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Monika Papież, Sławomir Śmiech[*]

Economic Growth and Energy Consumption in Post-Communist Countries: a Bootstrap Panel Granger Causality Analysis[**]

A b s t r a c t. The aim of this paper is to identify Granger causality between energy consumption and economic growth in post-communist countries in the period 1993 to 2011. Bootstrap panel Granger causality test was used as a research tool in order to accommodate for country-specific heterogeneity and to avoid the problem of cross-sectional dependence.
The analysis allowed for the verification of the hypothesis regarding the links between economic growth and energy consumption in nine countries. The hypotheses were confirmed: the growth hypothesis in three countries and the feedback hypothesis in one country.

K e y w o r d s: energy consumption, economic growth, bootstrap panel Granger causality test, energy efficiency.

J E L Classification: C33, Q43.

Introduction

Improving energy security is the priority of the EU policy. Growing dependence of the EU on energy import (its volume is predicted to increase from 50% at present to 80% in 2035) makes it imperative to limit energy

[*] Correspondence to: Monika Papież, Cracow University of Economics, Department of Statistics, Rakowicka 27, 31-510 Krakow, Poland e-mail: papiezm@uek.krakow.pl; Sławomir Śmiech, Cracow University of Economics, Department of Statistics, Rakowicka 27, 31-510 Krakow, Poland e-mail: smiechs@uek.krakow.pl.

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consumption (measured by CO2 emission) and replace non-renewable energy sources with renewable ones. On the other hand, energy consumption is inextricably linked with economic growth (the Environmental Kuznets Curve). Dynamically developing countries consume more and more energy, and curbing energy consumption can lead to stagnation or the drop in economic growth rate.

The analysis of links between economic growth and energy consumption was addressed by numerous research studies beginning with a pioneering study by Kraft and Kraft (1978). Four hypotheses regarding causal relations between energy consumption and economic growth can be found in the literature dealing with this topic: the growth hypothesis, the conservation hypothesis, the feedback hypothesis and the neutrality hypothesis. The growth hypothesis assumes that there are countries in which the growth of energy consumption is an important element of their economic development. In this case, the energy conservation policy advocating the introduction of limits in energy consumption will have a negative impact on economic growth. The growth hypothesis is based on unidirectional Granger causality running from energy consumption to economic growth. The conservation hypothesis claims that the changes in energy consumption stem from the changes in economic activity, and energy conservation policy does not negatively affect economic growth. This hypothesis is confirmed if unidirectional Granger causality running from GDP growth to energy consumption can be observed. The feedback hypothesis assumes that there are countries with bi-directional Granger causality between energy consumption and economic growth. The neutrality hypothesis states that there are countries in which GDP does not depend on energy consumption and vice versa.

As Karanfil (2009) demonstrates in his survey of empirical literature devoted to this issue, the relations between economic growth and energy consumption are not unambiguous. The differences can be attributed to different econometric approaches, differently specified time frames and different sets of variables used in each of those studies.

The occurrence of the relationship between economic growth and energy consumption is related to the changes in energy efficiency. Energy efficiency aims at reducing the amount of energy required to provide products and services in a given country. Most studies underline a positive influence of energy efficiency on economy and the environment. For example, Sarkar and Singh (2010) show that energy efficiency programmes can: conserve natural resources, reduce the environmental pollution and carbon footprint of the energy sector, reduce a country's dependence on fossil fuels, thus enhancing its energy security, ease infrastructure bottlenecks and impacts of temporary power shortfalls, as well as improve industrial and commercial competitiveness through reduced operating costs. However, rebound effects (see Turner, 2009; Turner and Hanley, 2011 for a recent review) can appear. When energy becomes more productive, and its price falls, the increase of energy use through the substitution effect can be observed.

This paper examines the relationship between energy consumption and economic growth in nine Eastern European countries and the Baltic states. It focuses on the production side model of the energy consumption-growth nexus, with labour and capital included in it (Stern, 1993). The analysis covers the period from 1993 to 2011. Such a choice was dictated by the need to cover the relations in the analysed countries, all of which witnessed rapid political and economic changes in the 1990s.

The aim of the analysis was to investigate the relations between energy consumption and economic growth in selected Eastern European countries and the Baltic states on the basis of the relations between overall energy efficiency gains (industry, transport, households) in 2000–2010[1] and countries' economic growth in the same period. The following research hypotheses were formulated:

a) Countries which increased energy efficiency the most will confirm the growth hypothesis, feedback hypothesis or conservation hypothesis (bidirectional unidirectional causality between energy consumption and economic growth).
b) Countries in which energy efficiency was not considerably increased will confirm the neutrality hypothesis.

