Associate Professor Iuliana BOTHA, PhD
E-mail: iuliana.botha@ie.ase.ro
Associate Professor Ștefan Cristian GHERGHINA, PhD
E-mail: stefan.gherghina@fin.ase.ro
Associate Professor Liliana Nicoleta SIMIONESCU, PhD
E-mail: liliana.simionescu@fin.ase.ro
The Bucharest University of Economic Studies
Associate Professor Mihai Alexandru BOTEZATU, PhD
E-mail: botezatu.mihai.alexandru@profesor.rau.ro
Romanian-American University
Associate Professor Cristina COCULESCU, PhD
E-mail: coculescu.cristina@profesor.rau.ro
Romanian-American University

INVESTIGATING THE DRIVERS OF RENEWABLE ENERGY PRODUCTION: PANEL DATA EVIDENCE FOR CENTRAL AND EASTERN EUROPEAN COUNTRIES

Abstract. *The current study investigates the factors that influence the renewable energy production in Central and Eastern European countries (CEECs), over the period 1990-2019. The empirical research covers several types of renewable energy (renewables and biofuels, hydro, wind, solar photovoltaic, primary solid biofuels, biogases), along with driving factors such as GDP per capita, energy dependence, total natural resources rents, greenhouse gas emissions, unemployment, foreign direct investment flows and patent applications. Mixed linkages are supported by the results of panel data fixed- and random-effects regressions, as well as panel fully modified least squares. Also, the empirical results indicate long-run cointegration between the explored variables. Besides, panel causality analysis reveals several causal relationships between each type of renewable energy and the selected measures. These findings have implications for decision-makers in the public and private sectors who invest in renewable energy.*

Keywords*: renewable energy production, panel data fixed- and random-effects regressions, cointegration, panel fully modified least squares (FMOLS), panel causality.*

JEL Classification: C33, Q42

1. Introduction

In most of the developed countries the power consumption has constantly increased along with the evolution of the technological progress, the increasing living standards by accessing the electronic devices used at home, at work, while

DOI: 10.24818/18423264/56.1.22.01

on holidays, and by improving the access to the communication and communication technology, by increasing the level of culture and civilization of peoples and, not least, by the process of globalization. In these conditions, the electrical energy becomes extremely important, having an essential role regarding the welfare of society and the economic development in all countries of the world, being associated with the challenges of the sustainable development. However, the increased demand of the production of electrical energy brings along the danger of damaging the natural environment by greenhouse gas emissions and CO2 releases caused by the usage of fossil fuel (coal, oil, gas) (MacKenzie, 2003; Sadorsky, 2009).

On the other hand, worldwide, lately there has been an increased concern regarding the climate change, global warming, pollution, and the more and more problematic supply of the necessary fossils needed for the productions of electrical energy. As a result, the process of increasing the price of the fossil fuel determined by the risk of its vanishing from the market through an intensive consumption might cause an energy insecurity. In this regard, the stringent need to protect the environment imposed several sustainable activities of searching for alternative energy resources, renewable ones. Therefore, in all countries globally, supported research is conducted aiming to identify and develop renewable energy technologies (RE), which uses the natural resources provided by each country, individually (wind, water, sun, biogas), leading to the decrease of greenhouse gas emissions.

The technological process, the research field, the current renewable resources, the subsidy policies, the international and European Union (EU) regulations regarding the need for the production of renewable energy to be adopted, all these led to considerable achievements and concerns in this area. The EU set as one of the objectives that the share of the renewable energy resources (geothermal, solar, tidal, wind, biomass, biofuel, and hydroelectricity) regarding the electrical energy consumption to reach between 60-80% in the year 2050 (European Commission, 2011), and the wind and solar energy should be a priority. The increasing production of renewable energy (RE) must take place simultaneously with the reduction process of its dependency of fossil fuels that, by emitting carbon dioxide into the atmosphere, represents the main cause of environmental damage. Moreover, several researchers indicated that the development of RE technologies of a certain type, from one particular geographical area, influences, in a beneficial way, the nearby areas through the similarity effect regarding the potential to obtain renewable energy and through the process of scientific knowledge dissemination in this particular field (Shahnazi and Shabani, 2020).

Hence, the research in the filed becomes promoted by joining the common effort of more states to provide efficient production solutions, to innovate and exploit new technologies related to the renewable energy with beneficial effects over the neighboring regions. In recent years, the process of identifying the key factors of the production of renewable energy has become an important topic to be approached in the research domain. Therefore, governments of all countries are interested to influence the government policy in this field, especially by the economic transition countries from Central and Eastern Europe (CEE).

Notwithstanding the production and distribution process of the renewable energy, embedding all its facilities and constraints, the present paper aims to examine the factors that influence renewable energy production. Thus, for CEE nations, the study identifies and measures the impacts of several factors (such as GDP per capita growth, energy dependence, total natural resources rents, greenhouse gas emissions, unemployment, foreign direct investment flows, patent applications) over each type of renewable energy obtained from different natural sources (for instance renewables and biofuels, hydro, wind, solar photovoltaic, primary solid biofuels, biogases). The empirical findings offered to decision-makers, at a national or European level, may contribute to measures or normative acts, or to making decisions regarding the fiscal, economic, or social policies, to stimulate the production of the best RE suitable with the existing natural resources, according to the economic development of each area or geographical region.

The rest of this study is organized as follows. Section 2 presents the literature review in the domain. Section 3 is focused on the research methodology. Section 4 shows the outcomes of the empirical study. The final section draws the concluding remarks and formulates policy implications of the study.

2. Prior literature

Several studies have indicated that the economic development, the technological progress, and digitalization significantly influence the increase of the energy consumption and, implicitly, the expansion of the long-term energy need worldwide. Prior scientific research has revealed that the production process of electric energy obtained from fossil fuels leads to the emission of large quantities of carbon dioxide into the atmosphere, thus creating the environmental pollution. The above-mentioned reasons represent the core of a mandatory, quick and disseminate switch to renewable energy (RE).

Abundant literature has analyzed the level of direct influence of the RE consumption and production over the economic development (Gogu et al., 2021; Menegaki, 2011), but less studies analyzed the reversed relation, meaning the RE production dependency over the economic development measured by GDP/per capita. (Bamati and Raoofi, 2020) explores the determining factors of the RE demand of the following types: technological, economic, social, and environmental, along others throughout developing and developed nations. The study indicates that the level of economic development measured by using the GDP/per capita indicator has a positive impact over the development process of the sources of renewable energy, but it also underlines that the impact of the price of fossil fuel and CO2 emissions per capita has both a negative and a positive effect.

