Renewable and Sustainable Energy Reviews 81 (2018) 768–774

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

The emergence of the effects and determinants of the energy paradigm changes on European Union economy

Gheorghe H. Popescu[a], Mihai Mieila[b], Elvira Nica[c], Jean Vasile Andrei[d,*]

[a] Dimitrie Cantemir Christian University, Splaiul Unirii Street, no. 176, District 4, 030134 Bucharest, Romania
[b] Valahia University of Targoviste, 13, Aleea Sinaia Street, Corp B, Targoviste, Dambovita, Romania
[c] Bucharest University of Economic Studies, Piata Romana, No. 6, 010374 Bucharest, Romania
[d] Petroleum-Gas University of Ploiesti, B-dul Bucuresti, No. 39, Ploiesti, 100680 Prahova, Romania

ARTICLE INFO

Keywords:
Energy
Environment
Taxation
Development
Economic paradigm
Renewable energy
Panel data

ABSTRACT

Analyzing of the effects and the determinants of the energy paradigm changes on influencing the economic growth in European Union starts from the assumption that the economy is highly dependent of energy consumption in achieving of the economic growth and welfare for population. Consequently, the changes in the energy paradigm imply significant transformations in the production structures and their evolution. The aim of the paper is to present and evaluate the effects and determinants of the energy paradigm changes on assuring economic growth in European Union, by using the panel data approach and its subsequent techniques. In this respect, there was considered the evolution of nine economic variables across 30 countries, representing the EU member States during the examined period, plus Iceland and Norway, in order to revile direct and irrefutable connections among these variables in shaping the new energetic paradigm in European space. The results obtained during the research confirm that all nine variables are determinant and significant elements in shaping a new and proactive energy policy and it undoubtedly contribute in achieving of the sustainable economic development

1. Introduction

The possibility of changing the energy paradigm at the EU level represents a complex issue that has attracted particular attention. The attention paid to energy aspects is linked by the use of energy in the economic processes, the fluctuations of energy intensities of the national economies, the effects on the population welfare, amid worsening the dependence on energy imports, sometimes from sources affected by conflicts or political instability. In this vision, the energy and the new energy paradigm represents not just a major research topic in literature [1–3] and academia, it become a strategic goal, for policy makers, governments, and public administration structures. All these stakeholders are involved in a demarche of assurance of the energy independence and stability, having deferent significance and impacts on developing the new economic paradigm and in shaping of the new production structures. In contemporary economic developments, the energy tends to become a major politic, social and economic objective. The energy is considered to be among the most important vectors in assuring and promoting of sustainable economic development in actual capitalist societies. The role of energy in society is complex and often hard to be identified and clearly measured.

The energy and complementary aspects related to the energy sector tends to become in the near future a fundamental problem not only in European economic space, but also a factor in achieving of the politic stability and a key element in limiting of the climate change.

The analysis of the effects and determinants of the energy paradigm changes on influencing economic growth had faced numerous aspects in the literature [4,5]. By its essence, the energy represents a factor with significant influence towards the quality of life and social well-being, and ensures a smoothly run for the other economic components and structures as [6] noticed As [7] argues energy represents a vital input in every economic system in any time period. In recent studies [8–12]; is emphasized the importance of energy in assuring of the sustainable economic development and diversification of economic structures towards their transition to improved energy efficient processes. A recent study [13] investigates in a panel of twenty-five OECD countries for the period 1981–2007, a possible long-run relation between economic growth and oil consumption. Another research [14], using the same technique in case of some of OECD countries for a longer period (1980–2010) identifies significant effects of economic growth on oil demand. Another study [15] point out the positive relationship of energy consumption and gross fixed capital on

* Corresponding author.
E-mail address: andrei_jeanvasile@yahoo.com (J.V. Andrei).

http://dx.doi.org/10.1016/j.rser.2017.08.055
Received 23 April 2016; Received in revised form 10 June 2017; Accepted 12 August 2017

economic growth

In the contemporary economic context, the national economies are generally dependent on traditional energy sources and rely on capitalizing on these sources in delivering consistent and long-term economic growth. Starting from this reality, contemporary economies have developed a specific energy paradigm [16,17], dependent on the exploitation and capitalization of classical sources of energy (coal, oil and natural gas). Nevertheless, the new environmental realities are urging the additional efforts to think of new sources and possibilities of sustaining the energy raw materials of the economy. The development of a sustainable energy policy however, has imposed an irreversible change from the fossil energy sources to renewable energies, in order to reduce the dependence on classic resources and to expand the possibilities of supply and the scientific research in the field. From this perspective, the examination of the emerging effects and the determinant factors involved in changing of the current energy paradigm on the economic growth in Romania and the EU represents an important analysis.

Generally, addressing the role of energy and its rational use towards the sustainable economic development in contemporary economies starts from classical economic theories [18,19]. These theories directly emphasize the aspects related to the production process, the incorporation of energy into the produced goods, and consider the energy as a production factor with special features. However, the energy is not just a production factor – it plays a complex social role. Considering the multidimensional nature of energy in contemporary economies, it exerts complex influences in economy and society; it represents a compulsory and constant element in determining of the economic growth, in modeling of the social system and the social consumption habits. Other researches [20–23] emphasize the importance of the availability of the energy and its influence in the production processes; other studies analyze the correlation between energy consumption and performances of the national economies [4,24].

Despite the current evolution of the European economies, and of a numerous and important technologic changes, massive investments, a new policy framework in the field and the changes of the European energy policy paradigm developments, the energy continues to be a most disputed topic in the field, which raises numerous approaches, solutions and academic debates.

