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The causal relationship between energy consumption and GDP in Albania, Bulgaria, Hungary and Romania: Evidence from ARDL bound testing approach

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ABSTRACT

The purpose of this study is to investigate the causal relationship between energy and economic growth in Albania, Bulgaria, Hungary and Romania from 1980 to 2006 by employing energy use per capita, electric power consumption per capita and real GDP per capita variables. To examine this linkage, we use the two-step procedure from the Engle and Granger model: In first step, we explore the long-run relationships between the variables by using recently developed autoregressive distributed lag (ARDL) bounds testing approach of cointegration. Secondly, we employ a dynamic vector error correction (VEC) model to test causal relationships between variables. The bounds test yields evidence of a long-run relationship between energy use per capita and real GDP per capita and evidence of two-way (bidirectional) strong Granger causality between these variables only in Hungary. On the other hand, the ARDL bounds test results show that there is no unique long-term or equilibrium relationship between energy consumption variables and real GDP per capita in Albania, Bulgaria and Romania. In other words, no cointegration exists between these variables in these three countries. The econometric analysis suggests that any causal relationships within dynamic error correction model for Albania, Bulgaria and Romania cannot be estimated.

1. Introduction

The relationship between energy consumption and economic growth has undergone extensive investigation after 1970s. The central issue has been whether energy consumption stimulates economic growth or economic growth promotes energy consumption. In the recent studies, cointegration and Granger causality tests have been extensively used to examine the presence of long-run equilibrium and the direction of causality between energy consumption and economic growth. 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.

In the energy economics literature, there exist four views regarding the causal relationship between energy consumption and economic growth. The first view argues that economic growth Granger causes energy consumption. It is also called "*conservation hypothesis*". The recent studies such as Cheng [1], Ghosh [2], Narayan and Smyth [3], Al-Iriani [4], Lise and Van Montfort [5] and Mehrara [6], among others support this hypothesis. The second view argues that energy consumption Granger causes economic growth. It is also called "*growth hypothesis*". This view has been supported by Stern [7], Oh and Lee [8], Shiu and Lam [9], Lee [10], Altinay and Karagol [11], Yuan et al. [12], Narayan and Smyth [13], Bowden and Payne [14] and Apergis and Payne [15], among others. The third view implies that both energy consumption and economic growth Granger cause each other (bidirectional causality). It is also called "*feedback hypothesis*". This view has been supported by studies such as Masih and Masih [16], Glasure [17], Paul and Bhattacharya [18], Tang [19] and Lee et al. [20]. The fourth view implies that there is no causality between energy consumption and economic growth (*neutrality hypothesis*). These findings have been supported by Cheng [21], Fatai et al. [22], Jobert and Karanfil [23] and Payne [24], among others.

According to the conclusion derived from these studies, the previous literature that focuses on the cointegration and causal relationship between energy consumption and economic growth is not conclusive to provide policy recommendation that can be applied across countries.

The purpose of this study is to investigate the relationship between energy consumption and economic growth in Albania, Bulgaria, Hungary and Romania from 1980 to 2006 using recently

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developed autoregressive distributed lag (hereafter ARDL) bounds testing approach of cointegration developed by Pesaran and Shin [25] and Pesaran et al. [26].

The rest of the paper is organized as follows. The next section presents the model and data description. The third section discusses the methodology and the fourth section reports the empirical findings of the study. The last section concludes the paper.

2. Model specification and data

Following the empirical literature, the standard log-linear functional specification of long-run relationship between energy consumption and real GDP in selected four countries may be expressed as:

$$\text{GDP}_t = a + \beta \text{EC}_t + \varepsilon_t \tag{1}$$

where GDP_t is the real GDP per capita (constant 2000 US$); EC_t, is the energy use (kg of oil equivalent per capita) or electric power consumption (kW h per capita) and ε_t is error term. All variables are transformed into natural logarithms to reduce heteroscedasticity and to obtain the growth rate of the relevant variables by their differenced logarithms. The annual time series data for Albania, Bulgaria, Hungary and Romania are obtained from the World Development Indicators (WDI) produced by World Bank for the 1980–2006 period.