On the other hand, the economic growth, the increase of the GDP value, urbanization and financial development increase the CO2 emissions on long term (Sadorsky, 2009; Al-Mulali et al., 2015), urging more and more the implementation system of RE production based of nonpolluting natural resources. The study demonstrates that a big level of the GDP value secures revenue for promoting the renewable sources, while in the underdeveloped countries this is still limited due to the relatively high production costs. This bidirectional dependency is strongly influenced by investments coming from the renewable energy domain (Shah et al., 2018) as supported by the analysis conducted in Norway, UK, and USA. All these types of investments, along the research and development ones in the domain, technological innovation and CO2 emissions are investigated in the study (Irandoust, 2016) for the Nordic countries (Denmark, Finland, Norway, and Sweden) and indicates the degree of influence over the renewable energy. Besides, the CO2 emissions have a direct and positive impact over the RE consumption (Sadorsky, 2009; Acaravci et al, 2010; Lehmann et al, 2012), which will influence the increase of RE production, thus leading to the reduction of emissions (J. P. C. Bento, 2016).

Other studies approach an important factor that influence the RE production, namely the richness of natural resources, extremely varied spread in EU countries. Therefore, the study of (Ahmadov and Van der Borg, 2019) examines the impact of the richness of natural resources and of the excise rate on oil over the renewable sources and over the RE production in EU. By connecting the renewable sources to the richness of natural resource of each country, the study indicates that there is a direct and positive connection between the economic performance and the rate of success of the projects regarding the renewable energy, by influencing the direct costs and the skilling of the labor force. However, there are also obstacles regarding the development of RE production, such as the oil richness, which might drawback the expenses regarding the innovation process in the RE production field. By comparatively analyzing Netherlands and Belgium, the study indicates that the richness of the natural resources may be beneficial for the RE production process, if it is stimulated through government policies, fiscal policies, private investments, and innovation in the domain. Further studies (Zeb et al, 2014) included in the analyses the GDP rate and the indicators related to carbon dioxide emissions and the resource depletion in Nepal, along with factors such as the energy production and the poverty level in Bangladesh, India, and Sri Lanka. Another study in the domain (Przychodzen and Przychodzen, 2020) examines and establishes the various difference of the labor force, unemployment, CO2 emissions, inflation rate, the availability of the internal credit, public debts, and research expenditures over the RE production in the transition period of many types of economies.

Several studies (Ergun et al, 2019; Alper and Oguz, 2016) investigate for 21 countries from Africa the connection between the same influencing factors, where the dependent variable is represented by the energy consumption. The study of Vural (2021) explored the similar factors of influence over the RE production for 6 countries in Latin America, whereas the influence of the economic development and of the technological innovation process is analyzed through the impact over the RE consumption by (Alam and Murad, 2020). The study of (Khan et al., 2021) identifies and demonstrates the influence of funding, of the technological innovation, of the research and of foreign investments over the renewable and non-renewable energy, and of the environment in 69 countries.

Different studies explored the factors that may influence the consumption or the production of renewable energy, the highly polluting greenhouse gas emissions, the used fossil fuels with the high risk of increased costs, the economic development, investments, research and development process and innovation, unemployment rate, natural resources. However, there was not explored the dependency production related to RE for each type of used natural resource, considering the conditions when the renewable energy sources are presently extremely different, unequal distributed across regions and underexploited in EU countries.

3. Research methodology

3.1. Sample and variables

This research included panel data from Bulgaria, Czechia, Estonia, Latvia, Lithuania, Hungary, Poland, Romania, Slovenia, and Slovakia, which are all part of the Central and Eastern European Countries (CEECs). Table 1 has a detailed description of the variables, including a symbol, measurement unit, data source, and time availability. The entire set of variables has a common timeline of 1990 to 2019.

Table 1. Variables' presentation

Variables	Description	Unit of measurement	Source	Period availability
• *Dependent Variables*				
REN	Production of renewables and biofuels (log values)	Thousand tones of oil equivalent	Eurostat NRG_BAL_PEH	1990-2019
HYDRO	Production of hydro energy (log values)		Eurostat NRG_BAL_PEH	1990-2019
WIND	Production of wind energy (log values)		Eurostat NRG_BAL_PEH	1990-2019
SOLAR	Production of solar photovoltaic energy (log values)		Eurostat NRG_BAL_PEH	1990-2019
BIOF	Production of primary solid biofuels (log values)		Eurostat NRG_BAL_PEH	1990-2019
BIOG	Production of biogases (log values)		Eurostat NRG_BAL_PEH	1990-2019
• *Explanatory variables*				
GDP	GDP per capita growth	%	World Bank NY.GDP.PCAP.KD.ZG	1961-2020
ED	Energy dependence	%	Eurostat T2020_RD320	1990-2019
RENTS	Total natural resources rents	% of GDP	World Bank NY.GDP.TOTL.RT.ZS	1970-2019

GHG	Greenhouse gas emissions (log values)	Tones per capita	Eurostat SDG_13_10	1990-2019
UNEMPL	Unemployment	% of total labor force	World Bank SL.UEM.TOTL.ZS	1991-2020
FDI	Foreign direct investment, net inflows (log values)	BoP, current US$	World Bank BX.KLT.DINV.CD.WD	1970-2019
PAT	Patent applications (residents and nonresidents) (log values)	Number	World Bank IP.PAT.RESD IP.PAT.NRES	1980-2019

3.2. Econometric design

When using panel data methods with heterogeneity, the conventional assumption is that fixed constants should capture the variations between cross-sectional units. However, (Cui et al., 2022) suggested that certain variations of cross-sections can occur, but that ignoring them could lead to biased outcomes and therefore incorrect deductions. The following are the steps in our econometric approach: (1) checking for cross-sectional dependence and slope homogeneity, (2) stationarity analysis, (3) fixed-effects (FE) and random-effects (RE) regressions, (4) examining the long-term relationship between variables using the panel cointegration method, (5) in the case of cointegration confirmation, the FMOLS method is used to assess the long-term elasticity among the dependent and independent measures, and (6) panel causality analysis.

The cross-sectional independence hypothesis is commonly used in traditional estimation techniques. However, cross-sectional dependence might lead to imprecise and biased predicted results. Thus, before estimating the fixed and random effects regression models for panel data, we use Pesaran's cross-sectional dependence (CD) test – Pesaran (2004), alike (Shahnazi and Shabani, 2020) and Vural (2021). The CD test properly matches a panel with a small cross-sectional dimension and a short time length, as well as a panel with a large cross-sectional dimension and a long-time length. The following is how the CD test statistic is calculated:

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right) \quad (1)$$

where N reveals the number of countries, T is the timeframe, while $\hat{\rho}_{ij}$ signifies the cross-sectional correlation estimate of residuals of nations i and j. The null hypothesis states that cross-section units are independent. Furthermore, the alternative hypothesis indicates that countries are interdependent.

