transition used annual data provided by the World Bank database over the time spanning from 1990 to 2018 (Table 1). The length of the period is dictated by the availability of data on energy consumption. Six countries are selected for the sample, representing the non-euro countries (Bulgaria, Czech Republic, Croatia, Hungary, Poland, and Romania). In order to draw an image of the status of renewable energy, most of the studies consider carbon dioxide emissions and renewable energy consumption as the core variables [91–95]. According to the extant literature, the economic development significantly influences the status of renewable energy. The level of economic development leading to renewable energy transition is usually reflected through investments [96–98], GDP [99–102], human development [103–105], and trade openness [106–108]. Therefore, the variables included in the analysis are carbon dioxide emission per capita (CDE), GDP/capita, renewable energy consumption as percentage of total energy consumption (RE), trade openness (TO), FDI, and human development index (HDI).

To examine the characteristics of the sample, the descriptive statistics were calculated and are presented in Table 2. Thus, the average CDE of the European countries in the sample in this study is 6.65 tonnes/capita, the lowest CDE is 3.12 tonnes/capita, and the highest CDE is 14.54 tonnes/capita with a standard deviation of 2.64 tonnes/capita. The average FDI is 4.61%, with the highest value of 54.24% and the lowest value of −40.33% and standard deviation of 8.41%. The medium GDP/capita is USD 15738.71, ranging from USD 4504.19 to USD 41143.09, with a standard deviation of USD 8156.46. The average renewable energy consumption as percentage of total energy consumption is 15.36%, with the lowest value being 1.92% and the highest value being 34.13%, with a standard deviation of 8.75%. HDI registers a mean of 0.78, ranging between 0.67 and 0.9, with a standard deviation of 0.06. Trade openness, the sum of trade as a percentage of GDP, varies between 43.72 and 168.24, with the mean value being 91.73 and a standard value of 32.84.

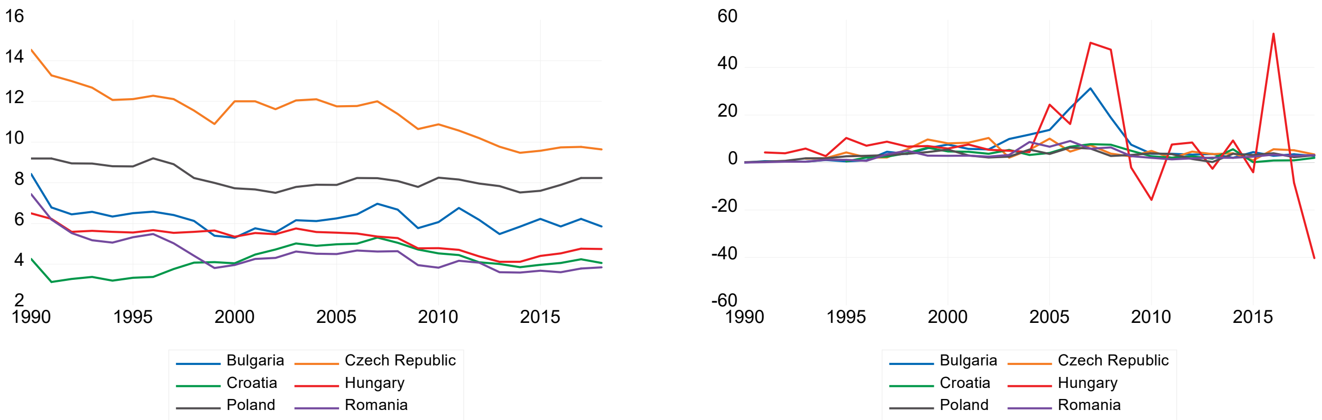
Table 1. Exhibition of the variables.

Variable	Description	Period	Source
CDE	Carbon dioxide emissions are the result of burning fossil fuels and the manufacturing of cement.	1990–2018	https://data.worldbank.org/indicator/EN.ATM.CO2E.PC
FDI	Net inflows represent the inward direct investment.	1990–2018	https://data.worldbank.org/indicator/BX.KLT.DINV.WD.GD.ZS
GDP	Gross domestic product (GDP) is reported to the size of the population.	1990–2018	https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD
RE	Renewable energy consumption represents the share of renewable energy from the total consumption.	1990–2018	https://data.worldbank.org/indicator/EG.FEC.RNEW.ZS
HDI	HDI is a composite index of human development.	1990–2018	https://databank.worldbank.org/Human-development-index/id/363d401b
TO	Trade represents exports and imports as a share of GDP.	1990–2018	https://data.worldbank.org/indicator/NE.TRD.GNFS.ZS

Table 2. Summary Statistics of Dependent and Explanatory Variables.

