An analysis of biomass consumption and economic growth in transition countries

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ABSTRACT

In this paper, the relationship between biomass energy consumption and economic growth was analysed for some European Transition Countries. Two econometrical methods, which are time series (Autoregressive Distributed Lag (A.R.D.L.) bounds testing approach and Granger Causality) and Panel data methods (Pedroni test, Panel Johansen test and Panel Causality test) were used to determine the cointegration relationship between the variables. A.R.D.L. and Granger Causality methods were practiced for Albania, Bulgaria and Romania for the 1981–2014 period. Panel Cointegration and Causality methods were applied for Bosnia and Herzegovina, Czech Republic, Hungary, Macedonia and Slovak Republic for the 1991–2014 period; and Croatia, Estonia, Latvia and Slovenia for the 1995–2014 period. According to the results, while short-run and long-run causality results demonstrate that the conservation hypothesis is valid for Albania and the countries in group 1, evidence of the growth hypothesis is supported for Bulgaria, Romania and the countries in group 2. In strong causality results, evidence of bidirectional causality for all countries is found.

1. Introduction

Biomass energy consumption is a significant part of energy consumption and is as old as humanity. However, traditional biomass energy consumption is not commonly used around the world because it has not met energy needs of the economy in recent years. As the economy has developed, fossil energy has gained popularity and traditional biomass energy consumption has diminished. Because of rapid urbanisation, traditional usage of biomass energy has lost its popularity. Further, because of problems such as environmental pollution, limited fossil reserves, increased oil prices and the Chernobyl disaster caused by fossil energy, worldwide interest has steered away from fossil energy sources such as coal, oil and natural gas to renewable energy resources like biomass, geothermal, solar power,

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wind and hydropower because renewable and sustainable energy is mainly regarded as a key factor for the future of the world (Bildirici & Ersin, 2015; Bildirici & Ozaksoy, 2013).

Biomass energy has a significant role, not only in the meaning of wealth, but also as a remarkable factor in economic growth. Besides other positive effects of biomass energy, it diminishes foreign dependency on oil and, especially in developing countries, modern biomass energy can benefit rural employment. Furthermore, biomass energy is highly appreciated because it contributes to poverty reduction and meets energy needs more economically. Biomass offers sustainable development as an important alternative of non-renewable energy resources. It provides opportunities for wide-ranging forms of energy. Additionally, it assists in developing biodiversity, soil fertility and water embowering (Balat, 2005; Bildirici & Ozaksoy, 2014). As other types of renewable energy, biomass energy consumption also has important effects on the economy.

The aim of this paper is to investigate the relationship between biomass energy consumption and economic growth in the transition countries.

The contribution of this study is in being the first paper focused on biomass energy by analysing the transition countries and discussing the importance of the relationship between economic growth and biomass energy consumption by four econometrical methods, which are the Autoregressive Distributed Lag (A.R.D.L.), Granger Causality, Panel Cointegration tests (Pedroni and Panel Johansen tests) and Panel Causality test. It is important to identify the direction of causality and long-term coefficients for each of the analysed countries, because this point of view makes significant contributions to the economy, especially in the context of energy politics proposals. However, because of data scarcity of the analysed countries, we preferred to test by Panel Cointegration and Panel Causality to make economic policy suggestions. The data for some selected transition countries does not cover the period 1981–2014. The A.R.D.L. method preference is not feasible for very small samples; in this situation the Panel model was used. The data covering the 1981–2014 period was tested by the A.R.D.L. method for Albania, Bulgaria and Romania, but the other countries' data covers the time after 1990 for which countries panel analyses were preferred. The panel cointegration method was applied for Bosnia and Herzegovina, Czech Republic, Hungary, Macedonia and Slovak Republic for the 1991–2014 period; and for Croatia, Estonia, Latvia and Slovenia for the 1995–2014 period.

The next section is the literature review. Econometric theory and methodology are identified in the third section and a further section consists of the empirical results, while the last section includes the conclusion and policy implications.

2. Literature review

Even if there are many papers that have analysed the relationship between energy consumption and economic growth, only a few of them explain the relationship between renewable energy consumption and economic growth and some of them deal with the relationship between biomass energy consumption and economic growth. The studies lay emphasis on four different hypotheses which are constructed as the 'growth hypothesis', 'conservation hypothesis', 'feedback hypothesis' and 'neutrality hypothesis'. First, the growth hypothesis accepts uni-directional causality from biomass energy consumption to economic growth. Biomass energy consumption has a significant impact on economic growth and an increase in biomass energy consumption causes a rise in economic growth. Second, the conservation

hypothesis postulates that biomass energy consumption is driven by economic growth. There is uni-directional causality from economic growth to biomass energy consumption. Third, the feedback hypothesis accepts an interdependent relationship between biomass energy consumption and economic growth. In such a case, energy conservation policies may decrease economic growth performance and the changes in economic growth may decrease energy consumption. Fourth, the neutrality hypothesis asserts that biomass energy consumption serves a relatively minor role in economic growth.

Table 1 indicates the relationship between renewable energy consumption and economic growth in these studies.

In the studies which researched the relationship between biomass energy consumption and economic growth, the causality relationship between biomass energy consumption and real G.D.P. (gross domestic product) was tested by Bildirici (2012, 2013, 2014, 2016), Bildirici and Ozaksoy (2013, 2014), Bildirici and Ersin (2015), Bilgili and Ozturk (2015) and Öztürk and Bilgili (2015).