Additionally, because certain countries may share specific characteristics but differ in others, it is critical to ensure that the dataset is homogeneous. The slope homogeneity test of (Pesaran and Yamagata, 2008) is being used, alike (Khan et al., 2021), yielding the following statistics:

$$\tilde{S} = \sum_{i=1}^{N}(\beta_i - \beta_{WFE})'\,\frac{x_i' M_\tau x_i}{\sigma_i^2}(\beta_i - \beta_{WFE}) \quad (2)$$

$$\tilde{\Delta} = \sqrt{N}\left(\frac{N^{-1}\tilde{S}-k}{\sqrt{2k}}\right) \quad (3)$$

$$\tilde{\Delta}_{adj} = \sqrt{N}\left(\frac{N^{-1}\tilde{S}-k}{\sqrt{\frac{2k(T-k-1)}{T+1}}}\right) \quad (4)$$

where *N* and $\tilde{S}$ relate to the individual and slope coefficient, β_i is the pooled ordinary least squares (OLS) coefficient, β_{WFE} is the weighted fixed effect pooled estimator,
x_i is the matrix covering explanatory variables in deviations from the mean, M_τ is the identity matrix, σ_i^2 is the estimate of σ_i, while *k* is the number of regressors. The null hypothesis posits that slope coefficients are homogenous, whereas the alternative hypothesis assumes that slope coefficients are heterogeneous.

Because nonstationary data usually causes false regression outcomes, it is critical to check if the variables are stationary prior to regression and panel cointegration analysis. In this vein, consistent with (L. Cui et al., 2022), the Im-Pesaran-Shin (IPS) test is used to check for a common unit root, which allows for heterogeneous autoregressive coefficients. The following is the equation used to check for a common unit root:

$$y_{it} = \rho_i Y_{it-1} + \delta X_{it} + \varepsilon_{it} \quad (5)$$

where X_{it} signifies the combined exogenous variables including two-way fixed effects, ρ_i describes the autoregressive coefficients and ε_{it} the disturbance term. Panel has a unit root in the null hypothesis, while panel is stationary in the alternative.

The following baseline model is used to investigate the drivers of renewable energy production, similar to (Przychodzen and Przychodzen, 2020):

$$REP_{it} = f(GDP_{it}, ED_{it}, RENTS_{it}, GHG_{it}, UNEMPL_{it}, FDI_{it}, PAT_{it}) \quad (6)$$

where *REP* illustrates the production of each type of renewable energy. To avoid potential heteroscedasticity and extreme data, we use the natural logarithm of the variables expressed as non-percentage values. Hence, fixed-effects and random-effects regression models for panel data will be evaluated using the following specifications:

Model (1) $$REN_{it} = \alpha + \beta_{1t}GDP_{it} + \beta_{2t}ED_{it} + \beta_{3t}RENTS_{it} + \beta_{4t}GHG_{it} + \beta_{5t}UNEMPL_{it} + \beta_{6t}FDI_{it} + \beta_{7t}PAT_{it} + \mu_{it} \quad (7)$$

Model (2) $$HYDRO_{it} = \alpha + \beta_{1t}GDP_{it} + \beta_{2t}ED_{it} + \beta_{3t}RENTS_{it} + \beta_{4t}GHG_{it} + \beta_{5t}UNEMPL_{it} + \beta_{6t}FDI_{it} + \beta_{7t}PAT_{it} + \mu_{it} \quad (8)$$

Model (3) $$WIND_{it} = \alpha + \beta_{1t}GDP_{it} + \beta_{2t}ED_{it} + \beta_{3t}RENTS_{it} + \beta_{4t}GHG_{it} + \beta_{5t}UNEMPL_{it} + \beta_{6t}FDI_{it} + \beta_{7t}PAT_{it} + \mu_{it} \quad (9)$$

Model (4) $$SOLAR_{it} = \alpha + \beta_{1t}GDP_{it} + \beta_{2t}ED_{it} + \beta_{3t}RENTS_{it} + \beta_{4t}GHG_{it} + \beta_{5t}UNEMPL_{it} + \beta_{6t}FDI_{it} + \beta_{7t}PAT_{it} + \mu_{it} \quad (10)$$

Model (5) $$BIOF_{it} = \alpha + \beta_{1t}GDP_{it} + \beta_{2t}ED_{it} + \beta_{3t}RENTS_{it} + \beta_{4t}GHG_{it} + \beta_{5t}UNEMPL_{it} + \beta_{6t}FDI_{it} + \beta_{7t}PAT_{it} + \mu_{it} \quad (11)$$

Model (6) $$BIOG_{it} = \alpha + \beta_{1t}GDP_{it} + \beta_{2t}ED_{it} + \beta_{3t}RENTS_{it} + \beta_{4t}GHG_{it} + \beta_{5t}UNEMPL_{it} + \beta_{6t}FDI_{it} + \beta_{7t}PAT_{it} + \mu_{it} \quad (12)$$

where *t* depicts covered years (1990, 1991, ..., 2019), the index *i* reveals the states (1, 2, 3, ..., 10), α is a constant term, β_1, β_2, β_3, ..., β_6 are the coefficients of the explanatory variables, and μ denotes the error term. By controlling for unobserved heterogeneity among units that is correlated with explanatory measures, a fixed effects model can provide unbiased estimates with efficient standard errors. Alternatively, in a random effects model, the unobserved and observed variables are believed to be unrelated. Alike (Ahmadov and Van der Borg, 2019), the Hausman test will be used to determine which estimator is the most suitable.

The Kao cointegration test is also used, consistent with (Bamati and Raoofi, 2020), to find out if there is a long-term relationship between renewable energy generation and the other factors. It is assumed that the cointegrating vector is constant throughout all panels. Kao's null hypothesis states that there is no cointegration between the series, whereas the alternate hypothesis states that the series in all panels are cointegrated with the same cointegrating vector. The following is a representation of the related model:

$$x_{it} = y_{it}\beta + z'_{it}\delta + \varepsilon_{it} \quad (13)$$

where x_{it} and y_{it} denotes the integration of order one process, ε_{it} is white noise error term, whereas variable z'_{it} is exogenous of any fixed effect.

In the case of cointegration validation, we employ fully modified ordinary least squares (FMOLS) estimators to quantify the long-term relationship between the variables under investigation, alike Vural (2021). The FMOLS regression approach is a residual-based test that yields efficient outcomes for cointegrated variables. When the sample size is small, FMOLS is also regarded a consistent estimate, as it eliminates the issues of endogeneity and serial correlation among the variables. The FMOLS estimator is represented as follows:

$$\beta_F^* = [\sum_{i=1}^{N} \sum_{i=1}^{T} (x_{it} - \bar{x}_i)']^{-1} [\sum_{i=1}^{N} (\sum_{i=1}^{T} (x_{it} - \bar{x}_i)\, \bar{y}_{it} + T\Delta_{\varepsilon\mu})] \quad (14)$$

where $\Delta_{\varepsilon\mu}$ is the serial correlation term and $\bar{y}_{it}$ is the transformed variable of y_{it} to succeed the endogeneity improvement.

