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Energy consumption and GDP causality: A three-step analysis for emerging European countries

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R T I C L E I N F O

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B S T R C T

The established European targets should play a leading role in the complex economic process of energy consumption, and the emerging countries have to consider their implications for adjusting the energy policies at national level. This paper develops investigations on the causality relationship between energy consumption and GDP in the context of emerging European countries covering the period 1980–2013. This research covers the limits identi ed by previous researchers, by detailing the energy consumption by sources and by referring to ve emerging countries in Europe. Unlike most of the previous studies it has a double approach: long and short-run bidirectional relationships. A detailed analysis on the impact of economic growth on the energy consumption by country is conducted in order to contribute to the enrichment of the research eld. Towards this objective, a three-step analysis is performed: stationarity, cointegration and causality tests are considered. The empirical study shows mixed results. There is a balance in con rming conservation, growth and neutrality hypotheses. In some speci c cases results imply that energy consumption and economic growth are jointly determined. However, a comparative analysis for different signi cance levels draws attention on the differences in judgment of results for this type of studies. Discussions on the results in terms of causality are conducted in order to identify future trends for research.

Contents

1. Introduction

The complex economic process of energy consumption has long attracted attention at the policy making level in the energy sector in order to achieve the established European targets. The relationship

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between energy consumption and economic growth indicators is a subject of great interest in the literature. Kraft and Kraft [1] opened the series of researches on the causality between energy consumption and economic growth, using a panel of US data from 1947 to 1974. They concluded that Gross National Product (GNP) leads to energy consumption. This seminal research was followed by an impressive number of studies on the same subject. Most of the empirical studies focused on either testing the role of energy in stimulating economic growth or examining the direction of causality between these two variables. Different studies have focused on different countries, time periods, proxy variables and different econometric methodologies have been used for energy consumption and growth relationship [2,3]. However, limited research has been published on the nexus between individual sources of energy consumption and Gross Domestic Product (GDP) growth. As Ohler and Fetters [4] observed, the countries' challenges in determining the optimal mix of energy consumption provide incentives for considering the role of individual sources in future research.

Performing a comprehensive review of the literature on energy-growth nexus for the period of 1978–2009 in the energy economics literature, Ozturk [2] presents four categories of causal relationship between energy consumption and economic growth, with important implications for energy policy. First, no causality relation, referred to as neutrality hypothesis implies that energy consumption is not correlated with economic growth. According to this type of results, the policies on energy consumption (whether conservative or expansion) have no effect on economic growth. Second, the unidirectional causality relation running from economic growth to energy consumption, referred to as conservation hypothesis suggests that the policy of conserving energy consumption may be implemented with little or no adverse effect on economic growth, meaning that an increase in economy causes an increase in energy consumption. Third, the unidirectional causality relation running from energy consumption to economic growth, referred to as growth hypothesis implies that energy consumption plays an important role in economic growth. Under this hypothesis, energy is a limiting factor to economic growth. Thus, restrictions on the use of energy may negatively affect economic growth while increases in energy may contribute to economic growth. Finally, the bidirectional causality relation, referred to as feedback hypothesis implies that energy consumption and economic growth are jointly determined and affected at the same time.

The present paper refers to these four hypotheses as they may be considered a framework in which most of the research on the causality between energy consumption and economic growth were conducted [3,5–14]. Mixed results generated by the studies conducted for countries, groups of countries or regions with common policies indicate that the subject proposed in this paper is still new and exciting.

In the current global crisis in which humanity is recovering slowly and with difficulties, the international organizations have sought new strategies for growth. Given that energy consumption and economic growth are intrinsically linked, the European challenge is to create and meet interrelated regulatory requirements in the newly competitive environment, as well as strategies for delivering a secure and sustainable energy supply. During economic crises, the emerging European countries have suffered larger output declines than other countries in Europe, and yet, significantly different from each other. This can be attributed to European economic and political integration [15]. Therefore, extended research is required on the role that policy differentiation has on economic growth for emerging countries as regard to primary energy consumption by sources. This idea is developed in the context of a differentiated cultural approach on energy consumption by sources in emerging countries, given the awareness, in the last period, for the pressure of natural resources limitation and depletion.

The present research extends previous surveys by detailing the energy consumption by sources (total, coal, oil, gas and renewables) and by referring to five emerging countries in Europe (Bulgaria, Hungary, Poland, Romania, and Turkey). The studied period (1980–2013) was chosen in order to reflect the causality relationship within a time when energy consumers became aware of the higher and higher impact of natural resources limitation and depletion. Additionally, the study examines both long and short-run bidirectional relationships using dual econometric testing, corroborating Kalimeris et al. [3] results, showing that most of the studies searched for the short-run relationship, and Al-mulali et al. [5] assertion that the country's energy policy is influenced by the sign of the long-run relationship.

The reminder of the paper is organized as follows: the mixed results of the relevant literature on energy consumption and economic growth causal relationships are presented in the second section of the paper. The third section discusses the research methodology and the fourth section reports the empirical findings of the study. The last section concludes the paper with debates on future trends for extending the concept of growth through the integration of current European Union policy to meet the requirements of sustainable development.

2. The hypotheses debate on energy consumption and economic growth causality

The previous studies focusing on the causality between energy consumption and economic growth have mixed results and could not reach to a conclusive recommendation on the policy that can be applied across countries [2]. The results of causal relation between energy and economic growth seem to be different depending on the direction of causality and the long-term versus short-term impact on energy policy. The policy implications of these relationships can be significant depending upon what kind of causal relationship exists [2,5,7].

Chen et al. [16] suggest that different factors may explain the results, sometimes contradictory, of the studies addressing the causal relation between energy consumption and economic growth: countries' characteristics such as different indigenous energy supplies, different political and economic histories, different political arrangements, different institutional arrangements, different cultures and different energy policies. All these limitations are highlighted in their study for a group of countries with similar policies and requirements in terms of energy consumption and trends in the consumption structure.

Customizing the energy variable, the country development level appears to be associated with intensity of electricity usage. According to Solarin and Shahbaz [6] the electricity consumption in the European Union was 11 fold the total consumption in sub-Saharan Africa in the year 2009, despite the reverse ratio of population Chandran et al. [17] incorporated electricity prices in modeling the relation between electricity consumption and economic growth reporting cointegrated variables and a unidirectional causality based on growth hypotheses (electricity consumption Granger causes economic growth). Karanfil [18] has suggested the same in exploring the causal links between energy consumption and economic growth by including other relevant variables rather than bivariate case. Tang [19] incorporated foreign direct investment and population into the electricity demand function in the relation to economic growth. Results show that the economic growth, foreign direct investment, and population have a positive impact on electricity consumption, but also that electricity consumption, economic growth, and foreign direct investment have bidirectional causality relation. Bartleet and Gounder [20] criticized on energy-growth association and recommended to incorporate other pertinent variables such as labor and capital that also play an important role to elucidate the electricity consumption–economic growth relation. Tang and Tan [21] reinvestigated the relationship between electricity consumption and economic growth by incorporating technological innovations in the electricity demand model. Cointegration among the variables, and bidirectional causality between electricity consumption and economic growth were found. Detailing, they showed a positive link between income and electricity consumption and a negative relation between electricity prices and technological innovations and electricity consumption.

The literature review of the studies conducted on panels that include European countries shows that different time periods are covered, different econometric models are employed, and different variables customizing energy consumption and explaining economic growth are used. The results have located the relationship between energy consumption and economic growth in all four hypotheses, and using a variety of methodologies. Some of the studies present the analysis by considering and presenting the con rmed hypothesis for each individual county, while other studies draw conclusion for the entire group of counties (Table 1).

Table 1
The hypotheses debate on energy consumption and economic growth causality.
Source: Authors' synthesis based on [2,3,5,7].