3. Methodology

We use the two-step procedure from the Engle and Granger [27] model to examine the causal relationship between the energy consumption per capita and economic growth per capita. First, we explore the long-run relationships between the variables. Second, we test causal relationships within vector error correction (hereafter VEC) model.

3.1. Autoregressive distributed lag (ARDL) cointegration analysis

To investigate the causality between energy consumption per capita and real GDP per capita for the selected four transition countries, this study employed recently developed ARDL bounds testing approach of cointegration developed by Pesaran [28], Pesaran and Shin [25] and Pesaran et al. [26]. The ARDL cointegration approach has numerous advantages in comparison with other cointegration methods such as Engle and Granger [27], Johansen [29], and Johansen and Juselius [30] procedures: First, the ARDL procedure can be applied whether the regressors are $I(1)$ and/or $I(0)$. This means that the ARDL procedure has advantage of avoiding the classification of variables into $I(1)$ or $I(0)$ and no need for unit root pre-testing. Second, while the Johansen cointegration techniques require large data samples for validity, the ARDL procedure is the more statistically significant approach to determine the cointegration relation in small samples. Third, the ARDL procedure allows that the variables may have different optimal lags, while it is impossible with conventional cointegration procedures. Finally, the ARDL procedure employs a single reduced form equation, while the conventional cointegration procedures estimate the long-run relationships within a context of system equations.

Eq. (1) can be presented at the following the ARDL form:

$$\Delta\text{GDP}_t = \alpha + \sum_{i=1}^{k} \phi_i \Delta\text{GDP}_{t-i} + \sum_{j=0}^{l} \beta_j \Delta\text{EC}_{t-j} + \delta_1 \text{GDP}_{t-1} + \delta_2 \text{EC}_{t-1} + v_t \tag{2}$$

where v_t and Δ are the white noise term and the first difference operator, respectively. An appropriate lag selection based on a criterion such as Akakie Information Criterion (hereafter AIC) and Schwarz Bayesian Criterion (hereafter SBC). The bounds testing procedure is based on the joint F-statistic or Wald statistic that is tested the null of no cointegration, $H_0{:}\delta_r = 0$, against the alternative of $H_1{:}\delta_r \neq 0$, $r = 1,2$. Two sets of critical values are generated, the upper bound critical values refers to the $I(1)$ series and the lower bound critical values to the $I(0)$ series. If the calculated F-statistics lies above the upper level of the band, the null is rejected, indicating cointegration. If the calculated F-statistics is below the upper critical value, we cannot reject the null hypothesis of no cointegration. Finally, if it lies between the bounds, a conclusive inference cannot be made without knowing the order of integration of the underlying regressors. The upper limit of the critical values for the F-test (all $I(1)$ variables) can be obtained from Pesaran et al. [26]. Recently, the set of critical values for the limited data (30 observations to 80 observations) were developed originally by Narayan [31].

If there is a cointegration between the variables, Eq. (3) presents the long-run model and Eq. (4) shows the short-run dynamics:

$$\text{GDP}_t = \alpha + \sum_{i=1}^{m} \phi_i \text{GDP}_{t-i} + \sum_{j=0}^{n} \beta_j \text{EC}_{t-j} + \mu_t \tag{3}$$

$$\Delta\text{GDP}_t = \alpha + \sum_{i=1}^{k} \phi_i \Delta\text{GDP}_{t-i} + \sum_{j=0}^{l} \beta_j \Delta\text{EC}_{t-j} + \psi \text{ECT}_{t-1} + \xi_t \tag{4}$$

where ψ is the coefficient of error correction term (hereafter ECT). It shows how quickly variables converge to equilibrium and it should have a statistically significant coefficient with a negative sign.

Table 1
Estimated ARDL models and bounds F-test for cointegration.