As the global environmental situation tends to worsening, is manifested a growing interest in mitigation of the carbon emissions. In this respect, exists a large number of researches [18,20,23–25], regarding the interrelated aspects to energy structure, production, prices, taxation, consumption, very often in relationship with the economic growth and economic structure diversification. Investigating the causality relationship between energy consumption and Gross Domestic Product (GDP) and the co-movement in case of eighteen developing countries during 1975–2001, [48] reviles significant causality relationships between the considered variables.

The analysis of the energy paradigm transformations during the last period reviles mostly an un-convergent policy in the field, with significant challenges of the paradigm, which needs to be properly understood in the context of the new European energy policy transformations. Obviously, the increasing dependence of contemporary economies by energy consumption has triggered numerous inner mechanisms in sustaining an ever more difficult economic growth, accentuated by the supplying inconstancies. Defining a new energy paradigm, closer to the actual economic demands it should not be left exclusively to public authorities and institutions or to the stock market mechanism. In this context, it is necessary to increase the involvement of the existing national regulatory authorities in each Member State to oversee the implementation of specific energy policy instruments. On the other hand, the academia and the study groups are called upon to provide the scientific basis for the policy measures and to orient the system towards the best practice in the field, and, not least, the public opinion as a barometer in assessment of the energy policy functionality.

The study of the emergence of the effects and determinants of the energy paradigm changes on influencing economic growth in Europe has offered numerous valuable insights. [26] noted in his study that the increases in energy consumption during the years have determined dramatically changes in historical energy transitions. Also, [21] identifies the influences of the energy service usage and the changes in energy consumption behavior towards the economic developments.

Understanding of the role and the energy influence in assuring of the sustainable development in contemporary economies represents a great challenge in context of the new energy paradigm adjustments and approaches. The evolution of the energy paradigm defines, in a tight manner, the transformation of the contemporary economies and societies, being a fundamental instrument in achieving of the sustainable economic development. In contemporary economies, the energy represents more than a simple production factor - it had started to become a determinant instrument in shaping economic structures and policies, being in the same time instrument in political negotiations.

In this context, achieving of the sustainable economic development implies not only a rational use of energy, but also new and diversified sources of energy, stability in supplying and designing a new paradigm. Energy transformations during the economic processes contribute in increasing the value of the classical production outcomes, assuring perspectives in developing economic stability by achieving fulfillment of the economic policy goals. In a research conducted by [27], they discovered that 60% of Latin American and Caribbean countries develop a positive bidirectional long-run relationship between energy consumption, carbon dioxide emissions, and economic growth.

Staring from the assumption that the energy represents one of the determinant factors in promoting, diversification and achieving of a high economic development, but also a constraining element in this respect it is necessary to examine the effects and determinants of the energy paradigm changes on influencing economic growth. From this perspective, the main aim of the paper is to asses a possible existence of direct and irrefutable connections among considered variables employed in research in shaping the new energetic paradigm in Europe from an economic perspective, by using the panel data approach, using the specific data regarding thirtieth countries including the EU-28 member states plus Iceland and Norway.

2. Data series and preliminary results

In the current research, there are employed the latest available datasets on the Eurostat website for nine economic variables and thirty states regarding the importance of the energy and renewable energy particularly, towards the economic growth. In the table below are presented the data series considered in designing the research, the range of data availability, and the symbols used for designate each series (Table 1).

For the data considered above, Table 2 contains the descriptive statistics of the datasets considered in the paper. As the common range of data availability is 2004–2015 and the present work is based on the panel data approach, the considered period is set accordingly.

In case of Table 2, the results of the Jarque-Bera test reveal that the considered series are normally distributed, for a significance level of 1%.

3. Materials and methodology

In designing of the current research, the main instrument used in carrying out the analysis is the panel data methodology and its subsequent techniques. This method is employed with the aim of identifying the existence of a certain economic behavioral pattern among the considered economies, regarding the effects and determinants of the energy paradigm changes on influencing economic growth.

The choice of employing this methodology is based on its robustness and its high degree of applicability and it can be used in order to

Table 1
Variables description and data series availability.
Source: authors based on: Eurostat [54]

Symbol	Variable description	Data availability
e_dep	Energy dependence (%)	2000–2015
e_int	Energy intensity (kg of oil equivalent per 1 000 Euro of GDP)	1995–2015
e_pty	Energy productivity (Euro per kilogram of oil equivalent)	1995–2015
el_rs	Electricity generated from renewable sources (% of gross electricity consumption)	2004–2015
e_tax	Environmental tax revenues (Percentage of GDP)	1995–2015
hc_rw	Households final energy consumption originated from renewable sources	1999–2015
i_txe	Implicit tax rate on energy (EUR per tonne of oil equivalent)	2002–2015
pp_re	Primary production of renewable energy (ths. tonnes of oil equivalent)	2004–2015
sh_rec	Share of renewable energy in gross final energy consumption (%)	2004–2015

identify significant economic transformations in terms of variable significance and expression. In order to examine different correlations between the employed considered variables, a framework based on panel data analysis is proposed and designed. The research approach is following the methods of LLC designed by [28] and the panel unit root tests Fisher-ADF and Fisher-PP as in [29].

As presented in the Table 1, the data series are annual, with twelve years, ranging between 2004 and 2015. The starting moment is 2004, as beginning with this year starts the availability of data for the following variables: primary production of renewable energy, electricity generated from renewable sources, and share of renewable energy in gross final energy consumption, respectively. Some series of data start in 1995 (energy productivity, energy intensity, and environmental tax revenues), other in 1999 (households final energy consumption originated from renewable sources), 2000 (energy dependence), or in 2002 (implicit tax rate on energy).