Statistics	CDE	FDI	GDP	RE	HDI	TO
Mean	6.65	4.61	15738.71	15.37	0.78	91.73
Min.	3.12	−40.33	4504.19	1.92	0.90	43.72
Max.	14.54	54.24	41134.09	34.13	0.67	168.24
Std. Dev.	2.64	8.41	8156.46	8.75	0.06	32.84

In Figure 2, it can be observed that all countries register an ascending trend regarding FDI, RE, FI, GDP, and HDI and a slightly descending trend regarding CDE, from which it can be concluded that all countries have taken measures to achieve the transition to renewable energy. The six countries are homogenous regarding the variables analyzed, not registering large differences among their dynamics.



CDE FDI

Figure 2. *Cont.*

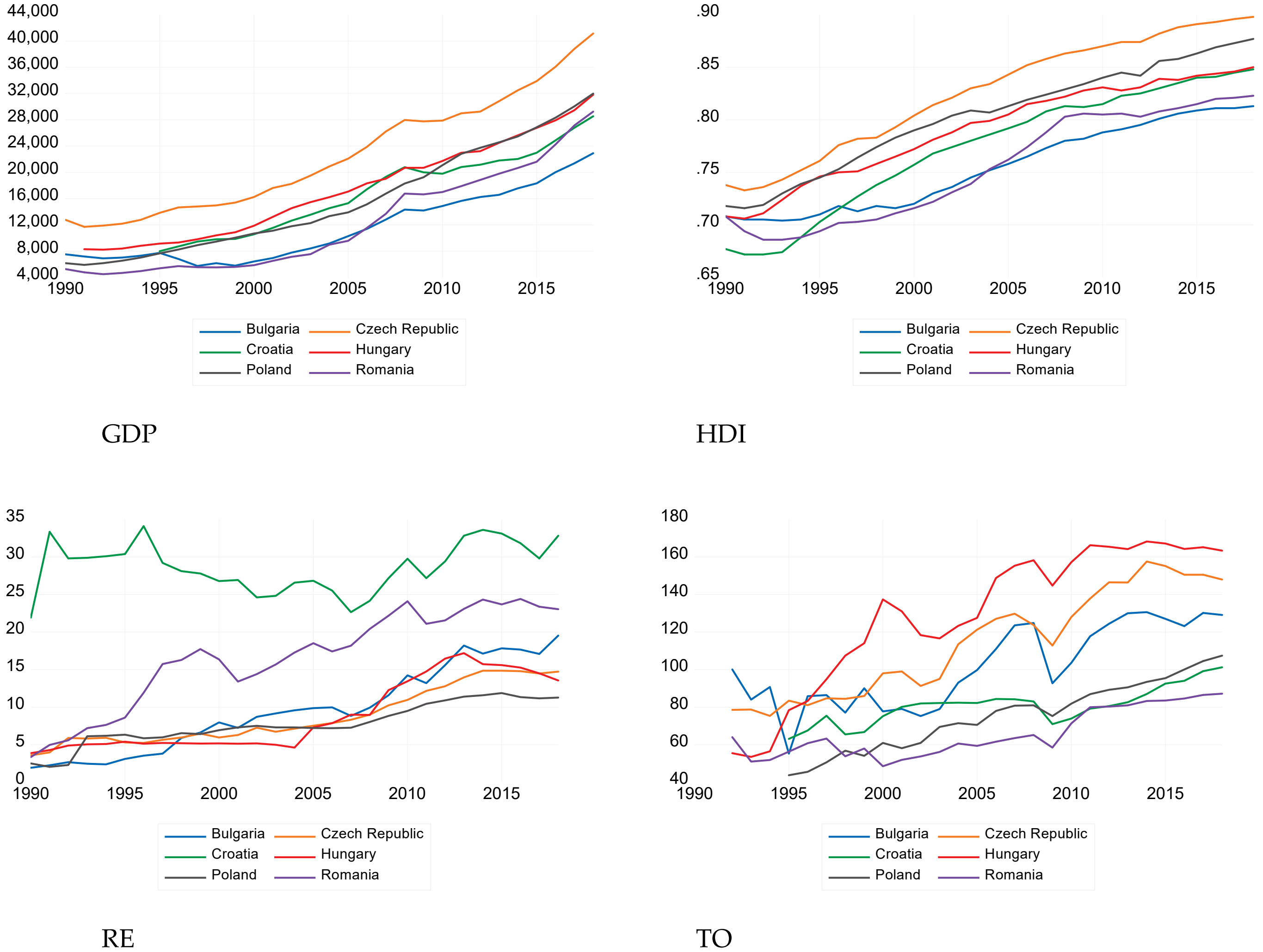


Figure 2. Trends regarding the variables reflecting renewable energy transition for the period 1990–2018. Source: Authors' projection, using Eview.

4. Empirical Results

In time series data, before beginning the analysis of cointegration and causality, the most important requirement is to check the stationarity [109]. In order to test the stationarity, we used Levin, ADT, and PP panel unit root tests for the full sample, the results being presented in Table 3. For four variables (GDP, RE, HDI, and TO), the null hypothesis of a unit root cannot be rejected, being nonstationary and integrated of order one. When structural breaks are considered, using Zivot and Andrews (1992) and Kwiatkowski et al. (1992) tests [110,111], we found that most of cross-sectional units are I(1) series and only few are I(0) in levels. Using the LM panel unit root test, we obtained stable results when considering series integrated of order one.

In order to test the existence of a long-run relationship, we used Pedroni's heterogeneous panel test and Johansen's tests [112]. The Johansen test results are presented in Table 4, indicating that in all countries except Czech Republic, the null hypothesis of no cointegration was rejected at the 10% significance level. In the case of renewable energy transition, Czech Republic does not exhibit a long-run relationship, while Bulgaria, Croatia, Hungary, Poland, and Romania do exhibit long-run relationships.