The hypotheses result from the following reasoning. The former group of countries had to bear the costs of the increase in energy efficiency on the one hand, and, on the other hand, modernisation allows for reducing the amount of energy used and, consequently, its costs, which should result in the appearance of causal relations between energy production and economic growth. In the latter group of countries the effects mentioned are non-existent, which rules out any relations between them.

We applied a bootstrap panel causality approach proposed by Kónya (2006), which allows for simultaneous examination of cross-sectional dependence.

The paper consists of the following sections. Section 1 presents the most important findings from studies dealing with energy-economy nexus in Central and Eastern European countries. In Section 2 the relations between over-

[1] The choice of the period for the analysis was dictated by the availability of the data provided by http://www.odyssee-indicators.org.

all energy efficiency gains and economy growth are described. Section 3 introduces methodology used in the study, and Section 4 presents the data and results obtained. The paper ends with the conclusion and the interpretation of the results.

The paper contributes to the existing literature because the analysis focuses on countries from Eastern Europe and the Baltic states. Most of them have not been analysed from this angle before. They have similar GDP and a similar level of energy consumption. As member states of the EU, they are obliged to follow a common energy policy. Thanks to these similarities, the data used were characterised by cross-sectional dependence. The application of the methodology suggested by Kónya (2006) made correct inference on causalities in this situation possible.

Two additional variables, labour and capital, were used to compare the models, which makes this study more general in scope than other studies. Our findings may provide valuable information for developing more effective energy policies with respect to both energy consumption and environmental protection.

1. Review of Literature

Existing literature offers a wide range of perspectives and insights into the issue of energy consumption-growth nexus, which sometimes report contradicting results. It can be divided into country-specific case studies and multi-country studies (Karanfil, 2009). In both types various econometric methods, the choice of the period analysed, and the choice of control variables can be found.

Taking into consideration the methodological perspective, four generations of contributions were identified (Belke et al., 2011; Costantini and Martini, 2010). The first-generation studies were based on VAR methodology (Kraft and Kraft, 1978) and assumed that the time series were stationary. The second-generation studies accounted for non-stationarity and applied Engle-Granger two-step procedure to test pairs of variables for cointegrating relationships. The third-generation studies used multivariate estimators (Johansen, 1991). This approach allowed for more than two variables in cointegration relationship and for analysing causality both in the short- and long-run simultaneously. The fourth-generation studies were based on panel methods testing for unit roots, cointegration and Granger causality. Using panel cointegration has several advantages. It allows for higher degrees of freedom, reduces multicollinearity between regressors, and improves the power of the cointegration test, especially in case of annual data. The main disadvantage of this approach is the need to assume cross-sectional independence, which is difficult to satisfy in a panel data. What is more, different countries are treated as an entity. As a result, it is impossible to identify the difference in the dynamic relationship between energy consumption and economy (slope homogeneity). As a result, it is impossible to identify the difference in the dynamic relationship between energy consumption and economy (slope homogeneity). What is more, in most studies based on panel models (except panel VAR, see surveys by Canova and Ciccarelli (2013), which has not been used in such analyses so far) different countries are treated as an entity.

In spite of a substantial number of studies concerning relations between energy consumption and economic growth, not all Eastern European countries were analysed, for example, the Baltic states were not included in any of them, and among the countries from Central and Eastern Europe only the following ones were studied: Poland (Gurgul and Lach, 2011a, 2011b, 2012), Romania (Apergis and Danuletiu, 2012), Albania, Bulgaria, Hungary, and Romania (Ozturk and Acaravci, 2010). Gurgul and Lach (2011b) found that energy consumption Granger caused GDP in Poland during the last decade. They (Gurgul and Lach, 2011a) also investigated causal relations between coal consumption and economic growth. In another paper Gurgul and Lach (2012) investigated causal interdependences between electricity consumption and GDP in Poland. Apergis and Danuletiu (2012) showed that energy consumption Granger caused GDP in Romania in the period 2000-2011. However, Ozturk and Acaravci (2010) did not find any relationship between energy consumption and real GDP in Romania and Bulgaria, while found bidirectional strong Granger causality between these variables in Hungary in the period 1980–2006. Using a two-way fixed effects model, Menegaki and Ozturk (2013) confirmed bidirectional causality between growth and political stability, capital and political stability, and capital and fossil energy consumption for 26 European countries in a multivariate panel framework over the period 1975–2009.