From the availability of the data there may be observed that current the European framework to account for the aspects regarding the renewable energy was settled in 2004. However, for the present work, employing longer series of data could represent an advantage, but, considering the missing variables above named, it would have less point.

A common trend of the literature concerned in the analysis of various aspects in the field of energy, is represented by the using of the panel data approach and of its subsequent techniques, in order to identify and explain possible correlations and influences between specific variables.

As the latest developments in the literature in the field [19,22,30]; of energies analysis suggest, the endogeneity of the variables represents a hypothesis that should be considered with a high degree of probability. In conditions of a non-stationary and cointegrated panel with endogenous variables, an adequate econometric specification represents a basic requirement in order to ensure correct and unbiased estimations [31]. In application of cointegration techniques, considering of the Granger non-causality tests represents the essential tool, aimed to ascertain the error correction mechanism (ECM) and to explore the short and long-run relationships existent between the examined variables [32].

As it is shown by numerous studies in the field, [33–35] cointegration analysis represents the specific technique used to evidence the existence of a long-term relationship between the set of integrated variables, but not only time sufficient for accepting the causality hypothesis two econometric variables. In this context, the cointegration once proved, the loss of information in the long-run relationship between the variables induced through differencing is avoided by using of the ECM, which implies the further existence of a long-term relationship of equilibrium between the variables in question.

First, it is necessary to test for panel unit root. However, panel unit root does not represent a fundamental problem in panel data approach, particularly in cases of relatively short range of time series, as in the case of present paper.

The heterogeneity of specific parameters for each country-section induces inherent difficulties in testing for the stationarity of panel data; on the other hand, if the cross-sectional units are considered as independent, sometimes, it may not represent the proper approach. In order collect as much as possible from the virtuous and to avoid backward aspects of using of these tests, there were considered examination via the commonly used tests for panel unit root.

These tests represent either specific developments, either improvements of the time series unit root tests, adapted in an applicable form to the panel data environment. The former include [28], and [36] as LLC and IPS; and the latter refers to Fisher-type tests based on PP [37] and ADF tests [29] as (F-PP and F-ADF).

All the four tests employed in this research have the null hypothesis of a unit root in various forms including against the alternative of stationarity. Fundamentally, the form of the autoregressive model is [38]:

$$\Delta y_{it} = \rho y_{i,t-1} + \sum_{L=1}^{pi} \theta_{iL} \Delta y_{i,t-L} + \delta X'_{it} + \varepsilon_{it}, \tag{1}$$

Implementation of the LLC test consists on running separate ADF regressions for each country. The null hypothesis assumes the existence of a common unit root process, thereby ρ has the same value across countries, against the alternative hypothesis of stationarity.

In recent literature, IPS is considered as the most used unit root test in panel data approach, because it has a greater contribution in relaxing the restriction of homogeneity specific in case of the LLC test, also allowing for values of ρ_i, which in most cases may differ among

Table 2
The descriptive statistics of the datasets.
Source: authors' computations based on Eurostat data.

Variables	*e_dep*	*e_pty*	*e_tax*	*e_int*	*el_rs*	*hc_rw*	*i_txe*	*pp_re*	*sh_rec*
Mean	32.6	6.49	2.6	1.98	26.2	19.1	1.795	5.852	18.86
Median	52.8	6.8	2.48	1.47	17.4	16.1	1.725	2.811	14.30
Maximum	104.1	16.1	4.99	6.31	113.7	52.4	4.360	38.886	72.50
Minimum	− 740.1	1.60	1.44	0.62	0.0	0.0	0.764	0.000	0.10
Std. Dev.	122.21	2.92	0.62	1.14	25.7	13.9	0.706	6.899	16.63
Skewness	− 4.88	0.44	0.92	1.58	1.6	0.5	1.142	1.815	1.56
Kurtosis	26.6	2.8	4.07	5.34	5.0	2.2	4.695	6.449	5.08
J-B test	9757.8	12.0	67.2	231.1	209.1	25.9	121.1	375.0	211.1
Probability	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sum	11,705	2330	934	711	9390	6847	644	2101	6771
S.Sq. Dev.	5,347,031	3047	138	469	236,461	69,460	178	17,039	99,063
Obs.	359	359	359	359	359	359	359	359	359

countries. In this case, the testing procedure for IPS test is based on computation of the $\bar{t}$-statistic as the average of the ADF unit root test statistics, using the following (2) as in [39]:

$$\bar{t} = \frac{\sum_{i=1}^{N} t_{\rho i}}{N} \tag{2}$$

In (2), $t_{\rho i}$ designates the individual t-statistic in case of testing the null hypothesis represented by each country in the panel which follows a unit root process as $\rho_i = 0$ for all i. The alternative hypothesis in this case is described by [40]:

$$H_1: \begin{cases} \rho_i < 0, \text{ for } i = \overline{1, N_1} \\ \rho_i = 0, \text{ for } i = \overline{N_1 + 1, N} \end{cases}, \tag{3}$$

Also, for a functional version of the alternative hypothesis it is required that the fraction of stationary cross-sectional series to be nonzero, by following the condition that $\lim_{N\to\infty}(\frac{N_1}{N}) = \gamma$, $0 < \gamma < 1$. For ensure the consistency of unit root test, if the lag order is always zero ($\rho_i = 0$, for each i), IPS test provide simulated critical values of $\bar{t}$ for different number of time-length series T, and cross-sections, N.