Table 3. Unit root tests for the full sample.

Variables	Levin—Lin and Chu		ADF—Fisher Chi-Square		PP—Fisher Chi-Square	
	Statistic	Prob.	Statistic	Prob.	Statistic	Prob.
			CDE			
Level	−3.33	0.0004 ***	28.26	0.0051 ***	26.85	0.0081 ***
			FDI			
Level	2.93	0.0017 ***	26.74	0.0084 ***	26.21	0.0100 ***
			GDP			
Level	12.74	1.0000	0.02	1.0000	0.00011	1.0000
First Difference	−15.99	0.0000 ***	191.88	0.0000 ***	224.66	0.0000 ***
			RE			
Level	3.82	0.9999	1.04	1.0000	0.83	1.0000
First Difference	−11.81	0.0000 ***	133.81	0.0000 ***	140.26	0.0000 ***
			HDI			
Level	12.49	1.0000	0.05	1.0000	0.01	1.0000
First Difference	−3.01	0.0013 ***	20.7	0.0500 **	34.51	0.0006 ***
			TO			
Level	4.27	1.0000	1.13	1.0000	0.71	1.0000
First Difference	−11.33	0.0000 ***	127.37	0.0000 ***	127.09	0.0000 ***

Note: ** indicates significance at the 5% level; *** indicates significance at the 1% level.

Table 4. Johansen's cointegration tests.

Country	H_0	Trace Statistics	Prob.	Country	H_0	Trace Statistics	Prob.
Bulgaria	None	60.3246	0.0960 *	Hungary	None	81.52	0.0008 ***
	At most 1	27.93	0.6262		At most 1	52.79	0.0039
Czech Republic	None	50.14	0.4076	Poland	None	81.22	0.0009 ***
	At most 1	30.46	0.4752		At most 1	34.58	0.2626
Croatia	None	67.60	0.0235 **	Romania	None	77.39	0.0024 ***
	At most 1	35.95	0.2081		At most 1	38.06	0.1407

Note: * represents significance at the 10% level; ** represents significance at the 5% level; *** represents significance at the 1% level [113].

In Table 5 are reported the results of the panel cointegration. Except for the Group ρ statistics for the full sample, all the statistics reject the null hypothesis of no cointegration for the sample. Hence, all six test statistics support a panel cointegration relationship among the variables.

Table 5. Heterogeneous panel cointegration results.