2. Energy Efficiency in Eastern European Countries and the Baltic States

Energy efficiency is considered to be one of the most cost effective ways of meeting the demands of sustainable development and lower fossil fuel dependence. So, the efficient use of energy is an important topic in public policy debates. Unfortunately, in literature dealing with energy issues there is no consensus on the appropriate method for defining and measuring energy efficiency. The authors of this paper adopted the definition of energy efficiency given by the Odyssee project[2]. The "ODEX" energy efficiency indicator provides an overall perspective of energy efficiency trends by sector and combines the trends of indicators by end-use or sub-sector. It represents a better proxy to evaluate energy efficiency trends at an aggregate level (overall economy, industry, households, transport, services). The ODEX indicators by sector (industry, transport, households) are calculated from unit consumption trends by sub –sector (or end-use or mode of transport) by aggregation of unit consumption indices by sub-sector in one index for the sector on the basis of the current weight of each sub-sector in the sector's energy consumption. The ODEX can be defined as the ratio between the actual energy consumption of the sector in year t and the sum of fictive energy consumption of each underlying sub-sector/end-use that would have been observed in year t had the unit consumption of the sub- sector been that of a reference year. The energy efficiency gains are calculated from ODEX and reflect efficiency gains since 2000.

Figure 1 presents relations between overall energy efficiency gains (industry, transport, households) in the period 2000–2010 and real growth of GDP per capita in the same period for Eastern Europe and the Baltic states. This diagram identifies two groups of countries with similar levels of energy efficiency and a similar level of economic development. The first group comprises countries with high overall energy efficiency gains (above 18 percent) and high (and medium) growth of GDP per capita in the period 2000–2010. The second group includes countries with low overall energy efficiency gains (below 14 percent) and low (and medium) growth of GDP per capita in the period 2000–2010.

In the analysed Eastern European countries and the Baltic states in the period 2000–2010 the mean energy efficiency index for the whole economy (ODEX) decreased by 15.3 percent. Countries with the highest improvement in energy efficiency in the period analysed include: Poland (25.7 percent), Bulgaria (23 percent), Latvia (21 percent), Lithuania (19.8 percent), and Romania (19.4 percent). Countries with the lowest improvement in energy efficiency in the same period include: Slovakia (3.7 percent), the Czech Republic (5.2 percent), Estonia (7.3 percent), and Hungary (13 percent). It should be noticed that countries which did not improve their energy efficiency substantially also had a lower increase growth in GDP per capita

[2] ODYSSEE is a project between ADEME, the EIE programme of the European Commission/DGTREN and energy efficiency agencies, or their representative, in the 27 countries in Europe plus Norway and Croatia (http://www.odyssee-indicators. org).

(except for Slovakia[3]) than countries with a considerable increase in energy efficiency.

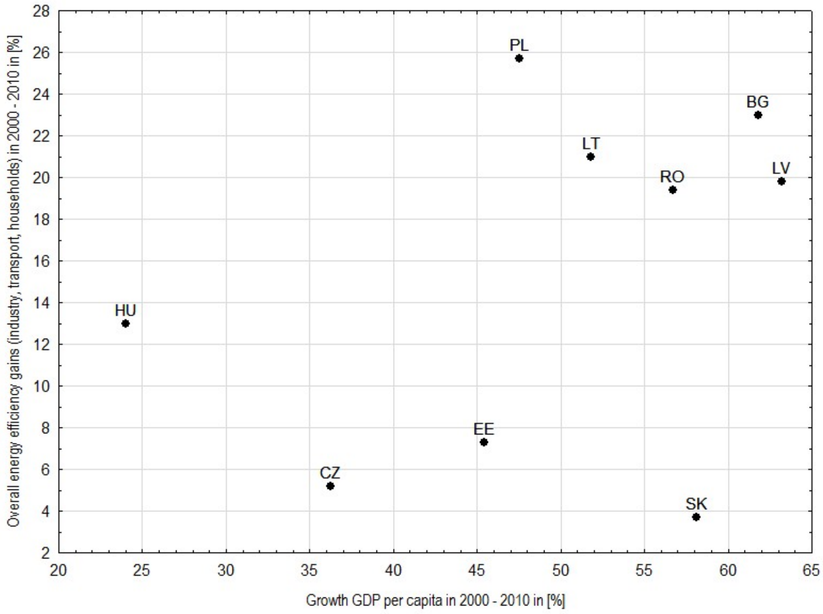

Figure 1. Relations between overall energy efficiency gains (industry, transport, households) in the period 2000-2010 and growth of GDP per capita in the period 2000–2010