As [36] argues in the general case, in which $\rho_i \neq 0$ for a fraction cross-sections, IPS shows that a properly standardized $\bar{t}$ follows an asymptotic normal distribution [36].

Alike to IPS test, the F-ADF and F-PP tests allow for ρ_i to vary across cross-sections and, consequently, a fraction of individuals to have a unit root. In the general framework of the Granger non-causality tests, the individuals which are found to follow an integrated process of the same order, usually, of order one, $I(1)$, this relationship has to be tested for cointegration.

For testing the cointegration among series in this research is used [41] Kao test. Although this test was initially designed to be applies in a bi-variate context, [42] indicates that this test has a higher power in comparison with other competing tests, especially in homogenous panels and when, as in our case, the length of time series is relatively short. Basically [43], Kao test is a version of ADF test, carried out either on the residual (ε_{it}) of the auxiliary regression $\varepsilon_{it} = \rho\varepsilon_{it-1} + \nu_{it}$, either based on the augmented variant of the pooling specification in (4) as in [43]:

$$\varepsilon_{it} = \rho\varepsilon_{it-1} + \sum_{j=1}^{p} \lambda_j \Delta\varepsilon_{it-j} + \nu_{it} \tag{4}$$

Under the null of no cointegration, the augmented version is constructed upon the (5) [44]:

$$ADF = \frac{t_\rho + \frac{\sqrt{6N}\hat{\sigma}_v}{2\hat{\sigma}_{0v}}}{\sqrt{\frac{\hat{\sigma}_{0v}^2}{\hat{\sigma}_v^2} / + \frac{3\hat{\sigma}_v^2}{10\hat{\sigma}_{0v}^2}}} \sim N(0, 1), \tag{5}$$

Whereby $\hat{\sigma}_v^2$ is denoted the estimated variance and $\hat{\sigma}_{0v}^2$ represents the estimated long-run variance of the error term.

The basic assumption of the Kao test is that the value of ρ does not vary across the countries in the panel. As [45,46] propose in his research seven types of cointegration tests residual - based that relax this assumption, and allows for meaningful heterogeneity. All the Pedroni tests are based on the estimated residuals of panel regression described by: $\varepsilon_{it} = \rho_i\varepsilon_{it-1} + \nu_{it}$, under the null hypothesis of no cointegration, where $\rho_i = 1$.

The denomination of error correction term for the cointegration term is originated in the gradual correction of the deviation from the long-run equilibrium achieved via a series of partial short-run adjustments [39,40]. The model is specificated upon the following forms [2,17,39]:

$$\Delta edep_{i,t} = \alpha_i^{edep} + \beta_i^{edep} ECT_{i,t-1}^{edep} + \sum_{j=1}^{m} \delta_{ij}^{edep} \Delta edep_{i,t-j} + \sum_{s=1}^{q} \gamma_{1,is}^{edep} \Delta e\text{int}_{t-s} + \dots + \sum_{s=1}^{v} \gamma_{9,is}^{edep} \Delta shrec_{t-v} + u_{it}$$

$$\dots$$

$$\Delta shrec_{i,s} = \alpha_i^{shrec} + \beta^{v} ECT_{i,t-1}^{shrec} + \sum_{j=1}^{m} \delta_{ij}^{shrec} \Delta edep_{i,t-j} + \sum_{s=1}^{q} \gamma_{1,is}^{shrect} \Delta e\text{int}_{t-s} + \dots + \sum_{s=1}^{v} \gamma_{9,is}^{shrec} \Delta shrec_{t-v} + w_{it}$$

As a result of the correlation existent between the lagged endogenous variables and the error term, in specification of VEC models, it is necessary to be present an instrumental variable estimator. Consistent with the [39] approach, fixed effects are included into the model to remove the undetected heterogeneity of the within-dimension, whist inclusion of orthogonal deviations, alike to differences in the mean approach, is designed to remove the heterogeneity specific to between-dimension (panel members).

Following the [32] approach, the long-run causality is measured through the significance of *ECT* coefficients (or *beta* coefficients) using the standard t statistic, whilst the causality in short-run is evaluated by the joint-significance of lagged explanatory variables. In order to ensure the model stability, the *ECT* coefficient, which expresses the adjustment rate next to an exogenous shock, is assumed to be negative.

The option for using the panel VEC model approach in present study is based on its flexibility, which allows for using of heterogeneous panels and correction for both serial correlation and heteroskedasticity in standard errors. From the methodological point of view, it is noticeable that, in case of no significant evidence of cointegration, as the adequacy of EC models is limited for cases in which the series are integrated of order one, the EC terms are not included in the ECMs, and the standard Granger causality models are estimated without an EC term. In addition, in situations of no cointegration, the comparison of all the considered variables in the EC model has to be based upon their stationarity. Nevertheless, if added anyway, the literature indicates that they report insignificant results [43].

4. Results and discussion

As there has been presented in the literature review, a plenty of recent researches address different interrelations of the energy sector. Most of these scientific contributions regard the economic growth and energy taxation, examining the limits of energy taxation as a factor very specifically correlated to sustainable development, as the human aggression towards the environment represents an uncontestable reality. The first researches in the field were deployed from a national perspective, aimed mainly to compare results of VAR or OLS models for different countries [46–48].