Bildirici (2012) tested the long-run and short-run causality relationship between biomass energy consumption and economic growth and she found the cointegrated relationship between biomass energy consumption and the economic growth for nine of the 10 countries. Bildirici (2013) investigated the relationship between biomass energy consumption and real G.D.P. for the Central American countries, Argentina, Bolivia, Brazil, Chile, Colombia, Guatemala and Jamaica. Bidirectional causality between the analysed variables was found for all of the analysed countries in the long-run in this study. Bildirici and Ozaksoy (2013) tested the relationship between biomass energy consumption and economic growth in 10 selected European countries. According to strong and long-run causality, a bidirectional relationship between the variables was determined for all of the analysed countries.

Bildirici (2014) analysed the co-integration and causality relationship between biomass energy consumption and economic growth in the transition countries for the period from 1990–2011. Fully modified ordinary least square results of the study show that biomass energy consumption has a positive effect on the economic growth. Bildirici and Ozaksoy (2014) examined the relationship between biomass energy consumption and economic growth for the European transition countries in the period 1980–2011. The causality results suggest evidence of the conservation hypothesis from economic growth to biomass energy consumption for Slovenia and Slovakia; and for the growth hypothesis from biomass energy consumption to economic growth for Bulgaria and Romania.

Bildirici and Ersin (2015) discussed the relationship among biomass energy consumption, oil prices and economic growth in Austria, Canada, Germany, Great Britain, Finland, France, Italy, Mexico, Portugal and the USA for the 1970–2013 period. For Austria, Germany, Finland and Portugal, the Granger Causality test determined that the conservation hypothesis is supported. In the USA, the feedback hypothesis highlights the interdependent relationship between biomass energy consumption and economic growth. The Tado Yamamoto test determined the conservation hypothesis for Austria, Germany, Finland and Portugal. In the USA, the feedback hypothesis highlights the interdependent relationship between biomass energy consumption and economic growth.

Öztürk and Bilgili (2015) investigated the long-run dynamics of economic growth and biomass consumption by applying dynamic panel analyses for 51 Sub-Sahara African countries for the 1980–2009 period. The results show that economic growth is affected by biomass

Table 1. Renewable energy consumption and economic growth.

Study	Countries and period	Variables	Methodology	Result(s)
Sardorsky (2009a)	18 Emerging countries (1994–2003)	R.E.C.; Y	Panel models	Y increases have positive and statistically significant impact on per capita R.E.C.
Sardorsky (2009b)	G7 countries (1980–2007)	R.E.C.; CO_2; O.P.; Y	Panel Cointegration; F.M.O.L.S.; D.O.L.S.	Y increases and carbon dioxide emissions have significant impact on R.E.C.; O.P. has a negative impact on R.E.C.
Payne (2011)	USA (1949–2006)	R.E.C.; N.R.E.C.; Y	Toda-Yamamoto Causality	Growth Hypothesis
Apergis and Payne (2010b)	20 OECD countries (1985–2005)	R.E.C.; Y	Panel models; E.C.M.; Granger Causality	Bidirectional causality
Apergis and Payne (2010a)	13 Eurasian countries (1992–2007)	R.E.C.; Y	Panel Error Correction Models	Feedback Hypothesis
Menyah and Wolde-Rufael (2010)	USA (1960–2007)	N.E.C.; CO_2; R.E.C.	Granger Causality; V.A.R. model	Unidirectional causality from N.E.C. to CO_2; Unidirectional causality from CO_2 to R.E.C.
Apergis and Payne (2011a)	6 Central American countries (1980–2006)	Y; R.E.C.	Panel Error Correction Model	Feedback Hypothesis both in the short-run and long-run
Apergis and Payne (2011b)	16 Emerging markets (1990–2007)	Y; R.E.C.; N.R.E.C.	Panel Cointegration Models; Panel Error Correction Model	Unidirectional causality from Y to R.E.C. in the short-run and bidirectional causality in the long-run. Bidirectional causality between N.R.E.C. and Y, both in the short-run and long-run
Menegaki (2011)	27 European Countries (1997–2007)	Y; R.E.C.; G.G.E.; E	Multivariate Panel Model	Neutrality Hypothesis
Bildirici (2012)	10 Developing economies (1980–2009)	Y; B.E.C.	A.R.D.L.; Granger Causality	Cointegration relationship between the analysed variables for 8 of the 10 countries
Al-mulali, Fereidouni, Lee, and Sab (2013)	108 Countries (1980–2009)	R.E.C.; Y	F.M.O.L.S.; P.P.	79% of the countries, Feedback Hypothesis; 19% of the countries, Neutrality Hypothesis; 2% of the countries, Conservation and Growth Hypothesis
Bildirici and Ozaksoy (2013)	10 Countries (1960–2010)	Y; B.E.C.	A.R.D.L.; Granger Causality	Bidirectional causality for all analysed countries in the strong and long-run causalities
Bildirici (2014)	Transition countries (1990–2011)	Y; B.E.C.	P.A.R.D.L. model; Granger Causality	Bidirectional causality between the analysed variables, both in the short-run and long-run
Ocal and Aslan (2013)	Turkey (1990–2010)	R.E.C.; Y	A.R.D.L.; Toda Yamamoto	Conservation Hypothesis
Bildirici and Ersin (2015)	10 Countries (1970–2013)	B.E.C.; O.P.; Y	A.R.D.L.; Granger Causality; Toda and Yamamoto	Feedback and Conservation Hypotheses

Table 1. (*Continued*).