3. Methodology

The choice of a suitable method allowing for the analysis of causality for panel data requires the assessment of cross-sectional dependence. If cross-sectional dependence exists, the seemingly unrelated regressions (SUR) are more efficient then the ordinary least-squares (OLS) (Zellner, 1962). Kónya (2006) proposed a method which takes into account the characteristics of cross-sectional dependence. Therefore, before considering causality, we investigated the characteristics of panel data. The tools used for bootstrap panel causality test are presented below.

[3] A specific situation of Slovenia is a result of numerous phenomena which are described in detail in the study: *Energy Efficiency Policies and Measures in Slovakia in 2012*, ODYSSEE- MURE 2010, http://www.odyssee-indicators.org/publications/PDF/slovakia_nr.pdf [30.12.2013].

3.1. Tests of Cross-Sectional Dependence

An important issue to be considered in a panel data analysis is testing for cross-sectional dependence across countries, because a shock that affects one country may spillover on other countries.

Let us consider the standard panel data model:

$$y_{it} = \alpha_i + \beta_i'\mathbf{x}_{it} + u_{it}, \tag{1}$$

where $i = 1,2,\ldots,N$ represents the cross section dimension, $t = 1,2,\ldots,T$ refers to the time series dimension, $\mathbf{x}_{it}$ is a (K × 1) vector of observed regressors (individual-specific as well as common regressors). The individual intercepts α_i and the slope coefficients β_i are defined on a compact set and allowed to vary across *i*. For each *i*, $u_{it} \sim IID\left(0, \sigma_{iu}^2\right)$ for all *t*, although they may exhibit cross- sectional dependence.

The null hypothesis of no-cross-sectional dependence – $H_0 : Cov\left(u_{it} u_{jt}\right) = 0$ for all *t* and $i \neq j$ – is tested against the alternative hypothesis of cross-sectional dependence – $H_1 : Cov\left(u_{it} u_{jt}\right) \neq 0$, for at least one pair of $i \neq j$. In literature several tests for error cross-sectional dependence have been proposed.

Breusch and Pagan (1980) proposed a Lagrange multiplier (LM) statistic for testing the null hypothesis of no-cross-sectional dependence, which is defined as:

$$LM = T \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij}^2 , \tag{2}$$

where $\hat{\rho}_{ij}$ is the sample estimate of the pair wise Pearson correlation coefficient of the residuals from the Ordinary Least-Squares (OLS) estimation of Eq. (1) for each *i*. LM is asymptotically distributed as chi-squared with $N(N-1)/2$ degrees of freedom under the null hypothesis, as $T \to \infty$, with *N* fixed. It is important to note that the LM test is valid for relatively small *N* and sufficiently large *T*. So, where $T \to \infty$ and $N \to \infty$, Pesaran (2004) proposed the following LM statistic for the cross-sectional dependence test (the so-called CD test):

$$CD_{lm} = \sqrt{\frac{1}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \left(T\hat{\rho}_{ij}^2 - 1\right). \tag{3}$$

Under the null hypothesis, the CD_{lm} test converges to the standard normal distribution.

However, this test is likely to exhibit substantial size distortions for N large and T small, a situation that can frequently arise in empirical applications. To overcome this problem, Pesaran (2004) proposed the following simple alternative test, which is based on the pair-wise correlation coefficients rather than their squares used in the LM test:

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right), \tag{4}$$

and showed that under the null hypothesis of no cross-sectional dependence $CD \rightarrow_d N(0,1)$ for $N \rightarrow \infty$ and T sufficiently large. Pesaran (2004) concluded that it is also clear that, since the mean of CD is exactly equal to zero for all fixed $T > K+1$ and N, the test is likely to have good small sample properties (for both N and T small).