However, in the first studies conducted in the framework of panel data approach, the used datasets account for reduced number of countries, often divided into groups, upon the economic development, geographical placement, or other criteria. Grouping based on various criteria represented the factor that leaded to homogenous characteristics within the respective groups. As presented in the previous paragraph, employing of the panel data approach allows just for control of heterogeneity. Despite the homogeneity of the policy, settings across the European Union countries, regarding the level of development still stand important disparities.

Our panel consists of the 30 countries, representing the European Union member states in 2015 plus Iceland and Norway. Other countries also adhered to the framework of reporting to Eurostat, but the availability of data concerning them is usually limited at less than five years. Yet, these data regard the candidate countries, which are following the specific roadmap in order to ensure the improvement domestic energy balances as a provision for joining the European Union.

Choosing to use the Eurostat data is based on their compatibility along the panel countries. From the econometric point of view, that ensures the variables compatibility across the considered countries.

Table 3
Panel unit root tests.

Variable	LLC		IPS		ADF-Fisher Chi-square		PP-Fisher Chi-square	
	Level	Differenced	Level	Differenced	Level	Differenced	Level	Differenced
e_dep	− 4.2***	− 17.18***	− 0.29	− 13.98***	58.4	267.2***	66.7	366.7***
e_int	− 4.68***	− 15.76***	1.10	− 9.66***	53.6	193.7***	69.9	256.7***
e_pty	− 1.22	− 15.04***	3.70	− 9.52***	36.94	199.39***	38.13	274.135***
el_rs	10.44	− 9.07***	11.58	− 6.69***	19.17	159.24***	23.03	179.19***
e_tax	− 5.49***	− 10.7***	− 0.81	− 6.35***	70.61	143.9***	83.53**	179.1***
hc_rw	− 1.75**	− 14.74***	2.96	− 9.42***	37.11	203.4***	44.65	264.75***
i_txe	− 0.646	− 14.87***	1.99	− 9.6***	58.38	195.46***	76.2	302.13***
pp_re	1.23	−15.23***	5.25	− 10.02***	28.39	209.7***	35.81	261.22***
sh_rec	1.96	− 11.46***	7.13	− 7.3***	17.62	158.35***	40.08	211.57***

Notes: Lag length determined upon the modified Schwartz Info Criterion.
Probabilities for the LLC and IPS tests are computed assuming asymptotic normality. Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution.
All tests equations include individual constant term („fixed effects").
Differenced refers to series resulted from first-difference.
***, **, * indicates the rejection of the null hypothesis at 1%, 5%, and 10% levels of significance (one tailed test).

The figures resulted from running of the panel unit root tests are presented in the Table 3.

From the above data, it is obviously that, in general, the cross-sectional units and the cross-sections are integrated of order one. Only the using of the LLC test reported a significant part (though, a minority) of the cross-sections to be stationary, for various levels of significance. The results of the pairwise Granger non-causality tests for the considered variables are presented in Table 4; consistent with the approach described in [32], the running of the cointegration test is performed considering, both variables as the dependent variable.

The results in the Table 4 suggest that, in majority of the cases, exist a biunivocal significant relationship of Granger causality between the considered datasets. According to these results, the *energy dependence* represents a causal variable for *energy productivity*; *electricity generated from renewable sources*, *primary production of renewable energy* and is caused by all these variables, plus *share of renewable energy in gross final energy consumption*.

The *energy intensity* is in a biunivocal causal variable with *electricity generated from renewable sources* and *share of renewable energy in gross final energy consumption*, and is caused by *energy productivity*.

Besides, the *energy productivity* represents a causal variable for *electricity generated from renewable sources* and *share of renewable energy in gross final energy consumption*, and is in a biunivocal cause relationship with *energy dependence*.

The *electricity generated from renewable sources* represents a causal variable for *households final energy consumption originated from renewable sources*, is in a biunivocal cause relationship with *energy dependence, energy intensity*, and *primary production of renewable energy* and is caused by *share of renewable energy in gross final energy consumption*.

Despite the series of researches aimed to highlight the importance of taxation for economic growth and social welfare, based on the available data may be observed that, in fact, the *environmental tax revenues* does not cause any of the considered variables. This may be considered consistent to the resultative specific-character of this variable. Interestingly, this variable is caused only by *households final energy consumption originated from renewable sources*, which may represent a proof for the effectiveness of the specific policies put in place by the appropriate authorities.

Besides the *environmental tax revenues,* the *households final energy consumption originated from renewable sources* represents a causal variable for *electricity generated from renewable sources* and *primary production of renewable energy,* is in a biunivocal relationship of causality with *implicit tax rate on energy* and causes *electricity generated from renewable sources* and share *of renewable energy in gross final energy consumption.*

The *primary production of renewable energy* is also in a biunivocal relationship of causality with both *electricity generated from renewable sources* and *energy dependence*, causes *implicit tax rate on energy* and is caused by *share of renewable energy in gross final energy consumption*.

The *share of renewable energy in gross final energy consumption* also causes *energy dependence, electricity generated from renewable sources* and *households final energy consumption originated from renewable sources*; it is in a biunivocal relationship of causality with *energy intensity,* and is caused by *energy productivity*.

The results of the pairwise Granger causality may suggest that the variables are in a relationship of contegration. In order to ensure a double-check of this relationship of cointegration the authors considered to examine the partial correlation between the considered variables. The results are presented in the Table 5.

Table 4
The results of the pairwise Granger causality tests.