Con rmed hypothesis	Methodology	Country/group of countries	Period	Study
Conservation	Ordinary least squares (OLS), fully modi ed OLS, dynamic OLS	18 emerging countries	1994–2003	Sadorsky [22]
	Panel VARs (vector autoregressive) and GMM (generalized method of moments)	18 developing countries	1971–2002	Lee and Chang [23]
	Bootstrapped causality testing	30 OECD countries: Finland, Hungary, Netherlands	1960–2002	Narayan and Prasad [24]
	Toda–Yamamoto procedure based on a developed Granger causality test	11 developed countries: France, Italy, Japan	1960–2001	Lee [12]
	Multivariate cointegration (Johansen and Juselius cointegration), error correction model (ECM)	G-7 countries: Germany	1960–2004	Soytas and Sari [13]
	Cointegration, vector error correction model (VECM)	France (in the short run)	1960–2000	Ang [25]
	VEC Granger causality	Turkey	1970–2003	Lise and Montfort [26]
	Granger causality	6 industrialized countries: Italy, Germany	1952–1982	Erol and Yu [27]
	Co-integration, vector error correction model and Granger causality	10 emerging countries (China excluded) and G7 countries: Italy, Korea	1950–1992	Soytas and Sari [14]
	Panel cointegration and panel causality tests	51 low and middle income countries: in low income countries	1971–2005	Ozturk et al. [10]
Feedback	Panel cointegration and panel causality tests	20 OECD countries	1985–2005	Apergis and Payne [28]
	Panel model	Developed and developing countries	1984–2007	Apergis et al. [29]
	Panel cointegration and panel causality tests	13 countries within Eurasia	1992–2007	Apergis and Payne [30]
	Panel cointegration and panel causality tests	Emerging countries	1990–2007	Apergis and Payne [31]
	Panel cointegration, vector error-correction model, Granger causality	25 OECD countries	1981–2007	Belke et al. [9]
	Autoregressive distributed lag (ARDL)	Portugal, Italy, Greece, Spain and Turkey	1965–2009	Fuinhas and Marques [32]
	Panel co-integration, panel VEC model	22 OECD countries	1960–2001	Lee et al. [33]
	Granger causality test, Co-integration, VECM	Cyprus	1960–2004	Zachariadis and Pashouortidou [34]
	Multivariate cointegration (Johansen and Juselius cointegration), ECM, generalized variance decompositions	G7countries: Canada, Italy, Japan, UK	1960–2004	Soytas and Sari [13]
	Panel VARs and GMM	22 Developed countries	1965–2002	Lee and Chang [23]
	Panel error correction model	20 developed and developing countries: developed countries	1971–2002	Mahadevan and Asafu-Adjaye [35]
	Bootstrapped causality testing approach	30 OECD countries: Iceland, Korea, UK	1960–2002	Narayan and Prasad [24]
	Toda–Yamamoto procedure based on a developed Granger causality	11developed countries: Sweden, USA	1960–2001	Lee [12]
	Panel model	Developed and developing countries: 70 of the countries	1980–2007	Akkemik and Goksal [36]
	ADRL model, Granger causality test	Hungary	1980–2006	Ozturk and Acaravci [37]
	Panel cointegration and panel causality tests	51 low and middle income countries: in middle income countries	1971–2005	Ozturk et al. [10]
Growth	Granger causality	30 OECD and 78 non-OECD countries	1971–2000	Chontanawat et al. [38]
	Panel VECM	18 developing countries	1975–2001	Lee [39]
	Panel cointegration, Granger causality	G7 countries	1972–2002	Narayan and Smyth [40]
	Bootstrapped causality testing approach	30 OECD countries: Australia, Italy, Slovak Republic, Czech Republic, Portugal	1960–2002	Narayan and Prasad [24]
	Toda–Yamamoto procedure based on a developed Granger causality test	11developed countries: Belgium, Netherlands, Canada, Switzerland	1960–2001	Lee [12]
	Panel cointegration and panel causality tests	85 countries by income: developed and developing countries	1990–2006	Apergis and Tang [41]

Table 1 (*continued*)

Con rmed hypothesis	Methodology	Country/group of countries	Period	Study
	Multivariate cointegration (Johansen and Juselius cointegration), ECM, generalized variance decompositions	G-7countries: France, USA	1960–2004	Soytas and Sari [13]
	Co-integration, VECM	France: in long run	1960–2000	Ang [25]
	Panel co-integration, GMM, panel causality	12 European countries: in the long run	1970–2004	Ciarreta and Zarraga [42]
	Panel error correction model	20 developed and developing countries: developing countries	1971–2002	Mahadevan and Asafu-Adjaye [35]
	Co-integration, vector error correction techniques and Granger causality	10 emerging countries (China excluded) and G7 countries: Turkey, France, Japan, Germany	1950–1992	Soytas and Sari [14]
Neutrality	Granger causality	6 industrialized countries: France, UK	1952–1982	Erol and Yu [27]
	Pedroni panel cointegration tests	15 transition countries	1990–2006	Acaravci and Ozturk [43]
	Bootstrapping estimation	G7 countries	1990–2007	Balcilar et al. [44]
	One-way random effect model, Panel causality tests	27 European countries	1997–2007	Menegaki [8]
	Panel co-integration, GMM, panel causality	12 European countries: in the short run	1970–2004	Ciarreta and Zarraga [42]
	Toda–Yamamoto procedure based on a developed Granger causality test	11developed countries: Germany, UK	1960–2001	Lee [12]
	Bootstrapped causality testing approach	30 OECD countries: the other 19 countries	1960–2002	Narayan and Prasad [24]
	Granger causality	5 countries: UK, USA, Poland	1950–1976	Yu and Choi [45]
	Panel model	Developed and developing countries: for 20 of the countries	1980–2007	Akkemik and Goksal [36]
	ADRL model, Granger causality test	Albania, Bulgaria, and Romania	1980–2006	Ozturk and Acaravci [37]
	Generalized Method of Moment System (GMM SYS) panel model	82 countries by income: in middle income countries	1972–2002	Huang et al. [46]

To summarize, growth hypothesis was retained especially for the long-term causality between energy and economic growth, while the short-term elasticity was explained by the conservation and neutrality hypotheses. Different results appeared depending on the selected countries in the investigated panel and on econometric tests conducted by the researchers. Using cointegration and vector error correction (VEC) techniques, Soytas and Sari [14] examined the causal relationship between GDP and energy consumption from 1950 to 1992 in the top 10 emerging countries (China excluded) and the G7 countries. The results con rmed the growth hypothesis for Turkey, France, and West Germany (energy consumption is leading GDP) and the conservation hypothesis for Italy (GDP is leading energy consumption). Four years later, Lise and Montfort [26] validated the conservation hypothesis for Turkey, using VEC Granger causality for the period 1970–2003. Feedback hypothesis was found primary for the developed countries, as result of a large number of studies [9,12,23,28,33,35], without being able to make a rule or a basis for future projections. Studies like Soytas and Sari [13], Lee [12], Ciarreta and Zarraga [42], or Narayan and Prasad [24] found that different hypotheses were validated on different countries and for different periods.

Lee and Chang [23] investigated the causal relationship between energy consumption and GDP using the bivariate model under the panel VAR for 22 developed countries and 18 developing countries and discovered a unidirectional causal relationship (GDP growth leads to increasing energy consumption) in the developing countries and a bi-directional causality in developed countries. Narayan and Prasad [24] tested the causality for 30 OECD countries in the period 1960–2002 and found mixed results depending on the county. Growth hypothesis was retained for Australia, Italy, Slovak Republic, Czech Republic, and Portugal, conservation hypothesis for Finland, Hungary, Netherlands, feedback for Iceland, and UK, while the rest of the studied countries revealed no causality.