In Pesaran et al. (2008) the authors concluded that the CD test has an important drawback, namely it will lack power in certain situations where the population average pairwise correlations are zero, although the underlying individual population pairwise correlations are non-zero. That is why Pesaran et al. (2008) proposed a bias-adjusted test, which is a modified version of the LM test, by using the exact mean and variance of the LM statistic. The bias-adjusted LM test is as follows:

$$LM_{adj} = \sqrt{\frac{2}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\frac{(T-k)\hat{\rho}_{ij}^2 - \mu_{Tij}}{v_{Tij}}, \tag{5}$$

where μ_{Tij} and v_{Tij}^2 are respectively the exact mean and variance of $(T-k)\hat{\rho}_{ij}^2$ provided in Pesaran et al. (2008 p.108). Pesaran et al. (2008) showed that under the null hypothesis of no cross-sectional dependence with $T \rightarrow \infty$ first followed by $N \rightarrow \infty$, the statistics LM_{adj} follow an asymptotic standard normal distribution.

3.2. Bootstrap Panel Granger Causality Test

Taking into account cross-sectional dependence and heterogeneity across country groups requires a method of analysis which would be able to capture both these features. The bootstrap panel causality approach proposed by Kónya (2006) seemed to be a suitable method. This approach uses seemingly unrelated regression (SUR) and, therefore, is able to deal with cross-sectional dependence across the members of the panel.

The test for the direction of causality is based on Wald tests with country-specific bootstrap critical values. That is why it does not impose a joint hypothesis across all members of the panel. Using Kónya (2006) approach allows for the identification of specific countries in which a Granger causal relationship exists. What is more, Kónya (2006) claimed that 'this approach does not require pretesting for unit roots and cointegration', which is important 'since the unit-root and cointegration tests in general suffer from low power'. On the other hand, ignoring potential (common) stochastic trends results in a situation in which the results of the suggested procedure can be used only for the evaluation of short-term causality (one-period-ahead forecast).

Kónya's (2006) panel causality approach models the data as a system of two sets of the following equations[4]:

$$
\begin{aligned}
y_{1,t} &= \alpha_{1,1} + \sum_{l=1}^{mly_1} \beta_{1,1,l} y_{1,t-l} + \sum_{l=1}^{mlx_1} \delta_{1,1,l} x_{1,t-l} + \sum_{l=1}^{mlz_1} \gamma_{1,1,l} z_{1,t-l} + \\
&\quad + \sum_{l=1}^{mlv_1} \vartheta_{1,1,l} v_{1,t-l} + \varepsilon_{1,1,t}, \\
&\dots \qquad\qquad (6) \\
y_{N,t} &= \alpha_{1,N} + \sum_{l=1}^{mly_1} \beta_{1,N,l} y_{N,t-l} + \sum_{l=1}^{mlx_1} \delta_{1,N,l} x_{N,t-l} + \sum_{l=1}^{mlz_1} \gamma_{1,N,l} z_{N,t-l} + \\
&\quad + \sum_{l=1}^{mlv_1} \vartheta_{1,N,l} v_{N,t-l} + \varepsilon_{1,N,t},
\end{aligned}
$$

and

$$
\begin{aligned}
x_{1,t} &= \alpha_{2,1} + \sum_{l=1}^{mly_2} \beta_{2,1,l} y_{1,t-l} + \sum_{l=1}^{mlx_2} \delta_{2,1,l} x_{1,t-l} + \sum_{l=1}^{mlz_2} \gamma_{2,1,l} z_{1,t-l} + \\
&\quad + \sum_{l=1}^{mlv_2} \vartheta_{2,1,l} v_{1,t-l} + \varepsilon_{2,1,t}, \\
&\dots \qquad\qquad (7)
\end{aligned}
$$

[4] It is possible to include a deterministic component into the system of equations.

$$x_{N,t} = \alpha_{2,N} + \sum_{l=1}^{mly_2} \beta_{2,N,l} y_{N,t-l} + \sum_{l=1}^{mlx_2} \delta_{2,N,l} x_{N,t-l} + \sum_{l=1}^{mlz_2} \gamma_{2,N,l} z_{N,t-l} + \\ + \sum_{l=1}^{mlv_2} \vartheta_{2,N,l} v_{N,t-l} + \varepsilon_{2,N,t},$$

where $y_{i,t}$ denotes economic growth (in country *i* and *t* period), $x_{i,t}$ refers to energy consumption, $z_{i,t}$ is the capital formation, $v_{i,t}$ is the labour participation rate[5], *N* denotes the number of countries in the panel ($i = 1,2,\dots,N$), *t* is time period ($t = 1,2,\dots,T$), and *l* is the number of lags in equations. $\varepsilon_{1,i,t}, \varepsilon_{2,i,t}$ are supposed to be correlated contemporaneously across equations (due to common random shocks).