	GDP–EC1				GDP–EC2			
Countries	Models	F	LM	HET	Models	F	LM	HET
Albania	(1, 1)	3.063	1.42 (0.23)	0.38 (0.54)	(1, 0)	1.133	1.53 (0.22)	0.95 (0.33)
Bulgaria	(2, 1)	1.134	0.46 (0.50)	0.18 (0.68)	(2, 1)	1.131	2.15 (0.14)	0.13 (0.71)
Hungary	(1, 2)	4.053	0.02 (0.90)	0.78 (0.38)	(2, 1)	1.620	0.14 (0.70)	1.11 (0.29)
Romania	(2, 3)	1.360	0.04 (0.85)	0.02 (0.90)	(1, 2)	1.932	0.36 (0.55)	0.36 (0.55)
				$I(0)$				$I(1)$
Critical values at 1%				6.027				6.760
Critical values at 5%				4.090				4.663
Critical values at 10%				3.303				3.797

Notes:
GDP is the real GDP per capita.
Energy consumption variables EC1 and EC2 are the energy use (kg of oil equivalent per capita) and electric power consumption (kW h per capita), respectively.
F is the ARDL cointegration test. The critical values for the lower $I(0)$ and upper $I(1)$ bounds are taken from Narayan (2005, Appendix: Case II).
LM is the Lagrange multiplier test for serial correlation with a χ^2 distribution with only one degree of freedom.
HET is test for heteroskedasticity with a χ^2 distribution with only one degree of freedom.

3.2. Causality analysis

ARDL cointegration method tests whether the existence or absence of long-run relationship between the energy consumption per capita and the real GDP per capita. It does not indicate the direction of causality. Once the estimating the long-run model in Eq. (1) in order to obtain the estimated residuals, the next step is to estimate a VEC model, i.e. with the variables in first differences and including the long-run relationships as error correction terms in the system. Thus, the following dynamic VEC model is estimated to investigate the Granger causality between variables:

$$\Delta \mathrm{GDP}_t = \alpha_1 + \sum_{i=1}^{k} \phi_i \Delta \mathrm{GDP}_{t-i} + \sum_{j=1}^{l} \beta_j \Delta \mathrm{EC}_{t-j} + \psi_1 \mathrm{ECT}_{t-1} + \zeta_{1t} \quad (5a)$$

$$\Delta \mathrm{EC}_t = \alpha_2 + \sum_{i=1}^{k} \varphi_i \Delta \mathrm{GDP}_{t-i} + \sum_{j=1}^{l} \theta_j \Delta \mathrm{EC}_{t-j} + \psi_2 \mathrm{ECT}_{t-1} + \zeta_{2t} \quad (5b)$$