The occurrence of cointegration suggests that there is a high probability of causality between variables. Thus, the panel causality test proposed by (Dumitrescu and Hurlin, 2012) will be used to investigate the causality links between renewable energy production and the other variables, consistent with (Khan et al., 2021). This test has the benefit of addressing the problem of cross-sectional dependency and heterogeneity in panel data analysis. Also, in small sample datasets, the test yields robust and reliable results. The test in its functional version is as follows:

$$X_{it} = \alpha_i + \sum_{j-1}^{J} \lambda_i^j X_{i(t-j)} + \sum_{j-1}^{J} \beta_i^j Z_{i(t-j)} + \mu_{it} \quad (15)$$

where X and Z refer to the estimated observables, β_i^j and λ_i^j are estimated coefficients and autoregressive parameters which are supposed to fluctuate within individual i cross-sections. The null hypothesis states that no causal link exists in the panel, whereas the alternative hypothesis states that the causal link occurs in at least one subgroup.

4. Empirical findings

4.1. Descriptive statistics, correlations, and stationarity analysis

The descriptive statistics for each selected variable are shown in Table 2. Specifically, the production of renewables and biofuels has the highest mean value, whereas the production of biogases has the lowest mean value. The corresponding standard deviations, on the other hand, show that there are significant differences between countries regarding the production of renewables and biofuels, followed by the production of hydro energy.

Table 2. Summary statistics (raw data)

Variables	Obs.	Mean	Std.Dev.	Min	Max
REN	300	458.876	509.588	0	2373.2
HYDRO	300	323.711	382.687	0	1740.583
WIND	300	52.989	175.643	0	1298.947
SOLAR	300	15.487	42.83	0	202.827
BIOF	300	51.521	122.166	0	819.32
BIOG	300	13.694	36.516	0	226.936
ED	300	43.834	19.471	-0.191	88.963
GHG	300	7.85	3.739	-0.9	24.3
GDP	268	3.429	4.502	-14.269	14.344
RENTS	286	0.985	0.8	0.074	4.931
UNEMPL	290	9.542	4.232	1.1	20.7
FDI	286	3.96e+09	1.09e+10	-6.47e+10	9.22e+10
PAT	300	1258.013	1681.181	0	7740

Source: Authors' work

Figure 1 shows the mean values for each form of renewable energy production in Central and Eastern European countries. Accordingly, Romania (1561.16), Poland (842.6779), and Lithuania (112.942) reveal the greatest mean values for renewables and biofuels production, while Lithuania (112.942) and Estonia have the lowest (48.17553).

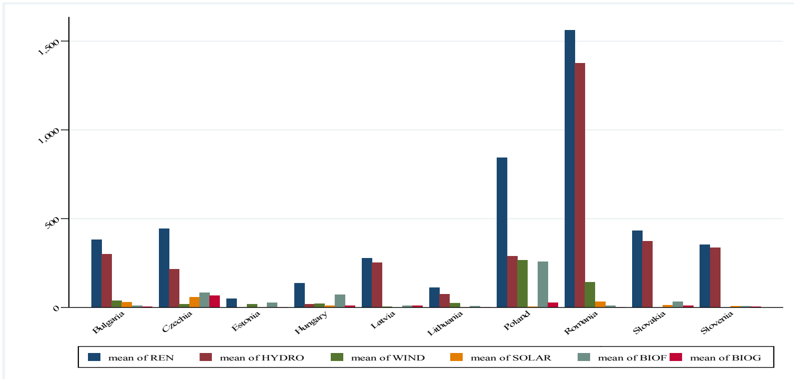

Figure 1. Mean values of every type of renewable energy production

Source: Authors' work

Furthermore, Romania (1376.611) and Slovakia (374.245) are the leading countries in hydro energy production, while Poland (265.8067) and Romania (141.0908) are the leaders in wind energy production. Czech Republic (58.66037) and Romania (32.24907) expose the highest mean values for solar photovoltaic energy generation. Additionally, Poland and Czech Republic exhibit the greatest average mean values for the generation of primary solid biofuels and biogases.

The correlations among covered variables are exhibited in Figure 2. Except for the variables measuring the production of each type of renewable energy, such as REN and HYDRO (0.7899), REN and WIND (0.6830), WIND and BIOF (0.6645), SOLAR and BIOG (0.6798), the results exhibit low correlations between selected measures. Hence, there is no threat of multicollinearity among explanatory variables because pairwise correlation coefficients are not high (e.g., over 0.7).

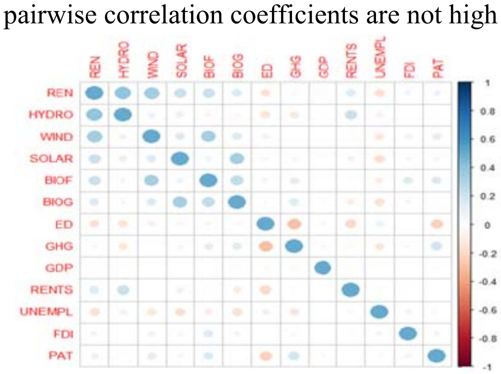

Figure 2. Correlation matrix

Source: Authors' work

The cross-section dependence and slope homogeneity tests are done prior to stationary analysis, with the results shown in Table 3. The outcomes reject the null hypothesis of no cross-sectional dependency at a 1% level for all variables except

ED. Hence, we can notice that the dataset has cross-sectional dependence. Moreover, with the exception of model (3), both statistics ($\tilde{\Delta}$ and $\tilde{\Delta}_{adj}$) significantly reject the null hypothesis of slope homogeneity, proving that the slope coefficients are heterogeneous in nature at a 1% significance level.

Table 3. Tests for cross-sectional dependence and slope homogeneity

Variables	Cross-section dependence test					Model	Slope homogeneity test			
	CD-test	p-value	average joint T	mean ρ	mean abs(ρ)					
REN	27.507	0	30	0.75	0.75					
HYDRO	9.268	0	30	0.25	0.46	(1) REN	$\tilde{\Delta}$	6.825	$\tilde{\Delta}_{adj}$	8.398
WIND	31.776	0	30	0.86	0.86		p-value	0	p-value	0
SOLAR	27.872	0	30	0.76	0.76	(2) HYDRO	$\tilde{\Delta}$	3.127	$\tilde{\Delta}_{adj}$	3.847
BIOF	28.115	0	30	0.77	0.77		p-value	0.002	p-value	0
BIOG	33.733	0	30	0.92	0.92	(3) WIND	$\tilde{\Delta}$	0.571	$\tilde{\Delta}_{adj}$	0.703
GDP	18.743	0	25.36	0.56	0.56		p-value	0.568	p-value	0.482
RENTS	8.05	0	27.51	0.23	0.37	(4) SOLAR	$\tilde{\Delta}$	5.537	$\tilde{\Delta}_{adj}$	6.813
ED	-0.479	0.632	30	-0.01	0.52		p-value	0	p-value	0
GHG	14.688	0	30	0.4	0.53	(5) BIOF	$\tilde{\Delta}$	3.36	$\tilde{\Delta}_{adj}$	4.135
UNEMPL	15.526	0	29	0.43	0.43		p-value	0.001	p-value	0
FDI	20.724	0	27.89	0.59	0.59	(6) BIOG	$\tilde{\Delta}$	5.196	$\tilde{\Delta}_{adj}$	6.394
PAT	15.218	0	30	0.41	0.43		p-value	0	p-value	0

Source: Authors' work. Notes: Under the null hypothesis of cross-section independence, CD ~ N(0,1). P-values close to zero indicate data are correlated across panel groups. For slope homogeneity test H0: slope coefficients are homogenous

Table 4 shows the results of the panel unit root test for all selected variables. The findings support the null hypothesis that the variables are not stationary at the level and that the panel has a unit root process. Except for SOLAR, all of the variables are stationary at the first difference. As such, the variables are integrated of order one (I(1)).