Ozturk and Acaravci [37], using a two-step procedure based on Engle and Granger model, an autoregressive distributed lag (ARDL), and a dynamic VEC found a bidirectional causality in Hungary, and a neutral one for Albania, Bulgaria, and Romania (as no causal relationships within dynamic error correction model could be determined). On the other hand, Kayhan et al. [47], studding the Romanian data for the period of 2001–2010, con rmed the growth hypothesis, with causality running from electricity consumption to economic growth, on the base of the Dolado-Lutkepohl, Tado-Yamamoto and traditional Granger causality tests. In Poland, Gurgul and Lach [48] applied trivariate model to examine causality between electricity consumption, employment, and economic growth. Their results indicated that economic growth Granger causes employment but the neutrality hypotheses was chosen for the electricity consumption–growth causality.

The growing importance of sustainable development directed the researchers towards a speci c subject regarding the impact of renewable energy consumption on economic growth. At the same time, the renewable energy sources have become important, yet not signi cant components in the total global energy consumption. Using panel cointegration tests Sadorsky [22] shows that increases in real per capita income have a positive and statistically signi cant impact on per capita renewable energy consumption for 18 emerging countries around the world. For 10 of the countries, the author used the electricity prices as a proxy, augmenting the estimation model. For the ten countries, including Hungary, Poland, and Turkey long-term renewable energy per capita consumption price elasticity estimates are approximately equal to 0.70 suggesting that renewable energy consumption is much more sensitive to electricity price changes than the electricity market as a whole.

An extended comparative study on the bidirectional long-run relationship between renewable energy consumption and GDP growth was conducted by Al-mulali et al. [5]. Using Phillip Peron test on the two variables, renewable energy consumption and GDP the authors con rmed the null hypotheses for Romania, Poland and Turkey (classi ed as upper middle income countries), but also for Hungary and Bulgaria (classi ed as high income countries).

The time series for those counties were stationary for the first difference, but with different levels of significance. The full modified least square (FMOLS) test was used to examine the causality and results showed a bidirectional causality between renewable energy and GDP for all the mentioned countries, except Romania, where the growth hypotheses verified (the energy consumption form renewable sources generated an increase in GDP).

3. Research methodology

According to Kalimeris et al. [3] various approaches of the causality relationships between energy consumption and GDP are available in empirical literature. The methodology based on Granger [49] causality econometric tests, including the modified Engle–Granger causality test [50] was the most used one (30.2% of Kalimeris et al. [3] researched papers) in the articles of: Kraft and Kraft [1], Erol and Yu [27], Nachane et al. [51], Chontanawat et al. [38], Narayan and Smyth [40], Ozturk and Acaravci [37], etc. Other methodological approaches based on the cointegration method [52], or alternatives such as Toda and Yamamoto [53] causality tests, Pedroni cointegration [54] or ADRL bound test was also extensively used [35,37,39,55–59]. For energy input sources, Kalimeris et al. [3] found that 39.7% of the papers used the energy per capita [9,25,35,38,40], while other types used were: electricity values for energy consumption variable, total energy or a single source of energy (coal, oil, gas or other). According to Ozturk and Acaravci [37:1983] "the empirical literature on the energy consumption-growth nexus have yielded mixed and often conflicting results due to the different data set, different countries' characteristics and different econometric methodologies used".

The present paper employs Granger methodology to research for the bidirectional relationship, and energy per capita as studied variable, as they were mostly used in similar researches. Measurement of diverse and distinct sources of energy requires an aggregation method. In this respect, the study employs energy a measurement method based on thermal equivalents (BTUs), adjusted by the population of each country. "The advantage of the thermal equivalent approach is that it uses a simple and well-defined accounting system based on the conservation of energy, and the fact that thermal equivalents are easily and uncontroversial measured" [60:302]. This energy measurement method was prior used in the literature by Nachane et al. [51] or Yin and Wang [61]. At the same time, in analyzing the relationships between energy consumption and economic growth, the paper presents an evolution of different sources of energy consumption for five EU emerging countries, and the GDP evolution, the main trends and changes for 1980–2013 period. Prior to determine the short-run and long-run relationships between the variables, stationarity tests [62–64], as unit root tests are applied to the data series. The cointegration between the stationary series is tested [65]. The long-run relationship between variables is completed by testing the Granger causality for the cointegrated series as an analysis of the short-run relationships Granger [66] and in Engle and Granger [50].

3.1. Model and data

The standard linear functional specification has become the statistical model for examining of the relationship between energy consumption and GDP. According to Ozturk and Acaravci [37], the standard linear functional specification of the relationship between energy consumption and GDP, can be described in brief as

$$GDP_t = \alpha + \beta PEC_t + \varepsilon_t \quad (1)$$

where *GDP* is the Gross Domestic Product breakdown per capita (constant 2005 prices in USD); PEC_t is the primary energy consumption[1] (millions BTUs per capita), and ε_t is the error term.

The variables used in the present study are expressed as per capita values in order to eliminate the possible inconsistencies given by the large variations of country's energy consumption and economic growth compared to the number of inhabitants in each country. The primary energy consumption per capita was collected for total (*PEC_T*), but by sources, as well: coal (*PEC_C*), gas (*PEC_G*), oil (*PEC_O*), and renewables (*PEC_R*). The annual time series data for Bulgaria, Hungary, Poland, Romania and Turkey were obtained from the United Nations Statistics Division [67], World Bank database [68] and the US Energy Information Administration (EIA) Official Energy Statistics [69] for the period 1980–2013.

However, to examine the statistical relationship between two variables, the correlation analysis is not enough, as "it gives no indication about the direction of relationship" [70:204]. To overpass the correlation test limits, and reach the properly interpreted causality between two variables, an assumption have to be included in the model, that the cause occurs before the effect. Thus, according to Granger [71], causality questions should imply considering the vector autoregressive form of the system and placing the variables at the time they are observed, by introducing the time lag into the causality equation.

3.2. Autoregressive time series with a unit root

Granger [70] used the stationarity properties of two series to introduce the concept of cointegration. Thus, the first step is to test the stationarity of the series, given that for the series to be cointegrated they should be stationary of the same order and be generated by an error-correction model.

This study uses Augmented Dickey–Fuller (ADF) tests [62,63], Phillips–Perron (PP) tests [64], as unit root tests developed in the literature to check the stationarity of the data, extensively detailed by Al Mamun et al. [72]. Gujarati [73] shows that the ADF test is applied by running the following regression:

$$\Delta Y_t = \alpha + \delta Y_{t-1} + \beta \Delta Y_{t-1} + \varepsilon_t \quad (2)$$

where α is the intercept, ΔY_t is the error, and ΔY_{t-1} is the lagged difference term. The maximum number of lags is computed using the following formula:

$$\mathrm{Max(LagLength)} = 12(T/100)^{1/4} \quad (3)$$

where *T* is the number of observations in the sample. In the present study, the sample consists of 34 observations per country (the 1980–2013 period), therefore the maximum lag length used is 9. The optimum lag length is selected based on the Schwartz Info Criterion [74].

The null and alternative hypotheses of the ADF test are H0: $\delta=0$ and H1: $\delta \neq 0$. These hypotheses can be evaluated using the conventional *t*-test for δ:

$$t_\delta = \delta_{es}/\mathrm{SE}(\delta_{es}) \quad (4)$$

where δ_{es} is the estimate of δ, and $\mathrm{SE}(\delta_{es})$ is the coefficient standard error.

The series are stationary, noted *I*(0) when the null hypotheses can be rejected based on a t-statistic value smaller than the critical value. The failure in rejecting the null hypothesis drives to the conclusion that the data series are non-stationary [74].