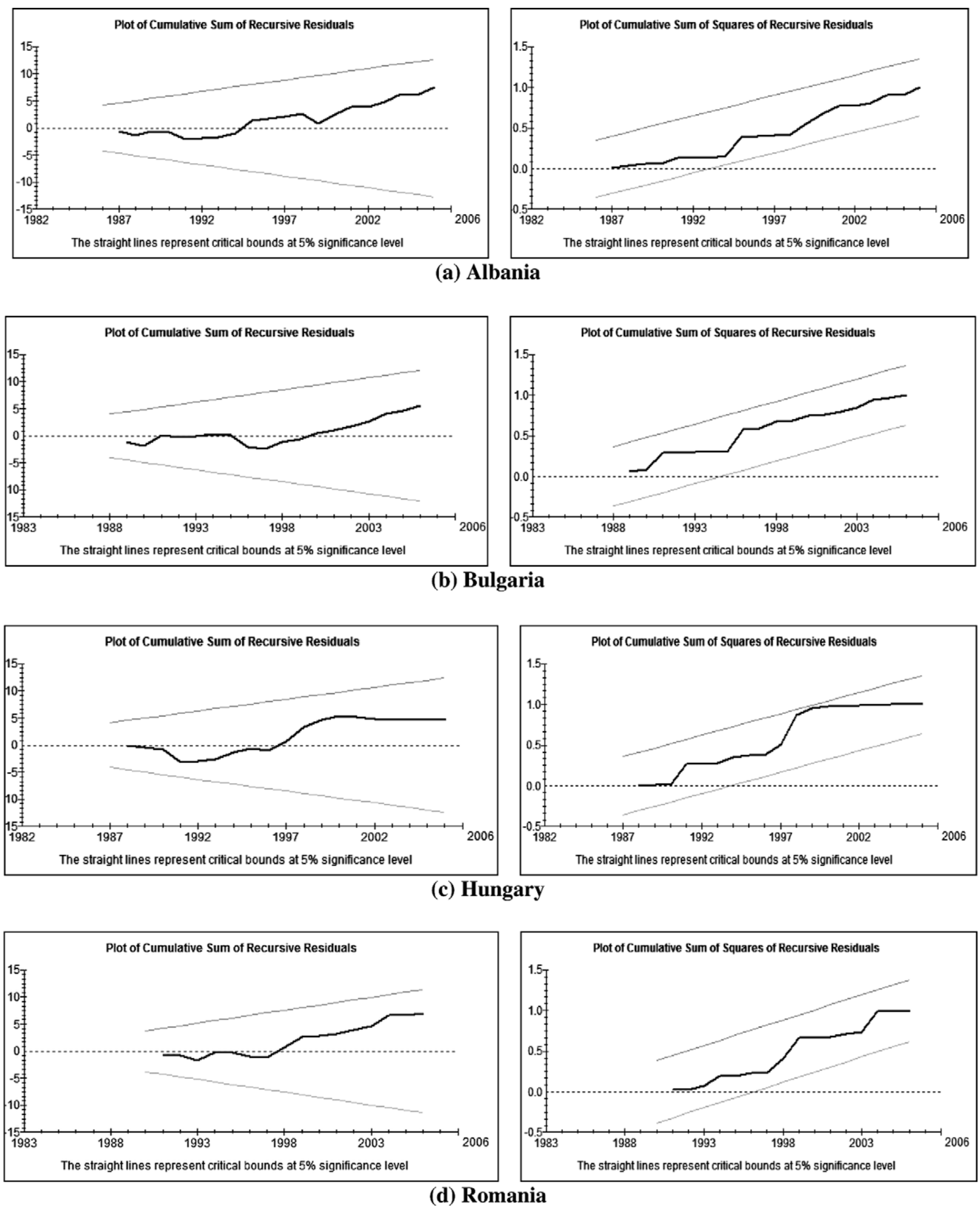

Fig. 1. Plot of CUSUM and CUSUMQ tests for the parameter stability of GDP–EC1 equation.

Residual terms, ζ_{1t} and ζ_{2t}, are independently and normally distributed with zero mean and constant variance. An appropriate lag selection based on a criterion such as AIC and SBC. Rejecting the null hypotheses indicate that EC does Granger cause GDP and GDP does Granger cause EC, respectively. Using Eqs. (5a) and (5b), Granger causality can be examined in three ways: (1) Short-run or weak Granger causalities are detected by testing $H_0{:}\beta_j = 0$ and $H_0{:}\varphi_j = 0$ for all j in Eqs. (5a) and (5b), respectively. (2) Another possible source of causation is the ECT's in equations. The coefficients on the ECT's represent how fast deviations from the long-run equilibrium are eliminated following changes in each variable. Thus, long-run causalities are examined by testing $H_0{:}\psi_1 = 0$ and $H_0{:}\psi_2 = 0$ for Eq. (5a) and (5b). (3) Strong Granger causalities are detected by testing $H_0{:}\beta_j = \psi_1 = 0$ and $H_0{:}\varphi_j = \psi_1 = 0$ for all j in Eqs. (5a) and (5b), respectively [32].

4. Empirical results

In this study we investigate the long-run and causal relationships between energy consumption per capita and economic growth per capita in Albania, Bulgaria, Hungary and Romania from