Table 4. Im-Pesaran-Shin unit-root test

Variables	Level				Variables	First-difference			
	t-bar	t-tilde-bar	Z-t-tilde-bar	p-value		t-bar	t-tilde-bar	Z-t-tilde-bar	p-value
REN	-0.4986	-0.377	4.2547	1	D.REN	-5.5139	-3.7319	-9.2198	0
HYDRO	-2.8583	-2.4673	-4.1197	0	D.HYDRO	-6.7849	-4.1213	-10.7835	0
WIND	0.7829	0.7467	8.7569	1	D.WIND	-4.5767	-3.4071	-7.9158	0
SOLAR	6.896	2.2535	14.7937	1	D.SOLAR	0.9882	-0.0797	5.4454	1
BIOF	0.4188	0.3941	7.3442	1	D.BIOF	-4.6669	-3.3847	-7.8258	0
BIOG	1.1749	1.0102	9.8123	1	D.BIOG	-2.929	-2.489	-4.2289	0
ED	-4.012	-3.0875	-6.699	0	D.ED	-6.4272	-3.8396	-9.7756	0
GHG	-3.0266	-2.5883	-4.6373	0	D.GHG	-5.8355	-3.7506	-9.3453	0
GDP	-1.5097	-1.4051	0.1357	0.554	D.GDP	-6.0547	-3.9092	-9.9319	0
RENTS	-3.438	-2.7525	-5.2624	0	D.RENTS	-4.9646	-3.5952	-8.671	0
UNEMPL	-1.2493	-1.1867	1.0004	0.8414	D.UNEMPL	-3.4649	-2.8524	-5.7141	0
FDI	-2.8693	-2.4837	-4.2169	0	D.FDI	-6.3517	-3.8791	-9.8602	0
PAT	-2.1572	-1.953	-2.0592	0.0197	D.PAT	-5.1707	-3.6300	-8.8109	0

Source: Authors' work

4.2. Econometric outcomes

The outcomes of the FE and RE regression models are provided in Table 5. The Hausman test was used to determine the significance of the non-observed individual effects. With non-rejection (p-value equal to 0.23 for REN, 0.72 for HYDRO, and 0.93 for BIOF regressions), we assume that the RE model performs better as our main specification for models (1), (2), and (5), while the rest of models are estimated using FE.

Table 5. The outcomes of panel data fixed- and random-effects regressions

Variables	Model (1) REN	Model (2) HYDRO	Model (3) WIND	Model (4) SOLAR	Model (5) BIOF	Model (6) BIOG
	RE	RE	FE	FE	RE	FE
GDP	-0.04***	-0.01***	-0.18***	-0.01	-0.12***	-0.06**
	(-4.02)	(-2.67)	(-3.78)	(-0.11)	(-3.71)	(-2.14)
ED	0.00	-0.01***	0.10***	-0.05	-0.01	0.05***
	(0.66)	(-3.27)	(4.24)	(-0.72)	(-1.00)	(3.81)
RENTS	-0.09	-0.06	-0.79*	-3.60***	-0.63***	-0.75***
	(-0.98)	(-1.58)	(-1.94)	(-4.24)	(-2.83)	(-2.72)
GH	-0.05	-0.01	0.27	-5.89*	0.46	0.62**
	(-0.38)	(-0.21)	(0.58)	(-1.83)	(1.57)	(2.05)
UNEMPL	-0.02	0.01*	-0.06	-0.25	-0.06*	-0.08**
	(-1.49)	(1.89)	(-1.02)	(-1.50)	(-1.69)	(-2.25)
FDI	0.15***	0.07***	-0.48*	-0.58	0.80***	-0.27*
	(3.43)	(3.28)	(-1.70)	(-1.13)	(7.18)	(-1.68)
PAT	-0.61***	-0.20***	-2.32***	-4.07***	-0.29***	-1.37***
	(-8.08)	(-5.51)	(-6.38)	(-4.73)	(-2.59)	(-6.61)
_cons	6.47***	4.99***	24.76***	57.61***	-11.78***	14.49***
	(4.87)	(6.04)	(3.54)	(4.40)	(-4.63)	(3.58)
F statistic			13.39***	10.94***		15.99***
Wald chi2	201.15***	124.33***			112.31***	
Hausman Prob>chi2	0.23	0.72	0.00	0.03	0.93	0.00
R-sq	0.50	0.36	0.41	0.49	0.34	0.43
Obs	242	242	154	97	197	168

Source: Authors' work. Notes: t statistics in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. FE denotes Fixed-effects (within) regression. RE denotes Random-effects GLS regression

In all models, except SOLAR, the impact of GDP is negative and statistically significant. Explicitly, a 1% increase in GDP reduces REN by 0.04%, HYDRO by 0.01%, WIND by 0.18%, BIOF by 0.12%, and BIOG by 0.06%. This outcome is also supported by (Khan et al., 2021) who contended that economic expansion is the major goal of most developing and developed nations. Thus, since nonrenewable and fossil fuel-based energy is considered the cornerstone for economic growth and is generally more affordable, conventional energy use will grow.

The effect of ED on HYDRO is negative, whereas it has a beneficial effect on WIND and BIOG. Considerable energy dependence and environmental deprivation could act as powerful spurs for renewable energy adoption. Countries' reliance on energy will diminish over time as they shift to renewables and advance towards decarbonization. In contrast to (Ahmadov and Van der Borg, 2019), total natural resource rents have a negative impact on renewable energy production, except for REN and HYDRO, as suggested by reduced supporting government and fiscal policies. Greenhouse gas emissions positively influence BIOG, but negatively SOLAR. Hence, alike (Bamati and Raoofi, 2020), huge CO2 releases upsurge the claim for a cleaner atmosphere and the use of renewable energy, explaining the positive relationship. Nevertheless, the occurrence of renewable energy with green technology lessens ecological concerns caused by carbon emissions, implying a damaging effect. A 1% increase in unemployment, on the other hand, increases HYDRO by 0.01%, outcome in line with (Przychodzen and

Przychodzen, 2020), while decreasing BIOF and BIOG by 0.06% and 0.08%, respectively, alike (Vural, 2021). Green energy strategies, which often entail replacing traditional fossil fuel-based power plants with clean electricity could generate new “green jobs” in the renewable energy industry, but they also have the effect of driving out work opportunities in other sectors, which explains the mixed results. FDI positively influence REN, HYDRO and, BIOF, but negatively WIND and BIOG. The negative relationship reinforces the findings of (Khan et al., 2021) who claimed that FDI inflows are not directed toward alternative energy sources. Proper reward policies to promote green FDI in these nations are needed to redirect FDI from non-renewable to green energy. Furthermore, patent applications exert a negative impact on all forms of renewable energy production, consistent with (Khan et al., 2021), argued by the fact that the innovations are not guided to the renewable energy segment.