Variable	*e_dep*	*e_int*	*e_pty*	*el_rs*	*e_tax*	*hc_rw*	*i_txe*	*pp_re*	*sh_rec*
e_dep	–	1.18	15.94***	4.57***	0.20	1.27	1.55	6.16***	1.68
e_int	0.96	–	1.25	5.97***	1.29	1.56	0.68	0.22	6.36***
e_pty	1.57**	3.51**	–	9.24***	1.84	0.54	2.01	4.43	2.73*
el_rs	3.78**	6.02***	0.51	–	0.53	3.05**	0.12	8.52***	1.64
e_tax	1.37	0.059	0.13	1.01	–	1.82	1.30	0.20	0.46
hc_rw	0.42	1.79	2.19	1.48	3.45**	–	3.13**	3.26**	1.13
i_txe	1.94	1.88	1.65	0.01	0.69	3.45**	–	2.01	1.13
pp_re	4.08**	0.027	1.53	3.67**	0.64	0.52	2.87**	–	0.15
sh_rec	5.34***	4.35**	1.23	3.20**	0.90	6.78***	0.20	9.38***	–

Notes: In the first columns, the explanatory variable in the cointegrating relation; in the headings, the dependent variable.
***, **,* Indicates rejection of the null hypothesis of no cointegration at the at the 1%, 5%, and 10% levels of significance.

Table 5
Results of partial correlation analysis.

Correlation	*e_dep*	*e_int*	*e_pty*	*el_rs*	*e_tax*	*hc_rw*	*i_txe*	*pp_re*
e_int	0.086							
e_pty	− 0.234***	− 0.854***						
el_rs	− 0.583***	0.042	0.134**					
e_tax	− 0.074	− 0.185***	0.235***	− 0.047				
hc_rw	0.003	0.280***	− 0.374***	0.156***	0.141***			
i_txe	− 0.152***	0.265***	− 0.194***	0.193***	− 0.120**	0.369***		
pp_re	− 0.179***	− 0.306***	0.304***	0.279***	− 0.210***	− 0.126**	− 0.0004	
sh_rec	− 0.556***	0.230***	− 0.071	0.922***	− 0.070	0.266	0.291***	0.212***

***, **, * indicates the significance of *t*-statistic at 1%, 5%, and 10% levels, respectively.

Table 6
Results of Pedroni and Kao panel cointegration tests.

Test statistic	Subgroup 1		Subgroup 2		Subgroup 3	
	Statistic	Weighted-stat	Statistic	Weighted-stat	Statistic	Weighted-stat
Panel *v*-Statistic	− 2.579	− 4.507	− 2.241	− 4.063	− 2.527	− 4.853
Panel *rho*-Statistic	6.053	5.755	5.912	6.544	5.570	6.546
Panel *PP*-Statistic	− 4.772***	− 10.855***	− 8.014***	− 5.200***	− 9.273***	− 10.358***
Panel *ADF*-Statistic	− 3.731***	− 6.747***	− 5.582***	− 2.984***	− 6.861***	− 4.779***
Group *rho*-Statistic	8.143	–	8.581	–	8.699	–
Group *PP*-Statistic	− 15.96***	–	− 12.692***	–	− 16.338***	–
Group *ADF*-Statistic	− 6.346***	–	− 4.377***	–	− 5.151***	–
Kao test	*ADF t*-Stat		− 4.082***	ρ = − 0.120 (− 3.842)***		

Notes: Lag length determined upon the modified Hannan-Quinn Criterion.
All tests equations include individual constant term ("fixed effects").
For the coefficient ρ afferent to the Kao test *t-Stat* value in parenthesis.
***, **, * indicates the rejection of the null hypothesis of no cointegration at the 1%, 5%, and 10% levels of significance (one-tailed test).

In the Table 6 are presented the results reported from Pedroni and Kao panel tests for cointegration, with the remark that the conducting of the Pedroni test is adapted to the Eviews software package specific that supports maximum seven cointegrated series. Therefore, considering the results of the partial correlation analysis, which indicate a significant and high value of the correlation coefficients between *share of renewable energy in gross final energy consumption* and *electricity generated from renewable sources*, and respectively, between *energy productivity* and *energy dependence*, there was considered three subgroups.

In this respect, every subgroup contains one of the two correlated variables, as follows: subgroup one (*energy productivity* and *energy generated from renewable sources*), subgroup two (*energy dependence* and *share of renewable energy in gross final energy consumption*), and subgroup three (*energy dependence* and *energy generated from renewable sources*), plus the other six remaining variables respectively.

From the Table 6, there might be observed mixed results leading to different conclusions. However, the null hypothesis of no cointegration is rejected in majority of cases. As stated in the above paragraph, Pedroni considers that in cases of *rho* and *pp* tests exists a bias to under-reject the hypothesis no cointegration, especially in the case of small samples. In our case, it is possible one may observe that, for all the considered cases, for the *rho* test is accepted the null hypothesis, whereas, for the *pp*-test the results are opposite. In addition, considering the result reported by the Kao test, besides the results of the pairwise non-causality Granger tests, the inclusion of the EC term in the VEC model is suitable. The estimation for the VEC model, using GMM method, consistent with the approach of Arellano-Bover are presented in the Table 7.

The significant results in the estimated α_i (Error-Correction-Term) highlight different situations of the considered variables. Therefore, the negative values tending towards zero indicate that the long-term adjustment process is slow; this is the case for the *energy intensity* and *electricity generated from renewable sources*. *Primary production of renewable energy* the acts as variable that tend to overshoot the economic equilibrium of the system. In case of *share of renewable energy in gross final energy consumption*, the positive coefficient expresses that the action of this variable is toward a deflection of the considered system from the long-run equilibrium path.

Table 7
Estimation of error-correction-term in the vector error-correction model.