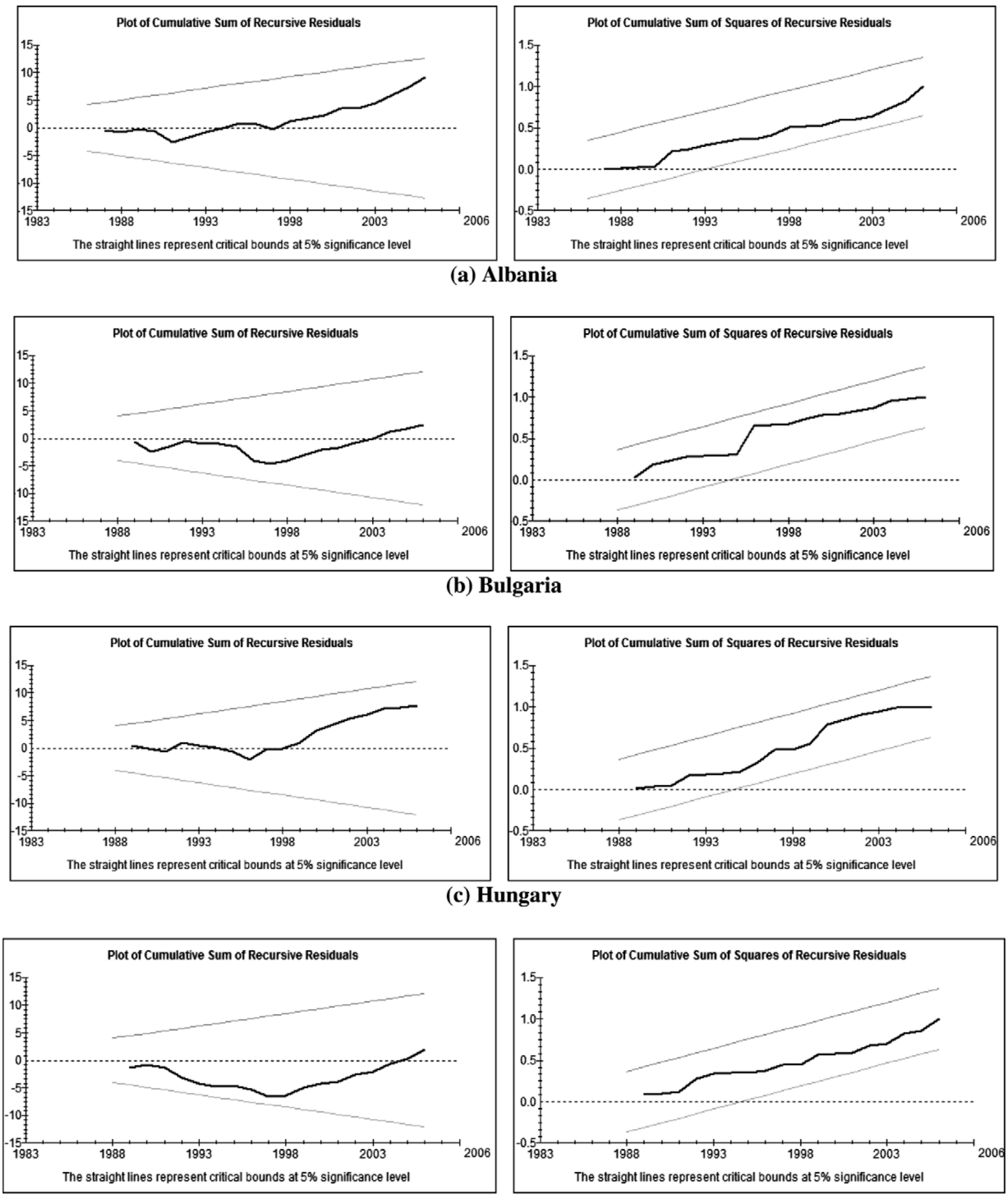

Fig. 2. Plot of CUSUM and CUSUMQ tests for the parameter stability of GDP–EC2 equation.

1980 to 2006 by employing energy use per capita, electric power consumption per capita and real GDP per capita variables. To examine this linkage, we use the two-step procedure from the Engle and Granger model: In first step, we explore the long-run relationships between the variables by using recently developed ARDL bounds testing approach of cointegration. In second, we employ a dynamic VEC model to test causal relationships between variables.

According to Pesaran and Shin [25], the SBC is generally used in preference to other criteria because it tends to define more parsimonious specifications. With the limited observations, this study used the SBC to select an appropriate lag for the ARDL model. Table 1 presents the estimated ARDL models that have passed several diagnostic tests that indicate no evidence of serial correlation and heteroscedasticity.