[1] According to OECD's Glossary of statistical terms, primary energy consumption refers to the direct use at the source, or supply to users without transformation, of crude energy, that is, energy that has not been subjected to any conversion or transformation process.

According to Greene [75] cited by Pirlogea and Cicea [76], the original series is integrated of order 1, noted $I(1)$ in the case that the time series is non-stationary, but it becomes stationary by differencing it once. Generally, if a time series has to be differenced d times in order to become stationary, it is integrated of order d, noted $I(d)$ [76:5723].

The PP test represents an alternative to the ADF test [77]. It involves tting the lagged difference term Y_t, and using the results to calculate the test statistics. They estimate Y_t instead of Y_t. The PP tests correct for any serial correlation and heteroskedasticity in the errors ε_t, non-parametrically by modifying the Dickey Fuller test statistics.

Cowpertwait and Metcalf [78] show that the main difference between the two tests is given by the semi-parametric characteristic of the PP procedure. The PP test estimates the autocorrelations in the stationary process using a kernel smoother rather than assuming an auto-regressive process approximation.

3.3. Long-run and short-run relationships between energy consumption and economic growth

Since the main goal of this research is to examine the bidirectional relationship between energy consumption and economic growth in EU emerging countries, the variables' cointegration is tested based on Brooks [65] theory. This asserts that two variables are cointegrated if a linear combination of them is stationary. This prerequisite is also explained and supported by Granger [79] when discussing a possible de nition of causality. The author argue that the causal (‘linear prima facie) relationship between Y_n and the mean of X_{n+1} implies the two series be stationary.

For two variables to be cointegrated, they have to be integrated of the same order. Another prerequisite for cointegration is the existence of a linear combination between the two original variables that are stationary. For testing the cointegration, the methodology explained by Pirlogea and Cicea [76] was followed. Thus, the series with the same integration order was established.

In order to exemplify, suppose that X and Y are two non-stationary series, but X and Y are stationary. Firstly, the long-run relationship between the two stationary variables is estimated:

$$Y = \ +\beta\ X+\varepsilon \quad (5$$

Then, a regression applied for the two stationary series is conducted. The residuals represent a linear combination of the two variables. By applying the ADF and PP tests for the residuals series (ε), it may be concluded that the relationship between the two variables is stationary and that the variables are cointegrated. Thus, whether ε is found to be a stationary process, then the two variables are cointegrated and a long-run relationship between them exists.

The cointegrating relationship can be seen as a long-run or equilibrium phenomenon, while the causality refers primarily to short-run inferences [70]. Also, the theory of cointegration, developed in Granger [66] and in Engle and Granger [50], integrates the short-run dynamics with long-run equilibrium [80].

To complete the research, the Granger causality test for the stationary and cointegrated variables is applied, in order to test for the short-run relationships. According to Granger [79] the causality between two variables, X and Y, should be considered both ways, without implying that one way causal relationship established influences or can generate conclusions on the reverse relationship. The Granger causality test assumes that the relevant information for predicting the variables is reflected in the time series data on these variables and a time lag of one of the series is considered [70]. The test involves estimating the following regressions:

$$Y = \ {}_{i}X_{t-i} + \ \beta_j Y_{t-j} + \varepsilon_{1t} \quad (6$$

and

$$X = \ \lambda_i X_{t-i} + \ \delta_j Y_{t-j} + \varepsilon_{2t} \quad (7$$

where Y and X are the variables and it is assumed that the errors ε_{1t} and ε_{2t} are uncorrelated.

The hypotheses tested with Eviews software are: “*Y* does not Granger cause *X*” and “*X* does not Granger cause *Y*”. Additionally, the interpretation of the results is based on the argument that “if both causations occur, one may say that there is feedback between the two series” [79:338]. The lag length used to test these hypotheses is two, as software recommended value. We limit the discussion on econometric models theory here to conserve space.

4. Economic and empirical results

The focus of the described research is the econometric test on the causality relationships between energy consumption per capita, by sources and the economic growth per capita in the ve emerging countries (Bulgaria, Hungary, Poland, Romania, and Turkey) covering the period 1980–2013. Four of the countries (Bulgaria, Hungary, Poland, and Romania) are EU members and Turkey is an associate member of the European Union.[2]

In establishing the covered period (32–34 observations for the latest data publicly available, as presented in Table 2) the judgment is based on the fact that the study consists in time series analysis with yearly published data. Of cial energy databases are used and the limits of the series are linked mainly to the availability of of cial aggregated data that could be used when multiple energy sources are considered. Consequently, the existing data varied depending on the type on energy: for coal consumption data range between 1980 and 2012, for gas consumption between 1980 and 2013 (except for Bulgaria and Romania, where the range is until 2012), for oil consumption between 1980 and 2013, for renewable energy consumption between 1980 and 2012 (except for Bulgaria and Hungary, where the range is until 2011). The limits could be understood in the circumstance that data referring to periods too far away in time could distort the results' interpretation as related to energy policies that emerging countries should adopt considering the availability of each energy source in the near future and the consumers' awareness of limited natural resources constraints. However, the limits of statistical analysis using nite data set [80] are recognized, and partially reduced as importance once the results of the study are interpreted.

4.1. Statistic analysis and economic evolution of studied variables

The big picture of the economic growth and the energy consumption evolution, detailed by sources in the ve countries is presented in the following data analysis.

The statistic analysis of the six variables, coded as *GDP*: Gross Domestic Product breakdown (constant 2005 USD prices) per capita; *PEC_C*: Primary Energy Consumption_Coal per capita; *PEC_G*: Primary Energy Consumption_Gas per capita; *PEC_O*: Primary Energy Consumption_Oil per capita; *PEC_R*: Primary Energy Consumption_Renewables per capita; and *PEC_T*: Primary Energy Consumption_Total per capita is presented in the following table.

[2] Turkey is of cially recognized as a candidate for full membership, but still under signi cant controversial discussions among the member states [81].

Table 2
Descriptive statistics.
Source: Authors' calculation using Eviews software

Variable	Country	Mean	Median	Std. dev.	Skewness	Kurtosis	Jarque Bera	JB prob.	Obs.
GDP	**BULGARIA**	3150.00	2833.10	759.45	0.91	2.40	5.06	0.08	33
	HUNGARY	8926.31	8453.20	1477.90	0.57	1.79	3.81	0.15	
	POLAND	6464.10	5517.67	1966.36	0.80	2.30	4.20	0.12	
	ROMANIA	4098.36	3900.46	887.93	0.81	2.44	4.07	0.13	
	TURKEY	5743.29	5685.88	1406.15	0.38	2.12	1.87	0.39	
PEC_C	**BULGARIA**	38.57	38.21	5.71	−0.18	2.01	1.52	0.47	33
	HUNGARY	19.36	15.92	6.70	0.58	1.66	4.32	0.12	
	POLAND	75.87	72.93	18.56	0.49	1.69	3.68	0.16	
	ROMANIA	19.96	18.59	5.39	0.79	2.49	3.81	0.15	
	TURKEY	12.42	12.40	3.82	−0.05	2.24	0.81	0.67	
PEC_G	**BULGARIA**	20.51	21.56	4.35	−0.65	2.45	2.71	0.26	33
	HUNGARY	40.83	39.38	5.58	0.57	2.37	2.31	0.32	
	POLAND	11.62	11.21	1.92	0.58	2.04	3.13	0.21	
	ROMANIA	41.68	37.43	16.88	0.40	1.56	3.75	0.15	
	TURKEY	7.63	5.18	7.44	0.68	2.07	3.73	0.16	
PEC_O	**BULGARIA**	40.79	30.20	19.17	0.84	1.87	5.85	0.05	34
	HUNGARY	33.77	32.45	5.66	1.02	3.14	5.98	0.05	
	POLAND	21.43	20.94	4.47	0.41	2.05	2.21	0.33	
	ROMANIA	25.28	23.21	5.03	0.72	2.16	3.96	0.14	
	TURKEY	18.52	19.15	2.15	−0.66	2.66	2.61	0.27	
PEC_R	**BULGARIA**	3.60	3.49	1.18	1.29	5.37	16.32	0.00	32
	HUNGARY	0.72	0.26	0.94	1.53	3.73	13.16	0.00	
	POLAND	0.93	0.68	0.68	2.25	7.18	50.36	0.00	
	ROMANIA	6.71	6.53	1.38	0.35	2.14	1.64	0.44	
	TURKEY	4.96	5.17	1.58	−0.12	1.92	1.65	0.44	
PEC_T	**BULGARIA**	122.94	112.58	22.58	0.53	1.65	3.92	0.14	32
	HUNGARY	108.34	108.09	6.54	0.13	1.76	2.15	0.34	
	POLAND	109.72	103.02	15.73	0.71	1.99	4.03	0.13	
	ROMANIA	96.45	85.51	23.99	0.50	1.50	4.35	0.11	
	TURKEY	42.85	43.77	13.00	0.05	1.94	1.52	0.47	