Öztürk and Bilgili (2015)	51 Sub-Saharan African Countries (1980–2009)	Y; B.E.C.	Panel Analysis	Unidirectional relation from B.E.C. to Y
Bilgili and Ozturk (2015)	G7 Countries (1980–2009)	Y; C.S.; H.C.; B.E.C.	Panel Models	Growth Hypothesis
Aslan (2016)	The USA (1961–2011)	Y; B.E.C; C.S.; H.C.	A.R.D.L.	Growth Hypothesis
Shahbaz, Rasool, Ahmed, and Mahalik (2016)	B.R.I.C.S. Region (1991–2015)	Y; B.E.C; C; T.O.	Panel Models	Feedback Hypothesis between B.E.C. and Y
Ali, Law, Yusop, and Chin (2016)	Sub-Saharan African Countries (1980–2011)	Y; B.E.C.; H.C.; C.S.	Dynamic Heterogeneous Panel Models; D.O.L.S.; F.M.O.L.S	B.E.C., H.C. and C.S. positively influences Y
Bildirici (2016)	Australia, Canada, Denmark, Finland, France, Japan, the UK and the US	Y; B.E.C.	A.R.D.L.; Granger Causality	In short-run causality, for Canada, France, the UK and the US, conservation hypothesis and for Australia, Belgium, Finland and Japan, the growth hypothesis. In Strong causality, bi-directional causality for the US, the UK and France

R.E.C., Renewable Energy Consumption; N.E.C., Nuclear Energy Consumption; CO_2, CO_2 Emissions; Y, Real G.D.P; O.P., Real Oil Price; E, Employment; B.E.C., Biomass Energy Consumption; N.R.E.C., Non-Renewable Energy Consumption; C.S., Capital Stock; H.C., Human Capital; C., Capital Use; T.O., Trade Openness; G.G.E., Green House Gas Emissions; E.C.M., Error Correction Model; A.R.D.L., Autoregressive Distribution Lag; P.A.R.D.L., Panel Autoregressive Distribution Lag; D.O.L.S., Dynamic O.L.S.; F.M.O.L.S., Fully Modified O.L.S.; PP., Phillips Perron.
Source: Authors.

consumption, openness and population, both significantly and positively in these African countries.

Bilgili and Ozturk (2015) determined the long-run dynamics of biomass energy consumption and G.D.P. growth through homogeneous and heterogeneous variance structures of the G7 countries for the 1980–2009 period by Panel unit root and Panel Cointegration analyses. The results confirmed the growth hypothesis in which biomass energy consumption has positive effects on the economic growth for the G7 countries.

Shahbaz, Rasool, Ahmed, and Mahalik (2016) studied the relationship between biomass energy consumption and economic growth for the B.R.I.C.S. (Brazil, Russia, India, China and South Africa) countries. The econometric results demonstrate that biomass energy consumption stimulates economic growth and the feedback hypothesis is supported for the relationship between biomass energy consumption and economic growth.

The results of Table 1 indicate that there is a bidirectional relationship between biomass energy and economic growth in 81.25% of the related studies. These findings confirm the importance of the relationship between biomass energy consumption and economic growth.

The papers in Table 1 used time series or panel data analysis methods. This paper is the first which uses two econometrical methods at the same time: the time series (A.R.D.L., Granger Causality) and Panel data analyses (Pedroni, Panel Granger and Panel Johansen tests) to test the relationship between economic growth and biomass energy consumption in the transition countries.

3. Data and econometric methodology

3.1. Data

In this paper, the relationship between biomass energy consumption and per capita G.D.P. was analysed by A.R.D.L. and Panel Cointegration approaches for some of the transition countries. The data of the 1981–2014 period could not be obtained for all of the analysed countries. For the countries whose data covers the period 1981–2014, the A.R.D.L. method was preferred and it was used for 35 years. However, the Panel method was used for the data of the 24 yearly and 20 yearly periods and two separate groups were comprised. Accordingly, Panel tests were applied to Bosnia and Herzegovina, Croatia, Czech Republic, Estonia, Hungary, Latvia, Macedonia, Slovak Republic and Slovenia. The countries of Group 1 are Bosnia and Herzegovina, Czech Republic, Hungary, Macedonia and Slovak Republic. Panel Cointegration analyses were applied to these countries during the 1991–2014 period. Group 2 consists of Croatia, Estonia, Latvia and Slovenia and the Panel Cointegration method was applied for the 1995–2014 period.

The data was taken from the Worldbank World Development Indicators. BC and Y show biomass energy consumption and per capita G.D.P., respectively. We used logarithmic transformation of the variables: bc is log (BC_t) and y is log (Y_t).

3.2. Methodology

Time series data and panel data methodologies, which were applied in this study, are as below.

3.2.1. A.R.D.L. methodology

The A.R.D.L. cointegration approach, which has numerous advantages over other cointegration methods, is commonly used in energy economics literature. First, the A.R.D.L. procedure can be applied if the regressors are I(1) and/or I(0), while the Johansen (1988), Johansen and Juselius (1990) cointegration techniques require that all variables in the system be in equal order of integration (Bildirici & Kayıkcı, 2012). The A.R.D.L. method does not need unit root pre-testing. Second, while the Johansen cointegration techniques require large samples for validity, the A.R.D.L. procedure is statistically more effective in determining the cointegration relationship in small samples. Third, the A.R.D.L. procedure allows the variables to have different optimal lags. Finally, the A.R.D.L. procedure employs only a single-reduced form of equation, while the other cointegration procedures estimate the long-run relationship within a context of system equations (Bildirici & Ersin, 2015; Narayan, 2005).