	Statistic	Prob.	Weighted Statistic	Prob.
Panel v	1.5383	0.0620 *	0.9761	0.1645
Panel ρ	−0.3419	0.3662	−0.0299	0.4881
Panel pp	−4.7129	0.0000 ***	−3.4082	0.0003 ***
Panel ADF	−4.7182	0.0000 ***	−0.5951	0.2759
Group ρ	0.8096	0.7909		
Group pp	−4.1510	0.0000 ***		
Group ADF	−4.1261	0.0000 ***		

Note: * indicates significance at the 10% level; *** indicates significance at the 1% level.

In the case of the Kao test, the cointegration is significant at the 1% level of significance (Table 6), confirming a panel cointegration relationship among the variables.

Thus, cointegration tests confirm the existence of a long-term relationships among CDE, GDP, FDI, HDI, RE, and TO in the six non-euro European countries. The p-value of 0.000 is less than 0.05; thus, the null hypothesis is rejected. This indicates that the long-run relationships exists among FDI, CDE, TO, GDP, CDE, and HDI. According to Pedroni's and Kao's residual cointegration tests, it is highlighted that variables are cointegrated in the long-term [114].

Table 6. Kao Test ADF.

	t-Statistic	Prob.
ADF	−4.9895	0.0000 ***
Residual Variance	0.1034	
Residual Variance	0.0982	

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

A panel vector error correction was conducted to see the convergence or the long-run causality. The cointegration equation and error correction revealed the long-run and short-run relationships among FDI, CDE, TO, GDP, CDE, and HDI.

In Table 7 is presented VECM, allowing us to identify short-term and long-term dynamic relationships among variables in the analysis. The variables with a negative sign and significant coefficient present a long-term relationship, and those with a negative sign but a non-significant coefficient present a short-term dynamic relationship. The results indicate a long-term relationship: the p-value is significant and amounts to 0.002%.

Table 7. The Long-Run and Short-Run Relationships.

Cointegrating Equation:	CointEquation (1)					
CDE(−1)			1.0000			
DGDP(-1)			−0.0048 (0.0032) [−1.4880]			
DHDI(−1)			−5.8374 (520.478) [−0.011]			
DRE(−1)			18.7188 (2.3329) [8.0239]			
DTO(−1)			1.5830 (0.4041) [3.9176]			
FDI(−1)			−1.1452 (0.2967) [−3.8605]			
C			−7.1369			
Error Correction:	D(CDE)	D(GDP)	D(HDI)	D(RE)	D(DTO)	D(FDI)
CointEq1	−0.0515 (0.0017) [−3.0841]	4.8829 (3.3478) [248.4671]	-1.64×10^{-6} (2.1×10^{-5}) [−0.0776]	−0.0402 (0.0072) [−5.6028]	−0.0824 (0.0477) [−1.7279]	0.1244 (0.0493) [2.5221]

Note: Standard errors in ( ) and t-statistics in [ ].

The error correction part represents the short-run relationship among variables. In the short run, when CDE lies above the long-term balance, the GDP and FDI will increase. A positive relationship between these variables in the short term indicates that the distribution of income and investments within a community group is unequal along with the increase in carbon dioxide emissions. As described earlier, in the long run, there is a negative relationship between CDE and GDP; in the short term, the relationship between the two variables is positive.

According to the result of PVECM above (Table 6), the cointegration equation of the variables is estimated as:

$$
\begin{aligned}
\text{D(CDE)} = {} & -0.00514751948054 \times \text{CDE}(-1) - 0.00481394966293 \times \text{DGDP}(-1) - 5.83742964978 \times \text{DHDI}(-1) + \\
& 18.7188391542 \times \text{DRE}(-1) + 1.5830023031 \times \text{DTO}(-1) - 1.14517261031 \times \text{FDI}(-1) - 7.13699144353) - \\
& 0.036777319216 \times \text{D(CDE}(-1)) - 0.304188452533 \times \text{D(CDE}(-2)) - 2.6766\text{w}8886627 \times 10^{-6} \times \text{D(DGDP}(-1)) - \\
& 3.61670141248 \times 10^{-5} \times \text{D(DGDP}(-2)) + 0.365300917573 \times \text{D(DHDI}(-1)) + 2.35080335289 \times \text{D(DHDI}(-2)) + \\
& 0.0549792019336 \times \text{D(DRE}(-1)) + 0.0182998305835 \times \text{D(DRE}(-2)) + 0.00767258447886 \times \text{D(DTO}(-1)) + \\
& 0.00238641318271 \times \text{D(DTO}(-2)) - 0.00221982795193 \times \text{D(FDI}(-1)) - 0.00344475574056 \times \text{D(FDI}(-2)) - \\
& 0.0529420314058.
\end{aligned} \tag{10}
$$

Equation (10) above provides the empirical evidence with respect to the long-run relationships among FDI, CDE, TO, GDP, CDE, and HDI. In the long run, there is a negative relationship between CDE and GDP, HDI, and FDI, but a positive relationship among CDE, TO, and RE. In other words, increasing carbon dioxide emissions in the non-euro European countries, in the long run, encourages the increase of trade openness and renewable energy share, and the decrease of GDP, HDI, and FDI.