In order to nd the basic features of the data and to appreciate the data homogeneity, descriptive statistics are developed (Table 2). The statistic indicators chosen for dispersion are Mean, Median, and Standard Deviation, and for distribution are Skewness, Kurtosis, and Jarque–Bera.

For all data series, the mean and median have similar values. Likewise, the standard deviation (Std. dev.) of energy consumption data series has low values for the majority of the countries and of energy sources, indicating that the series are relatively homogeneous. However, a quite high variability could be notices for total energy consumption in Bulgaria, Poland, Romania and Turkey, for coal consumption in Poland, oil consumption in Bulgaria, and gas consumption in Romania. The time series for GDP per capita reveals high values for standard deviations, which can be explained by the wide range of values for this series during the period 1980–2013.

In terms of symmetry of the data the skewness and kurtosis are analyzed (Table 2). For the majority of the series, the tail on the right side of the probability density function is longer or fatter than the left side, registering a high number of low values. Most of the variables are characterized by a platykurtic distribution, with a low probability for extreme values, and with values wider spread around the mean.

Jarque–Bera and the associated probabilities are used to examine the volatility of the data [82]. The high values recorded for Jarque Bera test, having associated probabilities close to zero indicate that the consumption of renewable energy in Bulgaria, Hungary and Poland, as well as oil consumption for Bulgaria and Hungary is characterized by a high volatility.

The economic evolution is presented in the following graphs. The time scale is represented on the horizontal axis. GDP per capita values, expressed in constant 2005 USD, and the values of

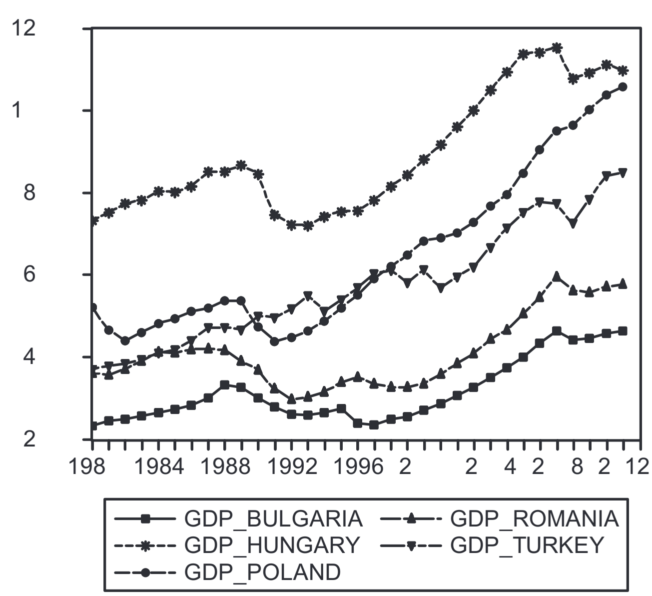

Fig. 1. The evolution of GDP per capita in the ve emerging countries.

different energy consumption sources (coal, gas, oil, renewable, and total), expressed in millions BTUs per capita, are represented on the left-hand axis.

The results reported in Figs. 1–6 indicate the evolution of the variables used in the present study. The GDP per capita (Fig. 1) has had a constant overall increasing trend from 1980 till 2012 for all the ve countries. Though, one may notice that the values of all the ve emerging countries range within a large interval (between

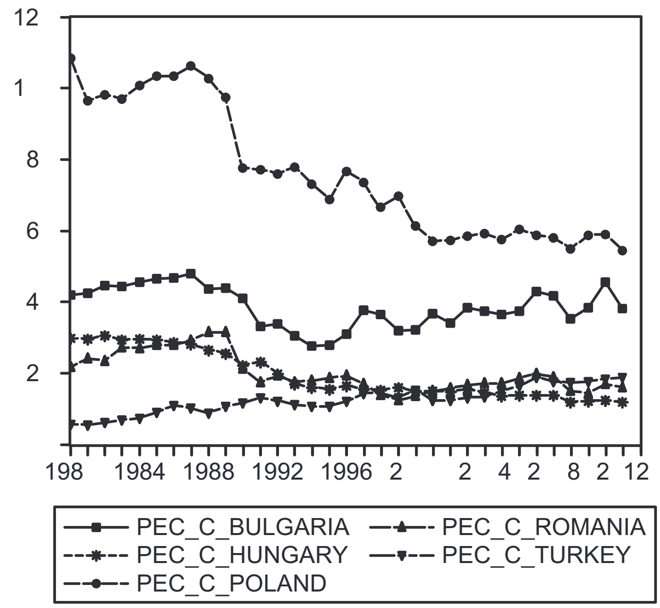

Fig. 2. The evolution of Energy consumption_Coal per capita in the ve emerging countries.

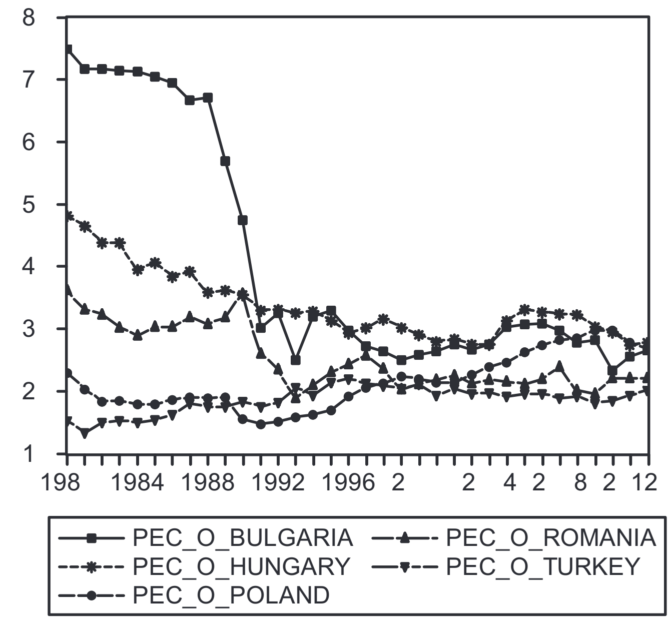

Fig. 4. The evolution of Energy consumption_Oil per capita in the ve emerging countries.