The A.R.D.L. approach to cointegration involves three steps for estimating the long-run relationship. The first step is to investigate the existence of a long-run relationship among all variables in the equation under estimation (Pesaran & Shin, 1999). In the A.R.D.L.-U.E.C.M. (Unrestricted Error Correction Model) method, the standard log-linear functional specification for the 'bc' variable is presented as:

$$\Delta bc_t = \alpha + \sum_{i=1}^{m} \beta \Delta bc_{t-i} + \sum_{j=0}^{n} \gamma \Delta y_{t-j} + \phi bc_{t-1} + \varphi y_{t-1} + \varepsilon_{1t} \tag{1}$$

where Δ and ε_{1t} are the first difference operator and the white noise term, respectively. The null hypothesis of no cointegration among the variables in equation (1) is H_0: $\phi = \varphi = 0$ against the alternative hypothesis H_1: $\phi \neq \varphi \neq 0$. If the calculated F-statistics are below the upper CV, we cannot reject the null hypothesis of no cointegration.

In the second step, if cointegration is established, the conditional A.R.D.L. long-run model for 'bc' can be estimated as:

$$bc_t = \lambda_0 + \sum_{i=1}^{m} \alpha_i bc_{t-i} + \sum_{i=0}^{n} \vartheta_i y_{t-i} + u_t \tag{2}$$

In the third stage, the short-run dynamic parameters are obtained by estimating an error correction model associated with the long-run estimates:

$$\Delta bc_t = \lambda_0 + \sum_{i=1}^{m} \alpha_i \Delta bc_{t-i} + \sum_{i=0}^{n} \vartheta_i \Delta y_{t-i} + \zeta ECM_{t-1} + e_t \tag{3}$$

where the residuals are independently and normally distributed with zero mean and constant variance and ECM_{t-1} is the error correction term. ζ is a parameter that indicates the speed of adjustment to the equilibrium level after a shock. It shows how quickly the variables converge to equilibrium and it must have a statistically significant coefficient with a negative sign.

3.2.2. Granger causality

The Vector Error Correction model should be a starting point for causality analysis (Lee & Chang, 2008; and Bildirici (2012, 2013)). The Vector Error Correction model was constructed as follows:

$$\Delta y_t = \alpha_0 + \sum_{i=1}^{m} \beta_i \Delta y_{t-i} + \sum_{j=1}^{n} \phi_i \Delta bc_{t-j} + \varsigma_1 ECM_{t-1} + e_{1t} \tag{4}$$

$$\Delta bc_t = \alpha_0 + \sum_{i=1}^{p} \vartheta_i \Delta bc_{t-i} + \sum_{j=1}^{q} \theta_i \Delta y_{t-j} + \varsigma_2 ECM_{t-1} + e_{2t} \tag{5}$$

where residuals e_t are independently and normally distributed with zero mean and constant variance and ECM_{t-1} is the error correction term resulting from the long-run equilibrium relationship. (1) Short-run or weak Granger causalities are detected by testing $H_0: \phi_i = 0$ and $H_0: \theta_i = 0$ for all i and j in equations (4) and (5). Long-run causalities are examined by testing $H_0: \varsigma_1 = 0$ and $H_0: \varsigma_2 = 0$. (3) Strong Granger causalities are detected by testing $H_0: \phi_i = \varsigma_1 = 0$ and $H_0: \phi_i = \varsigma_2 = 0$ for all i and j in equations (4) and (5).

3.3. Panel cointegration and Granger causality

3.3.1. Pedroni test

The Pedroni test is the most popular one in panel cointegration. Pedroni (1999, 2004) derived seven panel cointegration statistics. In its most general form, we will consider the following type of regression (Pedroni, 2004):

$$y_{it} = \alpha_i + \delta_i t + \beta_i X_{it} + e_{it} \tag{6}$$

for a time series panel of observations y_{it} and X_{it} for members $i = 1, ..., N$ over time periods $t = 1, ..., T$, where X_{it} is an m-dimensional column vector for each member i and β_i is an m-dimensional row vector for each member i. The variables y_{it} and X_{it} are assumed to be integrated of order one, denoted by $I(1)$, for each member i of the panel and, under the null hypothesis of no cointegration, the residual e_{it} will also be $I(1)$. The parameters α_i and δ_i allow for the possibility of member-specific fixed effects and deterministic trends, respectively. The slope coefficients β_i are also permitted to vary by individual country, so that, in general, the cointegrating vectors may be heterogeneous across members of the panel (Pedroni, 2004).

For the null hypothesis H0: 'all of the individuals of the panel are not cointegrated'. For the alternative hypothesis is simply H1: 'all of the individuals are cointegrated'. For the alternative hypothesis should be H1: 'a significant portion of the individuals are cointegrated' (Pedroni, 2004).

To test the null hypothesis of no cointegration, the following unit root test is conducted on the residuals as follows: $\varepsilon_{it} = \rho_i \varepsilon_{it-1} + u_{it}$. The first category of four statistics is defined as within-dimension-based statistics and includes a variance ratio statistic, a non-parametric Phillips and Perron type ρ statistic, a non-parametric Phillips and Perron type t-statistic and a DF type t-statistic. The second category of three panel cointegration statistics is defined as between-dimension-based statistics and is based on a group mean approach (Bildirici, 2004a, 2004b; Bildirici & Bohur, 2014). Pedroni's (2004) heterogeneous panel and

heterogeneous group mean panel cointegration statistics are then calculated. Both kinds of tests focus on the null hypothesis of no cointegration. The finite sample distribution for the seven statistics has been tabulated by Pedroni via Monte Carlo simulations (Bildirici & Kayıkci, 2012).

Asymptotic distributions of residual-based tests for the null hypothesis of no cointegration in heterogeneous panels are given in Pedroni (2004).

The calculated test statistics must be smaller than the tabulated critical value to reject the null hypothesis of the absence of cointegration.