Variables	ECT coefficients (*t*-statistic)	Speed of adjustment (*t*-statistic)	Lag coefficient (*t*-statistic)	*F*-statistic
e_tax	1.000	− 0.002 (− 1.150)	0.161 (2.878) ***	2.639**
e_int	− 0.069 (− 4.926) ***	− 0.124 (− 2.155) ***	0.005 (2.575) ***	5.271***
el_rs	− 0.098 (− 0.576) ***	− 0.005 (− 0.522)	0.010 (0.654)	9.458***
ppre	− 2.263 (− 8.361) ***	− 0.025 (− 8.365) ***	− 0.042 (− 1.045)	11.357***
sh_rec	0.739 (2.657)***	− 0.007 (− 1.371)	− 0.015 (− 0.527)	3.535***

Notes: Lag length: 1, 1.
***, **, * indicates the significance at the 1%, 5%, and 10% levels of significance.

5. Conclusions

During the recent years, many studies have focused on the different connections between energy and energy consumption and different economic aspects. However these researches, previously conducted have taken into consideration just direct connections between these aspects, without establishing future influences on the economic development. In the introduced approach, the measuring of the effects and determinants of the energy paradigm changes on influencing economic growth in European Union is carried out by employing of the panel data approach and its subsequent techniques in a panel investigating the interrelated evolution of nine economic variables within 30 European countries, (EU-28 in 2015, plus Iceland and Norway).

One of the major challenges in contemporary economies is represented by the transformation of the current energy paradigm which implies a proper approach in the field, as it is remarked in literature [49–53] in connection with complementary issues in the field (environmental performance, environment protection, sustainable development and EU institutions).

The analysis of the variables employed in the research reviles multi-objective combinations and inter-correlations among countries and variables. In this context, the emergence of the effects and determinants of the energy paradigm changes on influencing economic growth in European Union represents a determinant research topic in literature by its main implication in designing the new energy paradigm.

Referring to the speed of adjustment, the results express the significant influence of *energy intensity* and *primary production of renewable energy*. Considering the significance of the lagged explanatory variables, which expresses the causal effect in short-term, the results indicate important evidence in favor of variables *environmental tax revenues* and *primary production of renewable energy*. It is remarkable that the latter variable takes significant values for all the aspects in the VEC model, despite the reduced and various shares of renewable energies in total consumption, in most of the considered countries. This situation may be interpreted in connection with the important investments and production capacities in the field of renewable energies deployed especially in some European countries, aiming to comply with the Kyoto Protocol provisions.