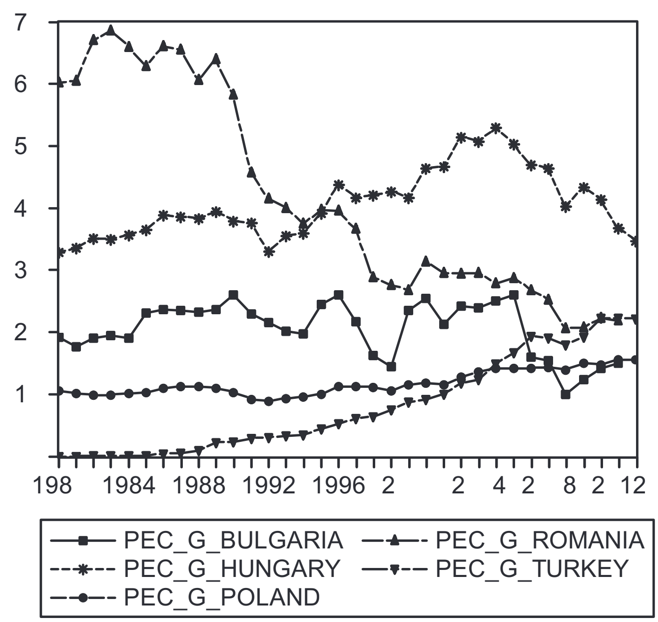

Fig. 3. The evolution of Energy consumption_Gas per capita in the ve emerging countries.

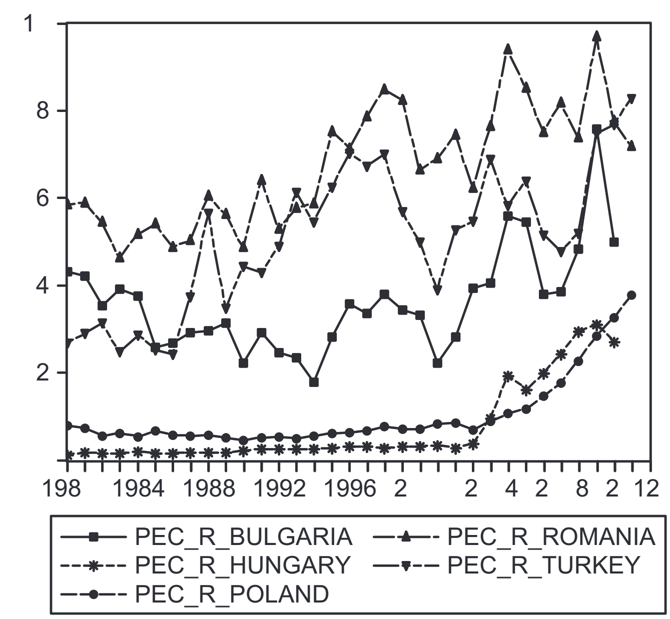

Fig. 5. The evolution of Energy consumption_Renewables per capita in the ve emerging countries.

2000 constant 2005 USD per capita for Bulgaria and 12,000 constant 2005 USD per capita for Hungary). Most of the countries have been affected by the global economic crisis determining signi cant decrease experienced in 2009. As noticed in Fig. 1, Poland has been an exception for GDP has constantly grown until 2012.

The level of total primary energy consumption (Fig. 6) has followed a constant trend for the period 1980–2012. However, the four emerging countries (Bulgaria, Hungary, Poland and Romania) have had the same constant evolution until 1989, followed by a severe decline until 1995 registered in the context of transition to the market economy. Another relatively constant evolution was reported until 2012.

The three sources of energy consumption: coal, gas and oil, as traditional sources have had the higher share in total energy consumption during the entire period. Thought, the evolution has been dependent of a large number of features such as country characteristics (limited and scarce natural resources, landforms, etc.), political and economic aspects. For example, in Bulgaria the mineral resources for energy utilization are limited and scarce. Therefore the country is highly dependent for its energy supplies on foreign sources, especially Russian gas, which has severely felt in the former ‘gas crisis (2008–2009) when disputes between Ukraine and Russia lead to gas scarcity [83]. Natural gas and oil dominate primary energy supply in Hungary.

According to European Commission's Report [84] the share of renewable energy is expected to grow in the future, the EU average target being 20 (share of renewables in gross nal energy consumption) for 2020, given the climate change concerns. Each country trend ts the EU requirements following a constantly increase till 2010 (the last Report date): for Bulgaria it reached 7 (with a 16 target for 2020), for Hungary 3 (with a 13 target for 2020), for Poland 3 (with a 15 target for 2020), and for Romania 14 (with a 24 target for 2020). For Turkey, a signi cant increase starts in 2002, reaching 12 share of renewables in gross nal energy consumption in 2010. While coal's dominance in the Poland's fuel mix has deteriorated substantially from 1980 to 2010, the share of fossil fuels fell over the same time period, due to the growing importance of oil and gas.

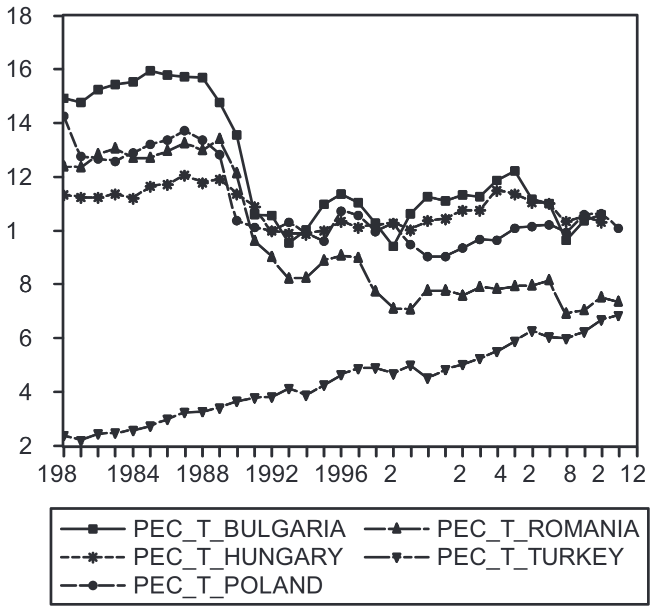

Fig. 6. The evolution of Energy consumption_Total per capita in the ve emerging countries.

4.2. Stationarity tests results

The results of ADF and PP tests (Table 3) indicate that the six variables have become stationary after the rst difference with few exceptions (oil series for Hungary, gas series for Bulgaria and renewables series for Poland) and generate comparable results when both tests were used. It is a common situation for macroeconomic data to become stationary after the rst difference [70,71]. However, Granger [70] points out that attention should be paid when interpreting the results in such cases.

Because the initial series are not stationary, the cointegration and causality test applied on those series cannot provide valid results. Therefore, a differentiation process is used in order to stationarize the time series characterized by meaningful sample statistics such as means, variances, and correlations with other variables. Thus, the future behavior can only be interpreted if the series is stationary. Therefore, the series for which different results were shown when applying the two tests are not utilized in the next step of the research, for prudency reasons. In other words, the data cannot be use to analyze any inference between oil consumption and

Table 3
Summary of the results for ADF and PP tests for unit root.
Source: Authors' calculation using Eviews software