The system of equations allows for testing unidirectional and bi-directional Granger causality for each country separately. There is unidirectional Granger causality running from economic growth to energy consumption (the equivalent of the conservation hypothesis) if in (7) not all $\beta_{2,i}$'s are zero, but in (6) all $\delta_{1,i}$'s are zero. There is unidirectional Granger causality running from energy consumption to economic growth in country *i* (the equivalent of the growth hypothesis) if not all $\delta_{1,i}$'s are zero, but all $\beta_{2,i}$'s are zero in (7). There is bi-directional Granger causality between energy consumption and economic growth if neither all $\delta_{1,i}$'s nor all $\beta_{2,i}$'s are zero. Finally, there is no Granger causality between energy consumption and economic growth if all $\delta_{1,i}$'s and all $\beta_{2,i}$'s are zero.

The country-specific bootstrap[6] critical values are obtained as follows[7]:

1. A system of equations (6) is estimated under the null hypothesis of non-causality running from energy consumption to economic growth (that is imposing the $\delta_{1,i,l} = 0$ restriction for all *i* and *l*) and the residuals are obtained:

[5] *Z* and v are treated as an auxiliary variable, and they will not be directly involved in the Granger causality analysis.

[6] On bootstrapping in general see e.g. Horowitz (2003). On bootstrapping in SUR models see Atkinson et. al (1992), and Rilstone and Veall (1996).

[7] We present a procedure for testing Granger causality running from *X* to *Y*. Similar steps are required for testing causality running from *Y* to *X*.

$$e_{H_0,i,t} = y_{i,t} - \hat{\alpha}_{1,i} - \sum_{l=1}^{mly_1} \hat{\beta}_{1,i,l} y_{1,t-l} - \sum_{l=1}^{mlz_1} \hat{\gamma}_{1,i,l} z_{1,t-l} - \sum_{l=1}^{mlv_1} \hat{\vartheta}_{1,i,l} v_{1,t-l}, \quad (8)$$

for $i = 1,\dots,N$ and $t = 1,\dots,T$. From these residuals $N \times T$ matrix $\left[e_{H_0,i,t}\right]$ is developed.

2. These residuals are re-sampled by randomly selecting a full column form the matrix $\left[e_{H_0,i,t}\right]$, and denote the selected bootstrap residuals as $\left[e^*_{H_0,i,t}\right]$ where $t = 1,2,3,...,T^*$.
3. The bootstrap sample of Y is generated under the assumption of no causality running from energy consumption to economic growth, i.e.:

$$y^*_{i,t} = \hat{\alpha}_{1,i} + \sum_{l=1}^{mly_1} \hat{\beta}_{1,i,l} y^*_{i,t-l} + \sum_{l=1}^{mlz_1} \hat{\gamma}_{1,i,l} z_{1,t-l} + \sum_{l=1}^{mlv_1} \hat{\vartheta}_{1,i,l} v_{1,t-l} + e^*_{H_0,i,t}. \quad (9)$$

4. $y^*_{i,t}$ is substituted for $y_{i,t}$ and a system of equations is re-estimated (without any restrictions). The Wald test for each country is implied by the no-causality null hypothesis.
5. The empirical distributions of the Wald test statistics are developed by repeating steps 2 – 4. The bootstrap critical values are specified by selecting appropriate percentiles of these sampling distributions.

Eventually, Wald test statistics obtained from original series are compared with the bootstrap critical values.

Specifying the number of lags in all equations is a crucial step in Kónya's approach. Following Kónya (2006), we decided to allow for different lags in each system but did not allow for different lags across countries. Assuming that the number of lags ranges from 1 to 4, we estimated all equations and used the Akaike Information Criterion (AIC) to determine the optimal solution. The Akaike Information Criterion[8] (AIC) was evaluated as:

$$AIC_k = \ln|\mathbf{W}| + \frac{2N^2 q}{T}, \quad (10)$$

where **W** stands for estimated residual covariance matrix, N is the number of equations, q is the number of coefficients per equation, T is the sample size.

[8] Kónya (2006) presented also Schwartz Information Criterion.