In Table 8, the error correction term (ECT) is seen to be negative and significant (−0.0051), indicating convergence, but with dampened fluctuations [115].

Table 8. The Summary of The Panel Vector Error Correction Model (PVECM) Result.

Exogenous Variable	Endogenous Variable					
	D(CDE)	**D(GDP)**	**D(HDI)**	**D(RE)**	**D(DTO)**	**D(FDI)**
Coint Equation1	−0.0051 (0.0017) [−3.0841]	4.8829 (3.3478) [1.4585]	-1.64×10^{-6} (2.1×10^{-5}) [−0.0776]	−0.04016 (0.0072) [−5.6028]	−0.0824 (0.0477) [−1.7279]	0.1244 (0.0493) [2.5221]
D(CDE(−1))	−0.0368 (0.0976) [−0.3769]	248.4671 (195.680) [1.2698]	−0.0017 (0.0012) [−1.3588]	−0.1181 (0.4189) [−0.2819]	3.6178 (2.7857) [1.2987]	2.8008 (2.8837) [0.9713]
D(CDE(−2))	−0.3042 (0.0939) [−3.2395]	−333.9738 (188.348) [−1.7891]	−0.0028 (0.0012) [−2.3785]	0.6752 (0.4033) [1.6742]	−5.5992 (−2.6813) [−2.0882]	2.4260 (2.7757) [0.8740]
D(DGDP(−1))	2.68×10^{-6} (4.7×10^{-5}) [−00575]	−0.4135 (0.0933) [−4.4307]	5.82×10^{-8} (5.9×10^{-7}) [0.0988]	−0.0005 (0.0002) [−2.3940]	−0.0036 (0.0013) [−2.7187]	−0.0001 (0.0014) [0.0908]
D(DGDP(−2))	-3.62×10^{-5} (4.7×10^{-5}) 0.7695	−0,2302 (0.0943) [−2.4414]	4.45×10^{-8} (5.9×10^{-7}) [0.0749]	0.0003 (0.0002) [1.3632]	−0.0039 (0.0013) [−2.9463]	−0.0003 (0.0014) [2.5059]
D(DHDI(−1))	0.3653 (6.6272) [0.055]	880.0882 (13292.9) [0.0662]	−0.4109 (0.0838) [4.9025]	32.8285 (28.4614) [1.1534]	439.2954 (189.238) [2.3214]	253.3226 (195.897) [1.2931]
D(DHDI(−2))	2.3508 (6.2056) [0.3788]	14215.29 (12447.3) [1.1420]	−0.1535 (0.0785) [−1.9553]	9.0937 (26.6509) [0.3412]	128.2871 (177.200) [0.7239]	−90.3354 (183.435) [−0.4925]
D(DRE(−1))	0.0549 (0.0259) [2.1169]	−114.6060 (52.0921) [−2.20007]	-2.42×10^{-5} (0.0003) [−0.0737]	−0.1032 (0.1115) [−0.9255]	1.2879 (0.7416) [1.7367]	−1.4869 (0.7677) [−1.9369]
D(DRE(−2))	0.0183 (0.0154) [1.1895]	−53.2202 (30.8580) [−1.7247]	−0.0004 (0.0002) [−2.0982]	−0.0482 (0.0661) [−0.6990]	0.5235 (0.4393) [1.1916]	−0.6676 (0.4548) [−1.4681]
D(DTO(−1))	0.0077 (0.0036) [2.1605]	−5.6168 (7.1232) [−0.7885]	3.07×10^{-5} (4.5×10^{-5}) [−0.6829]	0.0509 (0.0153) [3.3385]	−0.6435 (0.1014) [6.3461]	−0.0157 (0.1049) [−0.1500]
D(DTO(−2))	0.0024 (0.0030) [0.7887]	−1.7762 (6.0692) [−0.2927]	1.89×10^{-5} (3.8×10^{-5}) [0.4928]	0.0412 (0.0129) [3.1681]	−0,2096 (0.0864) [−2.4260]	0.0892 (0.0894) [0.9971]
D(FDI(−1))	−0.0022 (0.0032) [−0.7048]	3.4302 (6.3176) [0.5429]	7.73×10^{-5} (4×10^{-5}) [1.9399]	−0.0322 (0.0135) [−2.3842]	−0.1827 (0.8994) [−2.0317]	−0.3090 (0.0931) [−3.3195]
D(FDI(−2))	−0.0034 (0.0037) [−0.9358]	3.8556 (7.3837) [0.5222]	8.2×10^{-5} (4.7×10^{-5}) [1.7619]	−0.0196 (0.0158) [−1.2378]	−0.3528 (0.1051) [−3.3562]	−0.4176 (0.1088) [−3.8379]
C	−0.0529 (0.0271) [−1.9551]	100.8955 (54.3167) [1.8575]	−0.0003 (0.0003) [−0.9836]	0.0348 (0.1163) [0.2992]	0.8974 (0.7733) [1.1606]	0.0652 (0.8005) [0.0814]