Table 6 reports the results of Kao cointegration test. We find that null hypothesis is rejected, and alternative hypothesis is accepted. Hence, the selected variables reveal a long-term association.

Table 6. Kao Residual Cointegration Test

Model	Statistic	t-Statistic	Prob.	Model	Statistic	t-Statistic	Prob.
(1)	ADF	-5.661129	0	(4)	ADF	-4.065766	0
	Residual variance	17.30642			Residual variance	4.799427	
	HAC variance	5.511161			HAC variance	2.985816	
(2)	ADF	-5.532746	0	(5)	ADF	-5.242812	0
	Residual variance	17.28026			Residual variance	13.36379	
	HAC variance	5.89322			HAC variance	6.189606	
(3)	ADF	-3.743926	0.0001	(6)	ADF	-5.220559	0
	Residual variance	12.65604			Residual variance	11.39445	
	HAC variance	6.746793			HAC variance	8.000901	

Source: Authors’ work

The long-run estimates of the FMOLS are provided in

Table *7*. The reported results of FMOLS exhibit roughly the same influence but varying magnitudes when compared to panel data fixed- and random-effects regressions’ results. The outcomes indicate that GDP negatively influence renewable energy production. REN, HYDRO, WIND, SOLAR, BIOF, and BIOG are all lowered by 0.11%, 0.08%, 0.28%, 0.26%, 0.18%, and 0.15%, respectively, with a 1% growth in GDP. Other variables (e.g., ED, RENTS, GH, UNEMPL) have been found to have a detrimental impact on renewable energy generation. Nevertheless, the coefficients of FDI support a beneficial impact on all types of renewable energy production, whereas PAT has a mixed effect.

Table 7. The outcomes of panel fully modified least squares (FMOLS)

Variables	Model (1) REN	Model (2) HYDRO	Model (3) WIND	Model (4) SOLAR	Model (5) BIOF	Model (6) BIOG
GDP	-0.11^{**}	-0.08^{*}	-0.28^{**}	-0.26^{*}	-0.18^{**}	-0.15^{**}
	(-3.28)	(-2.19)	(-5.72)	(-2.40)	(-5.78)	(-5.01)
ED	-0.01	-0.00	-0.03	-0.07^{**}	-0.04^{**}	-0.01
	(-1.75)	(-0.04)	(-1.92)	(-3.68)	(-3.89)	(-0.80)
RENTS	0.01	-0.03	-0.03	-3.92^{**}	-1.36^{**}	-1.05^{**}
	(0.04)	(-0.19)	(-0.06)	(-6.39)	(-6.07)	(-3.93)

GH	-1.53**	-2.35**	-1.39*	-2.28**	0.09	0.18
	(-4.78)	(-6.58)	(-2.41)	(-2.88)	(0.31)	(0.64)
UNEMPL	-0.07**	-0.04	-0.20**	-0.26**	-0.07	-0.15**
	(-3.32)	(-1.74)	(-3.74)	(-2.94)	(-1.72)	(-3.98)
FDI	0.39**	0.28**	0.53**	1.11**	0.37**	0.19**
	(8.50)	(5.30)	(4.63)	(8.40)	(7.00)	(3.16)
PAT	0.26*	0.67**	-0.34*	-1.52**	-0.20	0.05
	(1.99)	(4.92)	(-2.39)	(-4.79)	(-1.85)	(0.54)
R-sq	0.24	0.30	0.16	0.31	0.29	0.14
Obs	221	221	143	78	183	156

Source: Authors' work. Notes: t statistics in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01. Panel method: Pooled estimation. Coefficient covariance computed using sandwich method. Long-run covariance estimates (Bartlett kernel, Newey-West fixed bandwidth)

The outcomes of panel causality analysis are exhibited in Table 8. For production of renewables and biofuels, the results indicate a single bidirectional causal association. Specifically, RENTS causes REN, and REN causes RENTS, which is weakly significant at a 10% level. Furthermore, there is evidence of unidirectional causality relationships between ED and REN, REN and UNEMPL, as well as REN and PAT. With respect to hydro energy production, the empirical findings show that there is bidirectional causality between PAT and HYDRO, but a unidirectional linkage among GH and HYDRO. As regards the production of wind energy, the outcomes provide support for a bidirectional causal link among GH and WIND, along with several unidirectional associations (between GDP and WIND, WIND and RENTS, UNEMPL and WIND, FDI and WIND, PAT and WIND). For production of primary solid biofuels, the results indicate bidirectional causality between PAT and BIOF, as well as a unidirectional linkage among BIOF and RENTS. In case of biogases production, Dumitrescu and Hurlin panel causality test revealed three bidirectional relationships, respectively between GH and BIOG, UNEMPL and BIOG, as well as PAT and BIOG. There are also found several unidirectional relationships (among GDP and BIOG, BIOG and ED, BIOG and RENTS).