4. Data and Empirical Results

The analysis of causal relationship between energy consumption and economic growth based on the annual panel data was carried out over the period 1993–2011 for nine European countries: Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, and Slovakia. Two variables from the World Bank Development Indicators were chosen for the analysis: real Gross Domestic Product per capita (*GDP*) in constant 2000 U.S. dollars and energy consumption (*EC*), represented by energy use in kg of oil equivalent per capita.

Taking into consideration rapid economic changes experienced by the countries analysed, a set of variables was extended to include real gross fixed capital formation per capita (*K*) in constant 2000 US dollars as a proxy of capital and labour participation rate (*L*)[9]. All variables were in natural logarithms.

Till 1989 Eastern European countries and the Baltic states were under the communist rule with centrally planned economies. In 1989 communism fell in Bulgaria, Czechoslovakia, Hungary, Poland, and Romania. After the dissolution of the Soviet Union in 1991, Estonia, Latvia, and Lithuania reappeared on the map, and in 1993 Czechoslovakia was divided into two countries: the Czech Republic and Slovakia. That is why year 1993 was chosen as an initial period of the analysis of causality between economic growth and energy consumption.

Table 1. Cross-sectional dependence tests

Variable	Cross-sectional dependence test			
	LM	CD_{LM}	*CD*	LM_{adj}
GDP	150,62***	13,51***	6,23***	21,654***
EC	324,84***	30,50***	17,84***	36,375***

Note: ***, **, and * indicate significance at the 1, 5, and 10% levels, respectively.

The first step in analysing panel data Granger causality is testing for cross-sectional dependence. Table 1 shows the results obtained for four different cross-sectional dependence test statistics: LM (Breusch and Pagan, 1980), CD_{LM} (Pesaran, 2004), *CD* (Pesaran, 2004), and LM_{adj} (Pesaran et al., 2008). The results indicate that for all countries with significance level $p = 0.05$ we reject the null hypothesis of no cross-sectional dependence among the four variable examined. These findings show that a shock which

[9] The use of real gross fixed capital as a proxy of capital follows the works by Sari and Soytas (2007) in assuming that under the perpetual inventory method with a constant depreciation rate, the variance in capital is closely related to the change in investment.

occurred in one post-communist country will be transmitted to other countries.

The existence of cross-sectional dependence in these countries means that it is justified to use the bootstrap panel Granger causality testing method. For each system of equations the number of lags was chosen according to the AIC criterion[10]. Additionally, specifications incorporating deterministic trend were taken into account.

The results from the bootstrap[11] panel Granger causality analysis are reported in Table 2 and Table 3.

Table 2. The bootstrap panel Granger causality analysis

Countries	H_0: Energy consumption does not Granger cause GDP (H_1: EC → GDP)			
	Wald statistics	Bootstrap critical value		
		10%	5%	1%
Bulgaria	12.915**	7.638	11.186	21.785
Czech Republic	0.686	7.715	11.176	19.899
Estonia	0.574	10.351	16.084	35.753
Hungary	0.317	7.751	11.784	20.686
Latvia	9.265*	8.842	13.331	24.626
Lithuania	3.378	8.856	14.397	29.298
Poland	18.917**	6.597	10.029	20.283
Romania	8.372*	8.245	11.548	25.975
Slovakia	2.235	7.584	12.652	23.370

Note: ***, **, and * indicate significance at the 1, 5, and 10% levels, respectively. Bootstrap critical values are obtained from 10,000 replications.

Table 2 and Table 3 present the results obtained for nine transition countries in Eastern Europe and the Baltic states. The results confirm the growth hypothesis for Bulgaria, Poland (both at the significance level 5%) and Romania (at the significance level 10%). This means that economies in those three countries can be called ‘energy dependent’, and that energy consumption plays an important role in their economic growth, both directly and indirectly in the production process as a complementary factor to labour and capital. Consequently, we may conclude that energy is a limiting factor to economic growth and, hence, shocks to energy supply will have an impact

[10] We used the AIC criterion to compare the specifications with and without a linear trend. Finally, we constructed SUR with one lag and without a linear trend.

[11] Following the original paper of Kónya (2006) and several others, e.g. Nazlioglu et. al (2011), we used 10000 replications in the procedure. Andrews and Buchinsky (2000) provide an exact method of evaluating the adequacy of the chosen number of replications.

on economic growth. Additionally, it can be claimed that excessive energy protection and a reduction in energy consumption may lead to stagnation.