Regarding the causality relationship among the variables, the result of PVECM reveals that GDP and FDI have a negative and significant effect CDE at the one-year horizon and two-year horizon, and the other variables have a positive impact on CDE. The result of the PVECM, which explains the causality relationship among variables, can be seen in Table 8.

Using the impulse response function, the variables response to CDE is fluctuating. The reaction of each endogenous variable to the structural shocks occurring in the exogenous variables is shown in Figure 3 below.

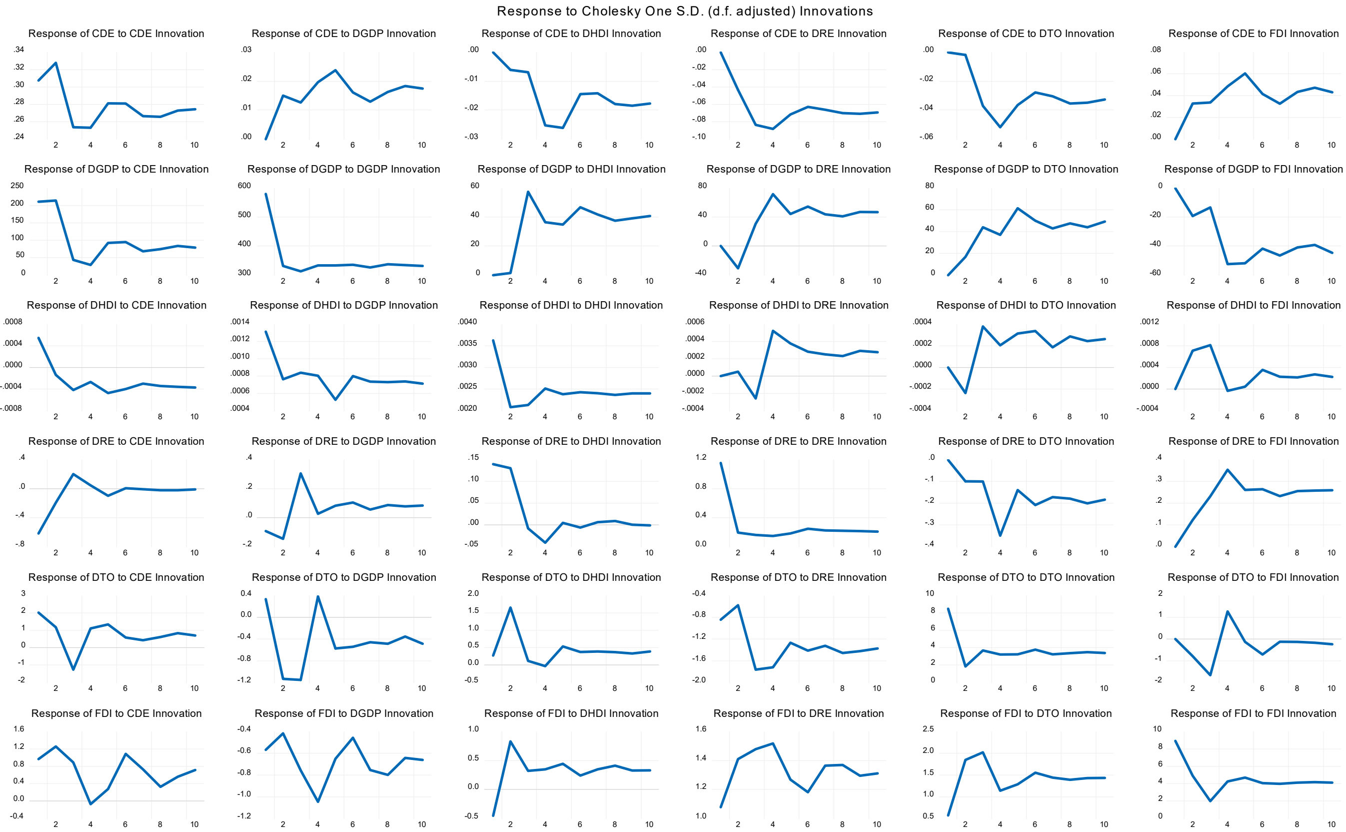


Figure 3. Impulse Response Function.

The Granger causality test is used to determine the causal relationship among variables, and the test results are presented in Table 9.

Table 9. The result of VAR Granger Causality/Block Exogeneity Wald Test.

Dependent Variable	Dependent Variable Excluded					
	D(CDE)	D(DGDP)	D(DHDI)	D(DRE)	D(DTO)	D(FDI)
D(CDE)		0.6442 (0.7246)	0.1457 (0.9297)	4.5015 (0.1053)	5.5941 (0.0610)	0.9698 (0.6157)
D(DGDP)	4.8957 (0.086)		1.3649 (0.5054)	5.0669 (0.0795)	0.7405 (0.6906)	0.3883 (0.8235)
D(DHDI)	7.3905 (0.0248)	0.0116 (0.9942)		6.776 (0.0338)	2.2274 (0.3283)	4.7151 (0.0947)
D(DRE)	2.9003 (0.2345)	11.2895 (0.0035)	1.3317 (9.5138)		12.5853 (0.0018)	5.7075 (0.0576)
D(DTO)	6.1459 (0.0463)	11.9063 (0.0026)	5.4011 (0.0672)	3.0412 (0.2186)		11.5568 (0.0031)
D(FDI)	1.6775 (0.4322)	0.0729 (0.9642)	2.4250 (0.2975)	3.8757 (0.1440)	2.3225 (0.3131)	

Note: The number in parenthesis ( ) is a probability value.

On the basis of the *p*-value, we conclude that there is statistical significance at the critical value level of 10%, which means that there is a bidirectional relationship or causality between TO and CDE in the long run [116] and unidirectional relationships from GDP to CDE and from HDI to CDE. Conversely, there is no causality running from CDE to GDP or HDI in the case of countries in non-euro area. This information is important because it tells us that the GDP affects the reduction of CDE [112].