3.3.2. Panel Johansen test

Following the Bildirici, Ersin, and Kokdener (2011) procedure, consider a V.A.R. (Vector Auto Regressive Models) model with Gaussian errors

$$X_t = \prod_1 X_{t-1} + \prod_2 X_{t-2} + ... + \prod_k X_{t-k} + D_t + \varepsilon_t, t = 1, ..., T \tag{7}$$

As shown by Johansen (1991), if the process is written in error correction form, the equation becomes

$$\Delta X_t = \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Pi X_{t-k} + \theta D_t + \mu + \varepsilon_t, t = 1, ..., T \tag{8}$$

where $\varepsilon_t (t = 1, ..., T)$ are independent p-dimensional Gaussian variables with mean zero and variance matrix Λ. D_t are defined as deterministic components which are seasonal dummies orthogonal to the constant term, $\Pi = -I + \sum_{i=1}^{k} \Pi_i$ and $\Gamma_i = - \sum_{j=i+1}^{k} \Pi_i$, where Γ_i, θ, μ and Λ are assumed to vary without restrictions. In order to show that $X_t \sim I(1)$ integrated to the order 1, the assumptions are:

(1) det $(A(z))$ = det $(I - \Pi_1 z - \Pi_1 z^2 - .... - \Pi_k z^k)$ are either outside the unit circle or equal to 1, which guarantees that the process is not explosive;
(2) the Π matrix has reduced rank, $r < p$, and can be presented as the product $\Pi = \alpha\beta'$; therefore, there are at least $p-r$ unit roots which leads to cointegration if $r \geq 1$ and
(3) the $\alpha'\Gamma\beta'$ matrix has full rank, where α' and β' are orthogonal complements to α and β, so that the process is restricted to the order of integration of 1.

If the model in equation (8) is denoted as H_1, then, by applying restrictions on Π, the hypothesis to test (at most) r cointegration vectors, produces $H_2:\Pi = \alpha\beta'$, where β and α are $p \times r$. matrices which denote the cointegrating vectors and adjustment coefficients, respectively (Bildirici et al., 2011; Johansen, 1991).

Extending the V.A.R. model in equation (8), for a panel dataset with N cross sections and T time periods, a panel V.A.R. is written as

$$X_{it} = \sum_{k=1}^{k_i} \Pi_{ik} X_{i,t-k} + \varepsilon_{it} \tag{9}$$

with $i = 1,2,...,N$ groups and $t = 1,2,...,T$ time periods and $j = 1,2,...,p$ variables, the errors are independently identically distributed $\varepsilon_{it} \sim N_p(0, \Omega_i)$. Error representation of the V.A.R. model following Engle and Granger (1987) and Johansen (1991) is

$$X_{it} = \Pi_i X_{i,t-1} + \sum_{k=1}^{k_{i-1}} \Gamma_{ik} \Delta X_{i,t-k} + \varepsilon_{it} \tag{10}$$

where Π_i is of order p × r. If Π_i has reduced rank, then extending the assumption i for panels, we obtain, $\boldsymbol{\Pi}_i = \alpha_i \beta_i'$ where α_i are the adjustment parameters and β' are the long-run parameters, respectively. α_i and β' are of order p × r_i and full column rank. The Cointegrating rank hypothesis is stated as $H(r){:}rank(\Pi) \leq r$ and tested against the alternative $H(r){:}rank(\Pi) = r$, where the likelihood ratio test, called the trace statistic is

$$-2InQ_T\big\{H(r) \mid H(p)\big\} = -T \sum_{i=r+1}^{p} In(1 + \hat{\lambda}_i) \tag{11}$$

where, $\hat{\lambda}_i$ trace statistic is the ith eigenvalue to a certain eigenvalue problem (Bildirici et al., 2011; Larsson & Lyhagen, 2007; Larrson, Lyhagen, & Lothgren, 2001).

3.3.3. F.M.O.L.S.

Pedroni proposed the Fully Modified Ordinary Least Squares (F.M.O.L.S.) estimator suggested by Phillips and Hansen (1990) for the heterogeneous panel. F.M.O.L.S. results produce consistent standard errors and t-statistics in the presence of endogenous regressors (Purna & Pravakar, 2007). We start with the Ordinary Least Squares (O.L.S.) regression in Pedroni (2004)

$$y_{it} = \alpha_i + \beta_i X_{it} + \mu_{it} \tag{12}$$

and these are cointegrated with slopes β_i. Let $\varepsilon_{it} = \hat{u}_{it}$, ΔX_{it} be a stationary vector including the estimated residuals and differences. Also, let

$$\Omega_{it} = \lim_{T \to \infty} E\left[T^{-1}\left(\sum_{t=1}^{T} \varepsilon_{iT} \right)\left(\sum_{t=1}^{T} \varepsilon_{iT} \right)' \right] \tag{13}$$

F.M.O.L.S. estimators are given as:

$$\phi = N^{-1} \sum_{i=1}^{N} \left(\sum_{i=1}^{T} (x_{it} - \bar{y}_i)^2 \right)^{-1} x \left(\sum_{i=1}^{T} (x_{it} - \bar{x}_i)^2 s_{it}^* - T\lambda_i \right) \tag{14}$$

where

$$y_{it}^* = (s_{it} - \bar{s}_i) - \frac{\hat{\Omega}_{21t}}{\hat{\Omega}_{22t}} \Delta x_{it*}$$

$$\hat{\lambda}_t = \hat{\Gamma}_{21t} + \hat{\Omega}_{21t} - \frac{\hat{\Omega}_{21t}}{\hat{\Omega}_{22t}}(\hat{\Gamma}_{22t} + \hat{\Omega}_{22t}) \tag{15}$$