Table 3. The bootstrap panel Granger causality analysis

Countries	H_0: GDP does not Granger cause energy consumption (H_1: GDP → EC)			
	Wald statistics	Bootstrap critical value		
		10%	5%	1%
Bulgaria	0.425	13.234	20.697	41.039
Czech Republic	0.330	12.162	18.667	37.114
Estonia	0.696	8.989	13.623	29.087
Hungary	1.244	12.947	20.043	42.007
Latvia	23.841**	13.824	22.365	61.726
Lithuania	4.246	9.716	14.063	26.881
Poland	12.580	17.470	25.420	51.422
Romania	2.910	11.334	17.488	34.534
Slovakia	0.632	10.430	15.556	31.457

Note: ***, **, and * indicate significance at the 1, 5, and 10% levels, respectively. Bootstrap critical values are obtained from 10,000 replications.

The feedback hypothesis was confirmed only for Latvia. This means that energy consumption and economic growth are jointly determined and affected at the same time.

The results support the neutrality hypothesis for 5 countries: the Czech Republic, Hungary, Estonia, Lithuania, and Slovakia. The neutrality hypothesis states that energy consumption and economic growth are not sensitive to one another. Therefore, any policy with respect to the consumption of energy, conservative or expansive, is expected to have a negligible effect on economic growth.

Conclusions and Discussion

We investigated the relations between energy consumption and economic growth. Labour and real gross fixed capital formations were added to the analysis in order to avoid the problem of impact of omitted-variables bias. The methodology used in the study, Kónya's procedure (2006), firstly, allowed for the assessment of causality in countries with cross-sectional dependence, and, secondly, avoided the problem of incorrect specification connected with unit root and cointegration.

Empirical results confirm the linkages between energy consumption and economic growth in four of nine countries. The growth hypothesis was confirmed in 3 countries: Bulgaria, Poland, and Romania. Energy consumption seems to be the bottleneck in their economic growth, and, hence, shocks to energy supply will have an impact on this growth. Latvia is the only country for which the feedback hypothesis was confirmed. In such countries energy consumption and economic growth are complementary to each other.

The results obtained in the study indicate that causality between energy consumption and economic growth can be equated with energy efficiency. The group of countries with the best energy efficiency indicators consisted of almost the same countries as the group in which the growth hypothesis, the conservation hypothesis or the feedback hypothesis were confirmed (the only exception was Latvia). Thus, it can be assumed that the hypotheses formulated in the introduction were confirmed. Unfortunately, the empirical strategy used in this study did not allow for showing the reactions of economic growth to the changes in energy consumption and vice versa. So, it is not possible to conclude whether modernisation of economies, which can be equated to energy efficiency, exerts a positive or negative impact on economy (the rebound effect).

In conclusion, a special situation of Poland and Bulgaria, countries confirming the growth hypothesis, should be mentioned. They rely on coal as the most important source of energy. In 2011 in Poland it accounted for 56.2 percent and in Bulgaria for 42.3 percent of the country's total primary energy consumption. The pressure on those countries is especially heavy because of the amount of their emission of carbon dioxide, which are the highest for coal. The necessity of limiting the use of this energy source without access to alternative energy sources can be a serious threat for their economies.

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Wzrost gospodarczy i zużycie energii w krajach postkomunistycznych - bootstrapowa panelowa analiza przyczynowości

Z a r y s t r e ś c i. Celem artykułu jest identyfikacja zależności przyczynowych (w sensie Grangera) pomiędzy zużyciem energii i wzrostem gospodarczym w krajach Europy Środkowo Wschodniej oraz w krajach Bałtyckich w okresie 1993–2011. Jako narzędzie badawcze wykorzystano procedurę bootstrapowej panelowej analizy przyczynowości zaproponowaną przez Kónya (2006). Procedura ta pozwala na wnioskowanie w przypadku występowania zależności przestrzennych w badanej próbie i nie wymaga wstępnej analizy stacjonarności oraz umożliwia opis relacji dla poszczególnych analizowanych obiektów. Przeprowadzone badanie wskazuje na prawdziwość hipotezy wzrostu w przypadku trzech krajów oraz hipotezy sprzężenia zwrotnego w przypadku jednego kraju. Otrzymane wyniki pozwalają podejrzewać, że zależność przyczynowa pomiędzy wzrostem gospodarczym i konsumpcją energii jest związana z zmianami efektywności energetycznej.

S ł o w a k l u c z o w e: zużycie energii, wzrost gospodarczy, bootstrapowa panelowa analiza przyczynowości, efektywność energetyczna.

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