The results regarding GDP and CDE reflect a negative and significant relationship, similar to those found in the literature [117–123]. Although the relationship expected in order to achieve renewable energy transition is negative, there are also studies in the literature in which this relation is positive, such as Tucker (1995), Chaabouni and Saidi (2017), and Cederborg and Snöbohm (2016) [124–126]. These studies suggested that a growing GDP leads to increased carbon dioxide emissions, as market economy mechanisms are not enough to lower the emissions. In this context, legal regulations are needed to avoid further environmental degradation because, as some theories claim, emissions start to decrease when a high enough GDP is reached.

The causality from trade openness and CO_2 emissions was found to be bilateral, confirmed also by Esty (2001), Mukhopadhyay (2007), Mukhopadhyay (2009), and Ertugrul et al. (2016) [57,127–129]. The improvement of globalization stimulates the dispersion of environmental technologies worldwide, promoting domestic environmental consciousness among firms and citizens [130]. However, there are studies in the literature, according to which the relationship between trade openness and Co_2 emissions is positive and insignificant [131,132].

The relationship between HDI and carbon dioxide emissions was found to be a unidirectional causality, as indicated in other studies by [133–138]. According to Ranis et al. (2000), there is no static link among these variables; a low HDI is not sustainable into the future, and policy reforms are necessary in order to help maintain at least this low level of human development [139].