The between-dimension estimator is $\phi_{GFM} = N^{-1} \sum_{i=1}^{N} \phi_{\kappa M,t}$, where $\phi_{\kappa M,t}$ is the F.M.O.L.S. estimator. The associated t-statistic for the between-dimension estimator is given as

$$t_{GFM} = N^{-1/2} \sum_{t=1}^{N} t\phi_{\kappa M,t}, \quad where$$

$$t\hat{\phi}_{\kappa M,t} = (\hat{\phi}_{\kappa M,i} - \phi_0)\left(\hat{\Omega}_{11t}^{-1} \sum_{t=1}^{T} (x_{it} - \bar{x}_i)^2 \right)^{1/2} \tag{16}$$

3.3.4. Panel Granger causality results

The Vector Error Correction (V.E.C.) model used to analyse the relationships between the variables was constructed. First a panel vector error correction model is estimated to perform Granger-causality tests (Bildirici & Bohur, 2014). The Engle and Granger (1987) two-step procedure is used afterwards, defining the lagged residuals as the error correction term and the following dynamic error correction models are estimated:

$$\Delta y_{it} = \lambda_{1j} + \sum_{k=1}^{m} \alpha_{ik} \Delta y_{it-k} + \sum_{k=1}^{n} \vartheta_{ik} \Delta X_{it-k} + \zeta_0 ECM_{it-1} + \varepsilon_{1it} \tag{17}$$

$$\Delta bc_{it} = \lambda_0 + \sum_{k=1}^{m} \alpha_{2ik} \Delta X_{t-k} + \sum_{k=1}^{n} \vartheta_{2ik} \Delta y_{it-k} + \zeta_1 ECM_{it-1} + \varepsilon_{2it} \tag{18}$$

where Δ is the first-difference operator; m is the lag length set at two based on likelihood ratio tests; and where the residuals ε_t are independently and normally distributed with zero mean and constant variance and ECM_{t-1} is the error correction term resulting from the long-run equilibrium relationship. ς is a parameter indicating the speed of adjustment to the equilibrium level after a shock. Short-run or weak Granger causalities are obtained by testing $H_0: \vartheta_{1ik} = 0$, in equation (17).

4. Econometric result

4.1. Time series results

The A.R.D.L. test was applied in four stages. First, the unit root test was applied. Second, bound test results were obtained. Third, long- and short-run results and E.C.M. results were obtained. Fourth, the Granger Causality test was practiced and the direction of causality was obtained.

4.1.1. Unit root test results

The unit root tests are used to determine if the variables are I(0) and/or I(1). The results of the A.D.F. (Augmented Dickey-Fuller) unit root tests are given in Table 2. The A.D.F. unit root tests conclude that the y and bc variables for the countries are stationary in the first differences.

4.1.2. A.R.D.L. results

According to the F-statistics, we have enough evidence to reject the null hypothesis of no cointegration at a 5% and 1% significance level for the relationship between biomass energy consumption and real per capita G.D.P. for Albania, Bulgaria and Romania.

This simply means that the computed F-statistics for these models are above the upper bound critical value. The results of the A.R.D.L. bounds tests for Albania, Bulgaria and Romania suggest evidence of the rejection of the null hypothesis. y is determined as a dependent variable for Bulgaria and Romania and bc is specified as a dependent variable for Albania in the Table 3.

Table 2. Unit root test result.

	Level	First diff.		Level	First diff.		Level	First diff.
Albania			*Croatia*			*Macedonia*		
y	−1.02	−4.32	y	1.36	−6.22	y	0.42	−4.99
bc	0.212	−6.81	bc	−0.14	−5.56	bc	0.19	−5.63
Bosnia and Herze-goniva			*Estonia*			*Slovak Republic*		
y	0.051	−4.32	y	0.724	−5.45	y	1.052	−4.96
bc	−0.77	−5.47	bc	−0.743	−3.86	bc	−1.52	−5.42
Bulgaria			*Hungary*			*Slovenia*		
y	1.11	−3.83	y	−0.24	−3.57	y	−0.86	−5.75
bc	−0.02	−4.32	bc	−1.17	−5.57	bc	−1.11	−6.85
Czech Republic			*Latvia*			*Romania*		
y	−2.33	−3.74	y	−0.15	−5.56	y	0.86	−6.42
bc	−1.13	−5.37	bc	−0.355	−6.32	bc	−1.02	−7.52

Critical Value for 1990–2014 period: −3.831,511 for 1% level; −3.029,970 for 5% level; −2.655,194 for 10% level and for 1980–2014 period: −3.639,407 for 1% level; −2.951,125 for 5% level; −2.614,300 for 10% level.
Source: Authors.

Table 3. Bounds testing for cointegration.

	$F_y(y|bc)$	$F_{bc}(bc|y)$
Albania	1.0523	18.7500*
Bulgaria	6.4850*	1.4365
Romania	5.8799*	0.0845

* Statistically significant.
The critical value for the *F*-test is 5.73 for 5% level and 4.78 for 10% level. The critical values of *F*-test are obtained from Pesaran, Shin, and Smith (2001).
Source: Authors.

Table 4. Long-run coefficients for A.R.D.L.

	c	bc	y	R^2 (LM)
Albania	1.6115 (2.52)	—	−0.2254 (−2.9265)	0.810
Bulgaria	0.9056 (0.7637)	0.6027 (1.7647)	—	0.702
Romania	0.5643 (1.8988)	0.4687 (1.9560)	—	0.803

t-values are given in parentheses.
The critical value for the *F*-test is 5.73 for 5% level and 4.78 for 10% level. The critical values of *F*-test are obtained from Pesaran et al. (2001).
Source: Authors.