References

[1] Devezas T, LePoire D, Matias JC, Silva AM. Energy scenarios: toward a new energy paradigm. Futures 2008;40(1):1–16.
[2] Andrei JV, Mieila M, Panait M. The impact and determinants of the energy paradigm on economic growth in European Union. PLoS One 2017;12(3):e0173282.
[3] Oksay S, Iseri E. A new energy paradigm for Turkey: a political risk-inclusive cost analysis for sustainable energy. Energy Policy 2011;39(5):2386–95.
[4] Apergis N, Payne James E. Energy consumption and economic growth in Central America: evidence from a panel cointegration and error correction model. Energy Econ 2009;31(2):211–6.
[5] Azam M, Khan AQ, Bakhtyar B, Emirullah C. The causal relationship between energy consumption and economic growth in the ASEAN-5 countries. Renew Sustain Energy Rev 2015;47:732–45.
[6] Hussain A, Arif SM, Aslam M. Emerging renewable and sustainable energy technologies: state of the art. Renew Sustain Energy Rev 2017;71:12–28.
[7] Zeng S, Streimikiene D, Baležentis T. Review of and comparative assessment of energy security in Baltic States. Renew Sustain Energy Rev 2017;76:185–92.
[8] Marques AC, Fuinhas JA, dos Santos Gaspar J. On the nexus of energy use-economic development: a panel approach. Energy Procedia 2016;106:225–34.
[9] Yu THK, Huang MC, Huarng KH. Causal complexity of economic development by energy consumption. J Bus Res 2016;69(6):2271–6.
[10] Carley S, Lawrence S, Brown A, Nourafshan A, Benami E. Energy-based economic development. Renew Sustain Energy Rev 2011;15(1):282–95.
[11] Soytas U, Sari R. Energy consumption, economic growth, and carbon emissions: challenges faced by an EU candidate member. Ecol Econ 2009;68(6):1667–75.
[12] Popescu GH. Does economic growth bring about increased happiness?. J Self-Gov Manag Econ 2016;4(4):27–33.
[13] Belke A, Dobnik F, Dreger C. Energy consumption and economic growth: new insights into the cointegration relationship. Energy Econ 2011;33(5):782–9.
[14] Isik C, Shahbaz M. Energy consumption and economic growth: a panel data aproach to OECD countries. Int J Energy Sci 2015;5(1):1.
[15] Streimikiene D, Kasperowicz R. Review of economic growth and energy consumption: a panel cointegration analysis for EU countries. Renew Sustain Energy Rev 2016;59:1545–9.
[16] Dusmanescu D, Andrei J, Subic J. Scenario for implementation of renewable energy sources in Romania. Procedia Econ Financ 2014;8:300–5.
[17] Andrei J, Mieila M, Popescu G, Nica E, Cristina M. The impact and determinants of environmental taxation on economic growth communities in Romania. Energies 2016;9(11):902.
[18] Jorgenson AK, Alekseyko A, Giedraitis V. Energy consumption, human well-being and economic development in central and eastern European nations: a cautionary tale of sustainability. Energy Policy 2014;66:419–27.
[19] Tiba S, Omri A. Literature survey on the relationships between energy, environment and economic growth. Renew Sustain Energy Rev 2017;69:1129–46.
[20] Chang DS, Yeh LT, Chen YF. The effects of economic development, international trade, industrial structure and energy demands on sustainable development. Sustain Dev 2014;22(6):377–90.
[21] Fouquet R. Lessons from energy history for climate policy: technological change, demand and economic development. Energy Res Soc. Sci 2016;22:79–93.
[22] Wang S, Li Q, Fang C, Zhou C. The relationship between economic growth, energy consumption, and CO2 emissions: empirical evidence from China. Sci Total Environ 2016;542:360–71.
[23] Yuan X, Mu R, Zuo J, Wang Q. Economic development, energy consumption, and air pollution: a critical assessment in China. Human Ecol Risk Assess: Int J 2015;21(3):781–98.
[24] Esso LJ, Keho Y. Energy consumption, economic growth and carbon emissions: cointegration and causality evidence from selected African countries. Energy 2016;114:492–7.
[25] Saboori B, Sulaiman J. Environmental degradation, economic growth and energy consumption: evidence of the environmental Kuznets curve in Malaysia. Energy Policy 2013;60:892–905.
[26] Grübler A. Technology and global change. Cambridge: Cambridge University Press; 1998.
[27] Al-mulali U, Lee JYM, Mohammed AH, Sheau-Ting L. Examining the link between energy consumption, carbon dioxide emission, and economic growth in Latin America and the Caribbean. Renew Sustain Energy Rev 2013;26:42–8.
[28] Levin A, Lin CF, Chu C. Unit root tests in panel data: asymptotic and finite-sample properties. J Econ 2002;108:1–24.
[29] Maddala GS, Wu S. A comparative study of unit root tests with panel data and a new simple test. Oxf Bull Econ Stat 1999;61:631–52.
[30] Fang Z, Chang Y. Energy, human capital and economic growth in Asia Pacific countries—evidence from a panel cointegration and causality analysis. Energy Econ 2016;56:177–84.
[31] Constantini V, Martini C. The causality between energy consumption and economic growth: a multi-sectoral analysis using non-stationary cointegrated data. Energy Econ 2010;32:591–603.
[32] Granger CWJ, Huang B, Yang CW. A bivariate causality between stock prices and exchange rates: evidence from recent Asian flu. Q Rev Econ Financ 2000;40:337–55.
[33] Mirza FM, Kanwal A. Energy consumption, carbon emissions and economic growth in Pakistan: dynamic causality analysis. Renew Sustain Energy Rev 2017;72:1233–40.
[34] Alinsato AS. Electricity consumption and GDP in an electricity community: evidence from bound testing co-integration and granger-causality tests. J Econ Int Financ 2013;5(4):99–105.
[35] Narayan PK, Smyth R. Energy consumption and real GDP in G7 countries: new evidence from panel cointegration with structural breaks. Energy Econ 2008;30:2331–41.
[36] Im KS, Persaran MH, Shin Y. Testing for unit roots in heterogeneous panels. J Econ 2003;115:53–74.
[37] Choi I. Unit root tests for panel data. J Int Money Financ 2001;20:249–72.
[38] Greene W. Econometric analysis, 7th ed.. Harlow: Pearson Education; 2012. p. 1011.
[39] Arellano M, Bover O. Another look at the instrumental variable estimation of error-component models. J Econ 1995;68:29–51.
[40] Bond S. Dynamic panel data models: a guide to micro data methods and practice. Port Econ J 2002;1:141–62.
[41] Baltagi BH. Econometric analysis of panel data, 3rd ed.. Chichester: John Wiley & Sons; 2005. p. 242.
[42] Kao Chinwa D. Spurious regression and residual-based tests for cointegration in panel data. J Econ 1999;90:1–44.
[43] Gutierrez L. On the power of panel cointegration tests: a Monte Carlo comparison. Econ Lett 2003;80:105–11.
[44] Abdullah S, Morley B. Environmental taxes and economic growth: evidence from panel causality tests. Energy Econ 2014;42:27–33.
[45] Pedroni P. Fully modified OLS for the heterogeneous cointegrated panels. Adv Econ 2000;15:93–130.
[46] Pedroni P. Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis: new results. Econom Theory 2004;20:597–627.
[47] Blundell R, Bond S, Windmeijer F. Estimation in dynamic panel data models: improving on the performance of the standard GMM estimator. In: Nonstationary panels, panel cointegration, and dynamic panels. Emerald Group Publishing Limited; 2001. p. 53–91.
[48] Lee CC. Energy consumption and GDP in developing countries: a cointegrated panel analysis. Energy Econ 2005;27:415–27.
[49] Sima V, Georgiana GI. Analyze of environmental performance in Romania based on environmental performance index. Ann-Econ Ser 2014;3:101–4.
[50] Buzoianu D. Strategic study on environment protection in the Romanian petroleum extraction industry. In: Annals of DAAAM & proceedings; 2009. p. 1639-41.
[51] Robison LJ, Ritchie BK. Relationship economics: the social capital paradigm and its application to business, politics and other transactions. CRC Press; 2016.
[52] Drăgan G, Drăgoi MC. Uniunea Europeană. Etape, instituții, mecanisme. București: Editura ASE; 2013.
[53] Hasnan B. Sustainable development impossible without shift in economic paradigm. Adv Manag 2016;9(3):6.
[54] Eurostat; 2017. ⟨http://ec.europa.eu/eurostat/data/database⟩.