Variable	Country	ADF test			PP test			Integration order
		At level	1st diff.	2nd diff.	**At level**	1st diff.	2nd diff.	
GDP	**BULGARIA**	−0.367	−3.259**	−5.429*	−0.046	−3.292**	−13.953*	1
	HUNGARY	−0.788	−3.421**	−7.529*	−0.639	−3.420**	−9.3106*	1
	POLAND	0.412	−3.430**	−5.915*	1.961	−3.458**	−5.5631*	1
	ROMANIA	−0.720	−2.974**	−6.656*	−0.191	−2.974**	−8.7485*	1
	TURKEY	0.299	−5.772*	−8.732*	1.367	−6.497*	−24.273*	1
PEC_C	**BULGARIA**	−1.941	−5.388*	−5.907*	−1.849	−5.568*	−17.330*	1
	HUNGARY	−1.126	−5.770*	−6.859*	−1.119	−5.783*	−24.282*	1
	POLAND	−1.374	−5.839*	−5.872*	−1.374	−5.829*	−27.480*	1
	ROMANIA	−1.248	−4.261*	−6.363*	−1.386	−4.481*	−15.987*	1
	TURKEY	−0.990	−5.582*	−8.730*	−0.707	−6.575*	−28.924*	1
PEC_G	**BULGARIA**	−2.195	−5.352*	−6.374*	−2.252	−6.389*	−19.849*	1
	HUNGARY	−1.524	−5.628*	−4.202*	−1.691	−5.690*	−16.799*	1
	POLAND	0.325	−4.777*	−5.169*	0.325	−4.765*	−15.555*	1
	ROMANIA	−0.524	−4.429*	−4.019*	−0.591	−4.350*	−10.357*	1
	TURKEY	1.486	−4.196*	−6.992*	1.706	−4.425*	−11.178*	1
PEC_O	**BULGARIA**	−1.733	−2.283	−2.876***	−1.707	−4.725*	−16.470*	1
	HUNGARY	−2.778***	−6.104*	−5.986*	−3.311**	−6.107*	−31.701*	0
	POLAND	−1.098	−3.681*	−6.608*	−0.768	−3.681*	−6.889*	1
	ROMANIA	−2.320	−5.706*	−4.027*	−2.295	−6.798*	−30.600*	1
	TURKEY	−1.734	−8.267*	−8.813*	−1.584	−7.994*	−14.382*	1
PEC_R	**BULGARIA**	−2.339	−4.857*	−4.235*	−2.250	−6.791*	−11.654*	1
	HUNGARY	2.286	−4.078*	−3.622**	0.569	−4.086*	−12.371*	1
	POLAND	7.749	0.952	−6.802*	7.701	−1.208	−10.614*	2
	ROMANIA	−2.232	−7.608*	−6.237*	−2.035	−9.497*	−22.977*	1
	TURKEY	−1.333	−6.625*	−10.94*	−1.153	−7.477*	−38.205*	1
PEC_T	**BULGARIA**	−1.212	−4.277*	−8.675*	−1.212	−4.318*	−17.432*	1
	HUNGARY	−2.421	−4.935*	−11.374*	−1.668	−5.014*	−11.599*	1
	POLAND	−2.187	−5.207*	−5.037*	−2.187	−5.206*	−16.564*	1
	ROMANIA	−0.939	−3.893*	−4.053*	−1.035	−3.826*	−9.980*	1
	TURKEY	0.202	−6.727*	−10.117*	1.208	−8.514*	−35.121*	1

* Denote the signi cance level at 1 .
** Denote the signi cance level at 5 .
*** Denote the signi cance level at 10 .

GDP per capita in Hungary, nor for renewables consumption and GDP per capita in Poland.

4.3. Long-term relationship results

The existence of a long-term relationship between the series was tested by applying the regression equation: $Y= \ +\beta \ X+$, where the Y is the dependent variable and ΔX is the independent variable. The results estimated the long-run relationship between the stationary variables, pair wise. The residuals from each equation were then tested for integration using both ADF and PP tests.

The residuals series were integrated of order 0, lower than the integration order of the regression's variables (Table 4). The cointegration between the underlying variables indicates long-run relationship between different sources of energy consumption and GDP per capita for the emerging European countries considered in this study. This implies that the energy consumption affects the economic growth on the long-term, for emerging countries. Considering this, the policy makers in energy sector should analyze the strength of such relationships when strategize for future economic development. The different results by country and by energy source indicate that the strategies should be adjusted at national level and according to the energy recourses mix.

The negative correlation between the increase of GDP per capita and the increase of renewable energy consumption should be cautionary interpreted, given the mandatory required targets at EU level and the percentage of renewables in total energy consumption. Additionally, the incipient stage of development for renewable energy consumption as related to investments may have caused this negative relationship with economic growth.

4.4. Short-term causality results

The ADP and PP methods test the existence or absence of long-run relationships between the energy consumption per capita and the GDP per capita, without indicating the direction of causality [37]. Thus, the next step of the present research is to study the existence of short-term relationships using Granger causality test. Granger theory underlies on the idea that "true instant causality will never occur in economics" [70:205] and "there is always a delay in making a decision, as new information is assimilated, analyzed and a decision rule applied" [70:206]. Therefore, the causal lag should be considered. The test was applied for the stationary and cointegrated variables, only, using a significance level of 1 , 5 , and 10 , associated to F-statistic.

Valid short-run relationships, star highlighted in Table 5, were found in all countries. Thus, GDP per capita Granger causing primary energy consumption per capita-source renewables for Hungary, GDP per capita Granger causing primary energy consumption per capita-source gas for Poland, and GDP per capita Granger causing primary energy consumption per capita-source coal for Turkey confirm the conservation hypothesis, with 1 probability. The growth hypothesis was confirmed for Poland time series in case of primary energy consumption per capita-sources coal and total that were found to Granger causing GDP per capita, and for Romania in case of primary energy consumption per capita-sources coal. Neutrality hypothesis is established for the rest of the countries and energy sources.

The results generated for 5 significance level expanded the valid cases for: gas and total sources in Hungary related to conservation hypothesis, and oil sources for Romania related to growth hypothesis.

Considering the more permissive probability associated to F-statistic of 10 significance level, gas and total consumption for Romania does Granger cause GDP per capita, confirming the growth hypothesis. Unlike the previous, less permissive scenario, the total primary energy consumption in Hungary and renewable energy consumption in Bulgaria lies under the feedback hypothesis, meaning that the policy makers should consider the fact that economic growth and energy consumption are jointly determined and affected at the same time.

Table 4
Long-term relationships between variables.
Source: Authors' calculation using Eviews software

Dependent variable	Independent variable	Country	Intercept	value	ADF test	PP test	Integration order of residual series
Δ_1GDP	Δ_1 PEC_C	BULGARIA	73.223	9.892	−3.398**	−3.362**	0
		HUNGARY	151.568	65.703	−3.937**	−3.926*	0
		POLAND	214.986	28.109	−3.611**	−3.561**	0
		ROMANIA	75.538	41.333	−4.114*	−4.203*	0
		TURKEY	108.923	99.624	−6.335*	−7.104*	0
Δ_1GDP	Δ_1 PEC_G	BULGARIA	72.017	−0.362	−3.263**	−3.263**	0
		HUNGARY	108.773	47.639	−4.049**	−4.085*	0
		POLAND	125.389	271.163	−4.129*	−4.121*	0
		ROMANIA	104.893	30.635	−3.567**	−3.592**	0
		TURKEY	43.079	153.766	−7.042*	−7.547*	0
Δ_1GDP	Δ_1 PEC_O	BULGARIA	101.993	19.371	−4.379*	−4.417*	0
		POLAND	139.654	182.980	−2.954***	−2.972**	0
		ROMANIA	84.424	37.0234	−3.069**	−3.007**	0
		TURKEY	138.602	87.741	−5.194*	−5.302*	0
Δ_1GDP	Δ_1 PEC_R	BULGARIA	72.815	−20.126	−3.251**	−3.251**	0
		HUNGARY	127.436	−58.886	−3.324**	−3.291**	0
		ROMANIA	68.267	−0.952	−2.977**	−2.977**	0
		TURKEY	128.576	120.313	−5.442*	−5.922*	0
Δ_1GDP	Δ_1 PEC_T	BULGARIA	83.727	8.165	−3.494**	−3.438**	0
		HUNGARY	141.435	56.935	−5.573*	−5.573*	0
		POLAND	204.643	28.302	−3.960*	−3.927*	0
		ROMANIA	101.658	21.264	−3.735*	−3.728**	0
		TURKEY	14.223	97.121	−7.774*	−8.065*	0

* Denote the significance level at 1 .
** Denote the significance level at 5 .
*** Denote the significance level at 10 .