Table 8. The results of pairwise Dumitrescu Hurlin panel causality tests

REN				HYDRO			
Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.	Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.
GDP ⇏ REN	2.83	0.73	0.47	GDP ⇏ HYDRO	2.93	0.85	0.40
REN ⇏ GDP	1.11	-1.34	0.18	HYDRO ⇏ GDP	1.06	-1.40	0.16
ED ⇏ REN	4.02	2.27	0.02	ED ⇏ HYDRO	2.13	-0.07	0.94
REN ⇏ ED	3.06	1.08	0.28	HYDRO ⇏ ED	2.44	0.31	0.76
RENTS ⇏ REN	3.62	1.73	0.08	RENTS ⇏ HYDRO	2.96	0.91	0.36
REN ⇏ RENTS	3.64	1.75	0.08	HYDRO ⇏ RENTS	3.27	1.30	0.19
GH ⇏ REN	3.56	1.66	0.10	GH ⇏ HYDRO	3.74	1.89	0.06
REN ⇏ GH	2.29	0.11	0.92	HYDRO ⇏ GH	2.14	-0.08	0.94
UNEMPL ⇏ REN	2.42	0.27	0.79	UNEMPL ⇏ HYDRO	1.29	-1.12	0.26
REN ⇏ UNEMPL	5.83	4.48	0.00	HYDRO ⇏ UNEMPL	3.06	1.05	0.29
FDI ⇏ REN	1.34	-1.07	0.29	FDI ⇏ HYDRO	2.86	0.77	0.44
REN ⇏ FDI	1.52	-0.85	0.39	HYDRO ⇏ FDI	1.11	-1.34	0.18
PAT ⇏ REN	3.39	1.46	0.15	PAT ⇏ HYDRO	3.79	1.94	0.05
REN ⇏ PAT	6.79	5.63	0.00	HYDRO ⇏ PAT	6.42	5.16	0.00
WIND				BIOF			
Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.	Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.
GDP ⇏ WIND	17.31	14.20	0.00	GDP ⇏ BIOF	2.75	0.27	0.79
WIND ⇏ GDP	2.32	-0.13	0.90	BIOF ⇏ GDP	2.96	0.45	0.65
ED ⇏ WIND	3.18	0.70	0.49	ED ⇏ BIOF	2.78	0.30	0.76
WIND ⇏ ED	3.39	0.90	0.37	BIOF ⇏ ED	3.08	0.55	0.58

RENTS ⇎ WIND	1.54	-0.87	0.38	RENTS ⇎ BIOF	2.19	-0.20	0.84
WIND ⇎ RENTS	5.24	2.67	0.01	BIOF ⇎ RENTS	14.28	9.99	0.00
GH ⇎ WIND	4.55	1.97	0.05	GH ⇎ BIOF	1.96	-0.39	0.69
WIND ⇎ GH	6.52	3.83	0.00	BIOF ⇎ GH	3.83	1.18	0.24
UNEMPL ⇎ WIND	4.34	1.81	0.07	UNEMPL ⇎ BIOF	3.21	0.66	0.51
WIND ⇎ UNEMPL	3.41	0.92	0.36	BIOF ⇎ UNEMPL	3.00	0.48	0.63
FDI ⇎ WIND	6.56	3.42	0.00	FDI ⇎ BIOF	2.24	-0.18	0.86
WIND ⇎ FDI	3.50	0.82	0.41	BIOF ⇎ FDI	2.25	-0.17	0.87
PAT ⇎ WIND	6.73	4.10	0.00	PAT ⇎ BIOF	5.30	2.43	0.02
WIND ⇎ PAT	3.43	0.94	0.35	BIOF ⇎ PAT	5.05	2.22	0.03

BIOG			
Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.
GDP ⇎ BIOG	14.76	11.02	0.00
BIOG ⇎ GDP	0.89	-1.40	0.16
ED ⇎ BIOG	3.65	1.08	0.28
BIOG ⇎ ED	4.64	1.96	0.05
RENTS ⇎ BIOG	3.48	0.92	0.36
BIOG ⇎ RENTS	4.90	2.19	0.03
GH ⇎ BIOG	6.46	3.59	0.00
BIOG ⇎ GH	5.59	2.81	0.01
UNEMPL ⇎ BIOG	6.01	3.19	0.00
BIOG ⇎ UNEMPL	4.61	1.94	0.05
FDI ⇎ BIOG	4.54	1.56	0.12
BIOG ⇎ FDI	2.17	-0.31	0.76
PAT ⇎ BIOG	4.47	1.81	0.07
BIOG ⇎ PAT	5.65	2.87	0.00

Source: Authors' work. Notes: Due to data limitations, the results for REN, HYDRO, WIND, BIOF does not cover the data for Slovenia, while the outcomes for BIOG does not cover the data for Slovenia and Bulgaria. The outcomes for SOLAR are not reported due to limited data

5. Concluding remarks and policy implications

In recent times, the economic, social, and cultural growth along with the globalization process and the development of the communication technologies and the technological progress represent only some of the causes of the continuous increased demand for global electricity. The increasing concern regarding global warming and the extreme environmental pollution, due to the usage of fossil fuels to produce electric power, led to international and European focus on the production of renewable energy from the natural non-fossil resources: wind, solar, hydropower, waves, tides, landfill gas, biogas. In this context, the present paper aimed to identify to what degree various factors influence the production of energy, considering each type of resource. These factors include: the economic development considering GDP/per capita (GDP), energy dependence (ED), total natural resources rents (RENTS), greenhouse gas emissions (GHG), unemployment (UNEMPL), foreign direct investment, net inflows (FDI) and patent applications - residents and nonresidents (PAT). The obtained results indicate that there is a direct influence of the above-mentioned factors on the production of energy obtained from non-fossil and non-polluting resources.

In the aftermath of the Paris agreement in 2015, nowadays governments of all countries are more and more interested to develop government policies in the domain, especially those facing economies in transitions form Central and Eastern Europe (CEE). The results presented in this paper may be beneficial to decision-makers, at national or European level, and can contribute to the process of implementing measures, legislation, or decisions regarding the social, economic, or fiscal policies aiming to stimulate the production of energy from renewable resources according to the already existing natural resources, to the economic growth of each region or geographical area. The political decision-makers can promote such policies regarding pricing policy, financial and/or fiscal incentive, subsidies, regulations or even government investments regarding the renewable energy. At the same time, policies, taxes, and prices that may discourage the usage of fossil fuel regarding energy production can be promoted.

Moreover, the businesspeople who invest in renewable production may make decisions based on scientific background because they can select the richest natural resources or the most efficient ones that they may use in the production processes (Ahmadov and Van der Borg, 2019). By launching new production and storage technologies, investors would generate new jobs (Khan et al, 2021), thus influencing the employment growth and decreasing the unemployment rate. The obtained energy would contribute to maintaining a higher level of electricity consumption (Alam and Murad, 2020), together with improved living standards, reduced poverty level, and easy access to various types of energy in hard-to-reach places.

The renewable energy which is obtained from alternative energies that protect the environment is also sustainable, some resources being practically inexhaustible (e.g., wind, solar, hydropower, waves, tides, landfill gas, biogas). It is considered that the study represents a support for investors and political decision-makers because it may contribute to the increased production levels and to introducing new production technologies of renewable energy, caring benefits for the society, environment, economy, and society concerning any region or country. A region that would develop the energy production from a certain natural resource would boost the production process in other close regions by promoting regional similarities, by disseminating knowledge and good practice (Shahnazi and Shabani, 2020).

The present research study can be extended by covering further economic, social, and territorial factors that may influence the production of renewable energy, and guiding investors towards optimal solutions.