FDI was negatively associated with carbon dioxide emissions, such as we found in studies by Tang and Tan (2015), Halicioglu (2009), Ahmed and Long (2012), Suri and Chapman (1998), Hossain (2011), Nahman and Antrobus (2005), Jorgenson (2007), Jorgenson (2009), and Ali et al. (2021) [54,56,140–144]. Although the relationship between FDI and carbon emissions is treated in various studies, the results are not conclusive. Thus, is necessary reinvestigating the association of these indicators for reliable empirical analysis [145].

5. Conclusions

The countries analyzed have made remarkable efforts to change the structures of production and the economic system, moving in 30 years from the centralized economy to the market economy, where their desire to join EU was essential for their development. The process of economic transition has been successfully completed for these countries with their accession to the European Union, but the challenges for them are not over. The necessity to promote the principles of sustainable development requires the entry of these countries into a new transition process, this time an energy transition that involves many changes in economic, social, technical, and environmental fields.

The main goal of this study was to analyze the causality relationship among variables reflecting the energy transition for six selected CEE countries from non-euro areas. The variables selected are carbon dioxide emission per capita (CDE), GDP/capita, renewable energy consumption as percentage of total energy consumption (RE), trade openness (TO), foreign direct investment (FDI), and human development index (HDI). For all selected countries, an ascending trend regarding FDI, RE, TO, GDP, and HDI and a slightly descending trend regarding CDE can be observed for the period of 1990–2018, showing that these economies, as members of European Union, have taken measures to achieve the transition to renewable energy. The six countries are homogenous regarding the variables analyzed, not registering large differences among their dynamics.

Using cross-sectional panel data and employing the panel vector error correction model (PVECM), the key conclusions of the study are as follows: (1) there is a long-run relationship among FDI, CDE, TO, GDP, CDE, and HDI; (2) in the long-run, the CDE is negatively and significantly related to GDP and FDI and positively related to TO and HDI; (3) there is a unidirectional causality running from GDP to CDE and from HDI to CDE and a bidirectional causality between TO and CDE.

The efforts made by these countries by joining the European Union have generated economic development, with positive effects also being recorded on the protection of the environment, a fact due to the strict regulations adopted and rigorous implementation at the national level. Foreign capital had a positive impact on the transition to a low carbon economy because most of the FDI flows attracted by the non-euro countries in the CEE come from Western Europe, i.e., from EU member countries, located either among the founders or among the countries that joined during the first waves of union expansion. As the development progresses, the negative impact of economic activity on the environment is also observed in these countries, with the liberalization of trade and capital movements generating the increase of production capacities. The openness of these countries' economies to foreign direct investment has generated massive capital inflows, especially from European Union countries, with geographical proximity, the existence of common European values, and previous business ties being the main factors that generated significant financial flows in Central and Eastern Europe. The transfer of technology that has accompanied capital flows has not always been up to date, with foreign investors often relocating obsolete technology to countries in Central and Eastern Europe that no longer meet the emission standards of their home countries.

The complexity of the energy transition process requires the involvement of all stakeholders; in addition to public authorities and local companies, an essential role can be played by foreign capital, which can bring high-performance technology and know-how to Central and Eastern European countries. In this way, implementation of energy innovation and an increase in the acceptance of renewable energy among consumers can be achieved. Raising living standards increases consumers' awareness of their role in the transition process and their involvement in the process of saving energy, avoiding the Jevons effect, and using green energy.

The energy transition must be carried out in conditions of energy security, and the military conflict in the area (Ukraine) generated a reconfiguration of the priorities of these countries regarding the use of different energy sources. The need to reduce gas dependence on Russia has led to a reconsideration of the use of coal in the energy mix as well as other energy sources. This proves the fragility of the ambitious objectives set by the European Union and implicitly the six countries analyzed as well as the importance of geostrategic competence in shaping the energy mix in the coming decades.

The study shows the importance of a unitary legal and institutional framework that facilitates both economic growth and the transition to a low carbon economy, where an important role is the foreign capital that comes from developed countries which brings to the host countries not only financial resources but also know-how, a certain organizational culture, and a new approach to business strategy under the banner of sustainable development.

The limitations of the research are given by the selection of the number of countries, by the indicators used as independent variables, and by the period chosen for the analysis. In the future, this research could be extended to all former communist countries in Europe and the analysis period extended to better capture the efforts made by these countries in both the process of economic transition and the process of energy transition. Other indicators, such as natural gas consumption per capita, can be taken as independent variables to capture the energy dependence of these countries on Russia—with which they had a special economic and political relationship during the communist period—and their reorientation towards increasing energy security, given the military context in the area.

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