4.1.3. Long-run and E.C.M. results

Table 4 reveals the arguments for valid long-run relationships among the variables. It is possible to forecast the long- and short-run dynamic effects by using the A.R.D.L. approach. Table 4 shows the long-run elasticity for the A.R.D.L. model. The elasticities are interpreted as usual: for instance, a 1% increase in per capita income, when other things are equal, leads to a −0.2254% decrease in the consumption of biomass energy for Albania. According to this result, biomass energy consumption can be interpreted as 'inferior good'. Bildirici and Ozaksoy (2014) indicated biomass energy consumption as 'normal good' for Hungary, Slovenia, Slovakia and Croatia, respectively. Additionally, a 1% increase in biomass energy consumption caused 0.6027% and 0.4687% growth in per capita income for Bulgaria and Romania, respectively.

The E.C.M.s in Table 5 indicate that there is a mechanism to correct the disequilibrium between economic growth and biomass energy consumption. The coefficient of the error correction term must change between −0.232 and −0.5073. The error correction term was

Table 5. E.C.M. and short-run results.

	E.C.M.	dbc	dY	R^2 (LM)
Albania	−0.232 (−1.954)	—	−0.035 (−4.721)	0.651
Bulgaria	−0.507 (−1.878)	1.274 (1.878)	—	0.694
Romania	−0.379 (−1.901)	−1.003 (−2.634)	—	0.705

Source: Authors.

negative and statistically significant, showing a speed of adjustment of any disequilibrium towards a long-run equilibrium state, which is −0.232 for Albania, −0.3785 for Romania and −0.5073 for Bulgaria. Thus, for Bulgaria, the relationship between the variables will be approximately turned to equilibrium in 2 years.

4.1.4. Results for the Granger causality test

The A.R.D.L. methods do not indicate the direction of causality, but, since there is a long-run relationship between biomass energy consumption and economic growth, a causality relationship must exist in at least one direction. Therefore, we used the augmented Granger causality test by incorporating the error correction term. Table 6 summarises the causal relationship between biomass energy consumption and economic growth.

Table 6 exhibits the results determined by short-run, long-run and strong Granger causality for selected countries. According to the short-run causality results, the evidence was accepted to reject the null hypothesis for a one-direction causal relationship between variables for Albania, Bulgaria and Romania. For Albania, Bulgaria and Romania, the calculated Chi-square statistics are above the critical value with 2 degrees of freedom suggesting the rejection of the null hypothesis of no Granger causality between biomass consumption and economic growth at 5% significance level. It was found that there is evidence of uni-directional causality from economic growth to biomass energy consumption for Albania.

Similarly, the results obtained for Bulgaria and Romania suggest evidence of uni-directional causality from biomass energy consumption to economic growth at a 5% significance level. There is evidence of uni-directional causality from biomass energy consumption to economic growth for Bulgaria and Romania. Thus, the test results of this paper support the conservation hypothesis for Albania and the growth hypothesis for Bulgaria and Romania. The conservation hypothesis postulates that biomass energy consumption is driven by economic growth. According to the growth hypothesis, energy conservation policies may decrease economic growth performance. The long-run and strong Granger causality tests combined the variables and error correction terms to enhance the evidence in the Granger

Table 6. Granger causality.

	df	Short-run causality	Long-run causality	Strong causality
		Δy→Δbc Δbc →Δy	ECT→ Δy ECT→ Δbc	Δy, ECT →Δbc Δbc, ECT→Δy
Albania	2	11.892*** 1.0536	7.9856** 0.8561	10.8596*** 8.4687**
Bulgaria	2	1.0030 7.7760**	9.4560** 1.3380	11.6350*** 9.5560**
Romania	2	1.4051 8.5016**	8.7460** 1.0020	8.7450** 8.6980**

Note: Values in parentheses are *t*-values. Significance levels: * $p < 0.05$; ** $p < 0.01$; and *** $p < 0.001$.
For the co-joint test, we used the Wald-test (χ^2).
In this table, the symbol → shows the direction of causality.
Source: Authors.

Table 7. Panel unit root test.

	Group 1	Group 2		Group 1	Group 2		
	Levin, Lin and Chu *t**			Im, Pesaran and Shin W-stat			
	Level	First Diff.	Level	First Diff.	Level	First Diff.	Level	First Diff.
y	−1.490	−5.500	−1.256	−4.758	−2.204	−5.781	−0.856	−5.896
bec	0.632	−3.578	3.245	−3.156	−0.662	−3.986	2.875	−3.985

Source: Authors.

causality test. The long-run and strong causality results determined the calculated Chi-square statistics are above the critical value with 2 degrees of freedom suggesting the rejection of the null hypothesis of no Granger causality between biomass consumption and economic growth at the 5% significance level. According to the long-run causality results, evidence was found to reject the null hypothesis for uni-directional causality between biomass energy consumption and economic growth in Albania, Bulgaria and Romania and there was evidence of the growth hypothesis for all countries. The results of strong Granger causality determined that, in Albania, Bulgaria and Romania, there was evidence to reject the null hypothesis for bidirectional causality between biomass energy consumption and economic growth. Strong causality results determined the feedback hypothesis. According to the feedback hypothesis, an energy policy focused on diminishing biomass energy consumption negatively affects the countries' economic growth.

4.2. Panel data analysis

Panel analysis results were obtained in four stages. In the first stage, the Panel unit root test was applied. In the second stage, the results of the Pedroni Panel Cointegration test and Panel Johansen Cointegration test were used. In the third stage, F.M.O.L.S. test results were obtained and, in the last stage, Panel Granger Causality test results were acquired.