In addition, due to the structural changes in the economies of these countries it is likely that macroeconomic series may be subject to one or multiple structural breaks. For this purpose, the stability of the short-run and long-run coefficients is checked through the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests proposed by Brown et al. [33]. Unlike Chow test, requires break point(s) to be specified, the CUSUM and CUSUMQ tests are quite general tests for structural change in that they do not require a prior determination of where the structural break takes place. Figs. 1 and 2 present the plot of CUSUM and CUSUMSQ test statistics for four countries that fall inside the critical bounds of 5% significance. This implies that the estimated parameters are stable over the period of 1980–2006.

While the bounds *F*-test for cointegration test yields evidence of a long-run relationship between energy use per capita and real GDP per capita at 10% significance level, no cointegration exists between electric power consumption per capita and real GDP per capita in Hungary. On the other hand, the ARDL bounds test results show that there is no a unique long-term or equilibrium relationship between both energy consumption variables and GDP per capita in Albania, Bulgaria and Romania. In other words, there is no cointegration between energy consumption per capita and real GDP per capita in these countries. Thus, the econometric analysis suggests that any causal relationships within dynamic VEC model for Albania, Bulgaria and Romania cannot be estimated.

The existence of a cointegrating relationship among energy use per capita and real GDP per capita in Hungary suggests that there must be Granger causality in at least one direction. In this study we found that there is an evidence of two-way (bidirectional) long-run strong Granger causality between energy use per capita and real GDP per capita only in Hungary (see Table 2). Furthermore, there exists one-way long-run Granger causality from energy use per capita to real GDP per capita in Hungary. However, there is no weak (short-run) Granger causality in Hungary.

Table 2
Granger causality tests for Hungary.

The null hypotheses	*F*-statistics (*P*-values)
Short-run (or weak) Granger causality	
$\Delta EC2 \Rightarrow \Delta GDP$ (H_0:$\beta_j = 0$)	2.5727 (0.1041)
$\Delta GDP \Rightarrow \Delta EC2$ (H_0:$\varphi_j = 0$)	0.5568 (0.5826)
Long-run Granger causality	
ECT $\Rightarrow \Delta GDP$ (H_0:$\psi_1 = 0$)	6.1865 (0.0229)
ECT $\Rightarrow \Delta EC2$ H_0:$\psi_2 = 0$	0.5008 (0.4882)
Strong Granger causality	
$\Delta EC2$, ECT $\Rightarrow \Delta GDP$ (H_0:$\beta_j = \psi_1 = 0$)	3.0768 (0.0539)
ΔGDP, ECT $\Rightarrow \Delta EC2$ (H_0:$\varphi_j = \psi_1 = 0$)	9.0643 (0.0007)

Notes: GDP is the real GDP per capita, EC2 is the energy use (kg of oil equivalent per capita) and ECT is error correction term. Δ is the first difference operator. The number of optimal lags, *j* is 2, based on SBC.

5. Conclusion

This paper investigates the nexus between energy consumption and economic growth for Albania, Bulgaria, Hungary and Romania from 1980 to 2006. To examine this linkage, we use the two-step procedure from the Engle and Granger model: In first step, we explore the long-run relationships between the variables by using ARDL bounds testing approach of cointegration. Secondly, we employ a dynamic VEC model to test causal relationships between variables.

All results suggest that there is weak evidence about the long-run and causal relationships between energy consumption and economic growth in these countries. Our main findings are as follows: (a) there is no a unique long-term or equilibrium relationship between energy consumption variables and real GDP per capita in Albania, Bulgaria and Romania; (b) any causal relationships within dynamic error correction model for Albania, Bulgaria and Romania cannot be estimated; and (c) long-run relationship (cointegration) between energy use per capita and real GDP per capita and evidence of two-way (bidirectional) strong Granger causality between these variables is found only in Hungary. The empirical results of this study provide policymakers a better understanding of energy consumption and economic growth nexus to formulate energy policy in these countries. In addition, the governments of these countries should consider the economic stages (situation) when implementing the relevant energy policies.

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