REFERENCES

[1] **Acaravci, A., Ozturk, I.** (**2010*) , On the Relationship between Energy Consumption, CO_2 Emissions and Economic Growth In Europe***. *Energy*, 35(12): 5412–5420, https://doi.org/10.1016/j.energy.2010.07.009;

[2] **Ahmadov, A. K., Van der Borg, C. (2019), *Do Natural Resources Impede Renewable Energy Production in the EU? A Mixed-Methods Analysis***. *Energy Policy* 126: 361–369, https://doi.org/10.1016/j.enpol.2018.11.044;

[3] **Alam, M., Murad, M. (2020),** ***The Impacts of Economic Growth, Trade Openness and Technological Progress on Renewable Energy Use in Organization for Economic Cooperation and Development Countries***. *Renew. Energy* 145 (1): 382-390, https://doi.org/10.1016/j.renene.2019.06.054;
[4] **Al-Mulali, U., Ozturk, I., Lean, H.H. (2015),** ***The Influence of Economic Growth, Urbanization, Trade Openness, Financial Development, and Renewable Energy on Pollution in Europe***. *Nat. Hazards,* 79: 621-644, https://doi.org/10.1007/s11069-015-1865-9;
[5] **Alper, A., Oguz, O. (2016),** ***The Role of Renewable Energy Consumption in Economic Growth: Evidence from Asymmetric Causality***. *Renewable and Sustainable Energy Reviews*, 60: 953–959, http://dx.doi.org/10.1016/j.rser.2016.01.123;
[6] **Bamati, N., Raoofi, A. (2020),** ***Development Level and the Impact of Technological Factor on Renewable Energy Production***. *Renewable Energy,* 151: 946-955, https://doi.org/10.1016/j.renene.2019.11.098;
[7] **Bento, J. P. C., Moutinho, V. (2016),** ***CO2 Emissions, Non-Renewable and Renewable Electricity Production, Economic Growth, and International Trade in Italy***. *Renewable and Sustainable Energy Reviews*, 55, 142–155, http://dx.doi.org/10.1016/j.rser.2015.10.1;
[8] **Cui, L., Weng, S., Nadeem, A. M., Rafique, M. Z., Shahzad, U. (2022),** ***Exploring the Role of Renewable Energy, Urbanization and Structural Change for Environmental Sustainability: Comparative Analysis for Practical Implications***. *Renewable Energy*, 184, 215-224, https://doi.org/10.1016/j.renene.2021.11.075;
[9] **Dumitrescu, E. I., Hurlin, C. (2012),** ***Testing for Granger Non-causality in Heterogeneous Panels***. *Economic Modelling*, 29(4), 1450-1460, https://doi.org/10.1016/j.econmod.2012.02.014;
[10] **Ergun, S., Owusu, P., Rivas, M. (2019),** ***Determinants of Renewable Energy Consumption in Africa***. *Environmental Science and Pollution Research,* 26 (1): 15390-15405, https://doi.org/10.1007/s11356-019-04567-7;
[11]**Gogu, E., Radu, C., Deaconu, A., Frasineanu, C., Triculescu, M., Mișu, S., Toma, S. (2021)**, ***Assessing the Impact of Clean Energy on Sustainable Economic Growth in European Union Member States***. *Economic Computation and Economic Cybernetics Studies and Research*, 55(4): 183-197, *ASE Publishing;* http://www.ecocyb.ase.ro/Articles2021_4.htm;
[12] **Irandoust, M. (2016),** ***The Renewable Energy-Growth Nexus with Carbon Emissions and Technological Innovation: Evidence from the Nordic Countries***. *Ecological Indicators*, 69: 118-125, https://www.sciencedirect.com/science/article/abs/pii/S1470160X16301558;
[13] **Khan, A., Chenggang, Y., Hussain, J., Kui, Z. (2021)**, ***Impact of Technological Innovation, Financial Development and Foreign Direct Investment on Renewable Energy, Non-Renewable Energy and the Environment***

in Belt & Road Initiative Countries. *Renewable Energy*, 171: 479-491, https://doi.org/10.1016/j.renene.2021.02.075;

[14] **Lehmann, P., Creutzig, F., Ehlers, M.H., Friedrichsen, N., Heuson, C., Hirth, L., Pietzcker, R. (2012), *Carbon Lock-out: Advancing Renewable Energy Policy in Europe***. *Energies* 2012, *5*, 323-354, https://doi.org/10.3390/en5020323;

[15] **MacKenzie, J. J. (2003), *Technology Growth Curves: A New Approach to Reducing Global CO_2 Emissions***. *Energy Policy*, 31(12): 1183-1187, https://doi.org/10.1016/S0301-4215(02)00191-X;

[16] **Menegaki, A. N. (2011), *Growth and Renewable Energy in Europe: A Random Effect Model with Evidence for Neutrality Hypothesis***. *Energy Economics* 33: 257–263, https://doi.org/10.1016/j.eneco.2010.10.004;

[17] **Pesaran, M. H. (2004), *General Diagnostic Tests for Cross Section Dependence in Panels***. *IZA Discussion Paper No. 1240*, https://ftp.iza.org/dp1240.pdf;

[18] **Pesaran, M. H., Yamagata, T. (2008), *Testing Slope Homogeneity in Large Panels***. *Journal of Econometrics*, 142(1): 50-93, https://doi.org/10.1016/j.jeconom.2007.05.010;

[19] **Przychodzen, W., Przychodzen, J. (2020), *Determinants of Renewable Energy Production in Transition Economies: A Panel Data Approach***. *Energy*, 191, https://doi.org/10.1016/j.energy.2019.116583;

[20] **Sadorsky, P. (2009), *Renewable Energy Consumption, CO2 Emissions and Oil Prices in G7 Countries***. *Energy Econ.* 31: 456-462, https://doi.org/10.1016/j.eneco.2008.12.010;

[21] **Shahnazi, R., Shabani, Z. D (2020), *Do Renewable Energy Production Spillovers Matter in the EU?***. *Renewable Energy*, 150: 786-796, https://doi.org/10.1016/j.renene.2019.12.123;

[22] **Shah, I.H., Hiles, C., Morley, B. (2018), *How Do Oil Prices, Macroeconomic Factors and Policies Affect the Market for Renewable Energy?***. *Appl. Energy*, 215: 87-97, https://www.sciencedirect.com/science/article/abs/pii/S0306261918300990;

[23] **Vural, G. (2021), *Analyzing the Impacts of Economic Growth, Pollution, Technological Innovation and Trade on Renewable Energy Production in Selected Latin American Countries***. *Renewable Energy*, 171: 210-216, https://doi.org/10.1016/j.renene.2021.02.072;

[24] **Zeb, R., Salar, L., Awan, U., Zaman, K., Shahbaz, M. (2014), *Causal Links between Renewable Energy, Environmental Degradation and Economic Growth in Selected SAARC Countries: Progress towards Green Economy***. *Renew. Energy*, 71: 123-132, https://doi.org/10.1016/j.renene.2014.05.012;

[25] *** **European Commission (2011)**, *Communication COM(2011)885 Final "Energy Roadmap 2050" by the European Commission the European Parliament, the European Council, the European Economic and Social Committee and the Committed of the Regions, European Union, Brussel.*

[26] *** **Paris Agreement (2016)**, OJ L 282, 19.10.2016.