Table 5
Results of Granger causality test.
Source: Authors' calculation using Eviews software

PEC variables	Bulgaria		Hungary		Poland		Romania		Turkey	
	F-stat	*Prob.*	*F*-stat	*Prob.*	*F*-stat	*Prob.*	*F*-stat	*Prob.*	*F*-stat	*Prob.*
I. Null Hypothesis of the test: GDP does not Granger Cause Primary Energy Consumption (PEC) Variable										
PEC_C	0.039	*0.962*	1.553	*0.231*	0.298	*0.745*	0.301	*0.743*	6.131*	*0.007*
PEC_G	2.432	*0.108*	3.766**	*0.037*	5.855*	*0.008*	0.080	*0.924*	0.624	*0.544*
PEC_O	1.821	*0.182*	–		1.182	*0.323*	0.502	*0.611*	0.413	*0.666*
PEC_R	3.194***	*0.058*	7.243*	*0.003*	–	–	0.036	*0.964*	1.453	*0.252*
PEC_T	1.075	*0.357*	3.558**	*0.044*	0.120	*0.887*	0.168	*0.846*	0.238	*0.790*
PEC Variables	Bulgaria		Hungary		Poland		Romania		Turkey	
	F-stat	*Prob.*	*F*-stat	*Prob.*	*F*-stat	*Prob.*	*F*-stat	*Prob.*	*F*-stat	*Prob.*
II. Null Hypothesis of the test: Primary Energy Consumption (PEC) Variable does not Granger Cause GDP										
PEC_C	0.912	*0.414*	1.751	*0.193*	8.448*	*0.001*	6.542*	*0.005*	0.719	*0.497*
PEC_G	0.429	*0.656*	1.978	*0.159*	0.173	*0.842*	2.784***	*0.080*	1.651	*0.211*
PEC_O	1.258	*0.301*	–	–	0.770	*0.473*	3.508**	*0.045*	0.311	*0.735*
PEC_R	2.994***	*0.068*	0.464	*0.634*	–	–	1.803	*0.185*	0.101	*0.905*
PEC_T	0.273	*0.763*	2.980***	*0.069*	7.406*	*0.003*	2.597***	*0.094*	0.241	*0.788*

* Denote the significance level at 1%.
** Denote the significance level at 5%.
*** Denote the significance level at 10%.

For the other variables taken in the study for causality, the neutrality hypothesis may be retained, showing that the primary energy consumption is not correlated with economic growth.

5. Debates and conclusions

Many of the seminal studies generated conflicting and even contradictory findings which makes it difficult to draw macro policy implications. According to Kalimeris et al. [3] the state of knowledge on the energy-growth nexus still is controversial.

The aim of the present research was to focus on a smaller and homogeneous group of countries, from Europe, that may have similar patterns in designing their national developing policies. This paper investigates the causality relationship between primary energy consumption per capita by sources and economic growth for five emerging countries (Bulgaria, Hungary, Poland, Romania, and Turkey) from 1980 to 2013. The causality analysis based on Engle and Granger model indicates that for eight out of 21 cases the neutrality hypothesis is confirmed, meaning that for most of the primary energy sources there is not enough evidence for deciding on a possible impact on economic growth for the emerging European countries.

The primary findings are as follows: (1) the series have become stationary after the first difference with few exceptions (Hungary for oil consumption, and Poland for renewables consumption); (2) the existence of long-run relationship (cointegration) between energy consumption per capita variables by sources and GDP per capita; (3) valid short-run unidirectional relationships, with a 1% significance level for Hungary (conservation hypothesis for renewables consumption), Poland (conservation hypothesis for gas consumption, and growth hypothesis for coal and total energy), Turkey (conservation hypothesis for coal consumption), Romania (growth hypothesis for coal consumption), and (4) extended valid short-run unidirectional relationships, with a 10% significance level for Hungary (conservation hypothesis for gas consumption, and feedback hypothesis for total consumption), Romania (growth hypothesis for total energy, gas and oil consumption), and Bulgaria (feedback hypothesis for renewable energy consumption).

A comparative analysis (Table 6) asserts a partial consistency with previous studies conducted for European countries [5,24,26,37,47].

For Poland the conservation hypothesis was confirmed for gas consumption, unlike the studies of Yu et al. [45] and Huang et al. [46] where neutrality hypothesis was verified. The renewable energy consumption was set up under the feedback hypothesis for Poland, Turkey, Hungary and Bulgaria, and under growth hypothesis for Romania by Al-mulali et al. [5], while the present study posit only Bulgaria under feedback hypothesis, whereas for Hungary the conservation hypothesis verify, and for the rest of the countries neutrality hypothesis validate. Those mixed results may be explained by the different unit of measures used for the tested variables, by the different time series taken into study or by different econometric tests applied.

There are a number of external factors that put pressure on emerging countries' policy makers to pay special attention to the energy sector. In the context of the causality debate, the empirical results of this study contributes to providing governments and policymakers a better understanding of energy consumption by each of the five sources (coal, gas, oil, renewables and total) and economic growth nexus to formulate and implement relevant energy policy in these countries. Specifically, the results of the study indicate that for Hungary, the policy makers should consider the fact that conserving gas and renewables consumption may be implemented with little or no adverse effect on economic growth. For Romania the consumption of all energy sources could play an important role in economic growth, while for Bulgaria, renewable energy consumption may affect economic growth. Thus, the policy makers may consider those types of results when they adjust their national energy strategies.

The economic pressures highlighted by the current global crisis should be correlated to the global climate change in order to meet the related European Union energy targets regarding the greenhouse gas emissions, the energy intensity and the share of renewable energy sources. The increasing of renewable energy consumption in the emerging European countries must have a public policy support. Even if studies show no causality between renewable energies and growth for 1% and 5% significance level, this could be explained as an assessment of the past, but it is not necessary to persist in the future,

Table 6
Comparative analysis with previous studies' results: Granger causality.

Hypothesis	Previous studies	Our study 1 signi cance level	Our study 5 signi cance level	Our study 10 signi cance level
Conservation	Turkey [26] Hungary [24]	Hungary (PEC_R) Poland (PEC_G) Turkey (PEC_C)	Hungary (PEC_G; PEC_R; PEC_T) Poland (PEC_G) Turkey (PEC_C)	Hungary (PEC_G; PEC_R) Poland (PEC_G) Turkey (PEC_C)
Growth	Turkey [14] Romania [47] Romania [5] – for renewable energy	Poland (PEC_C; PEC_T) Romania (PEC_C)	Poland (PEC_C; PEC_T) Romania (PEC_C; PEC_O)	Poland (PEC_C; PEC_T) Romania (PEC_G; PEC_C; PEC_O; PEC_T)
Feedback	Hungary [37] Turkey [32] Poland, Turkey, Hungary and Bulgaria [5] – for renewable energy	–	–	Bulgaria (PEC_R) Hungary (PEC_T)
Neutrality	Bulgaria and Romania [37] Poland [48] Poland [45]	Each country, for different sources of energy	Each country, for different sources of energy	Each country, for different sources of energy

whether European countries will meet the established targets, and will implement macroeconomic strategies of cost minimizing consumers and pro t maximizing producers [8]. In these circumstances, future research could be directed towards analyzing and explaining the relationships between different factors resulting from climate change challenges and palliative measures for economic growth.

The limits of the study reside on the limited series used in the econometric analysis and on the limits of causality tests themselves, as well. As Granger [70] noted, the use of traditional time series modeling could generate misinterpretation of data related to causality in mean, while in other cases causality could exist without being detected. For further development of the study, a control variable, as suggested by Granger [71] will be considered.

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