4.2.1. Panel unit root test results

In this regard, Levin, Lin and Chu (L.L.C.) and Im, Pesaran and Shin (I.P.S.) unit root tests were examined in Table 7. The null hypothesis of unit root test cannot be rejected for the variables in levels. The unit root test is implemented in the first differences of the variables and the null hypothesis is rejected, implying that the levels are non-stationary and the first differences are stationary.

4.2.2. Pedroni cointegration results

Table 8a reports Pedroni test results for Groups 1 and 2. These statistics are based on averages of the individual autoregressive coefficients associated with the unit root tests of the residuals for each of the countries in the panel. All seven panel cointegration tests reject the null hypothesis of no cointegration. Thus, the evidence suggests that, in both panel datasets, there is a long-run equilibrium relationship between biomass energy consumption and economic growth.

For Groups 1 and 2, Table 8b exhibits the Johansen test results. The Johansen cointegration test results with 18.91 and 21.17 trace statistics and 17.66 C.V., which are significant

Table 8a. Pedroni panel cointegration test.

Group 1: Pedroni cointegration test results			
Within-dimension test statistics:		Between-dimension test statistics:	
Panel v-statistic	9.611	Group ρ-statistic	−6.735
Panel ρ-statistic	−6.073	Group P.P.-statistic	−6.265
Panel P.P.-statistic	−6.985	Group A.D.F.-statistic	−8.418
Panel A.D.F.-statistic	−9.140		
Group 2. Pedroni cointegration test results			
Within-dimension test statistics:		Between-dimension Test statistics:	
Panel v-statistic	9.390	Group ρ-statistic	−5.790
Panel ρ-statistic	−5.811	Group P.P.-statistic	−5.507
Panel P.P.-statistic	−5.415	Group A.D.F.-statistic	−6.495
Panel A.D.F.-statistic	−6.427		

Source: Authors.

Table 8b. Panel Johansen test results and individual cross-section results.

Group 1: Panel Johansen test results				
	Trace statistics	CV		
$r = 0$	28.910*	17.660		
$r < 1$	9.113	9.183		

Individual cross-section results

	Trace test		Max-Eign test	
Cross-section	Statistics	Prob.**	Statistics	Prob.**
Hypothesis of no cointegration				
Bosnia and Herzegovia	26.3925*	0.00	24.8718	0.00
Czech Republic	28.5896*	0.00	26.2559	0.00
Hungary	27.7139*	0.00	19.7097	0.00
Macedonia	21.0496*	0.00	19.8361	0.00
Slovak Republic	21.0481*	0.00	19.0135	0.00
Hypothesis of at most 1 cointegration relationship				
Bosnia and Herzegovia	1.5207	0.2551	1.5207	0.2551
Czech Republic	2.3337	0.1494	2.3337	0.1494
Hungary	0.0041	0.9581	0.0041	0.9581
Macedonia	1.2135	0.3157	1.2135	0.3157
Slovak Republic	0.0346	0.8790	0.0346	0.8790

Group 2: Panel Johansen test results				
	Trace statistics	CV		
$r = 0$	28.170*	17.660		
$r < 1$	8.986	9.183		

Individual cross-section results

	Trace test		Max-Eign test	
Cross-section	Statistics	Prob.**	Statistics	Prob.**
Hypothesis of no cointegration				
Croatia	26.8759*	0.00	17.4696	0.00
Estonia	26.5911*	0.00	17.2346	0.00
Latvia	22.2210*	0.00	21.8368	0.00
Slovenia	40.0522*	0.00	38.3709	0.0000
Hypothesis of at most 1 cointegration relationship				
Croatia	0.4063	0.5872	0.4063	0.5872
Estonia	0.3566	0.6133	0.3566	0.6133
Latvia	0.3843	0.5985	0.3843	0.5985
Slovenia	1.6813	0.2288	1.6813	0.2288

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level; * statistically significant; ** MacKinnon, Haug, and Michelis (1999) p-values; Probabilities are computed using asymptotic Chi-square distribution.
Source: Authors.

at the 1% level, support the cointegration relationships of economic growth and biomass consumption found in the Johansen test.

Pedroni results verify the cointegration relationship between the analysed variables. On the other hand, Table 8b shows the individual cross-section results in Groups 1 and 2. Thus, the evidence suggests that, in both panel datasets and in the individual cross-sections, there is a long-run equilibrium relationship between biomass energy consumption and economic growth.

For Group 2, Table 8b shows individual cross-section results for the panel Johansen test. Thus, the evidence suggests that, in both panel datasets and in individual cross-sections, there is a long-run equilibrium relationship between biomass energy consumption and economic growth.

4.2.3. F.M.O.L.S. estimates

F.M.O.L.S. results indicate the existence of a strong relationship between economic growth and biomass energy consumption in Table 9. Accordingly, a 1% increase in the G.D.P. enhances biomass energy consumption by 1.013% in Group 1, but 0.75698% for Group 2. In this regard, biomass consumption should be explicated as normal goods.

4.2.4. Panel Granger causality test

Table 10 shows the results of error correction estimates, the short-run and long-run results and Granger causality for the analysed panels denoted as Groups 1 and 2. For group 2 countries and Bulgaria, E.C.M. results show that the system turns back to its long-run equilibrium in ~ 2 years after an economic shock, similarly with A.R.D.L. result for Bulgaria (−0.5073), which is shown in Table 5. E.C.T. is −0.441 in Group 1 and −0.504 in Group 2 and speed of adjustment is high, so, after a shock, the system turns back to its long-run equilibrium level in ~ 2 years.

Table 9. F.M.O.L.S. results.

F.M.O.L.S. results		
c (t-stat)	y (t-stat)	R^2
Group 1		
−0.5808 (−4.096)	1.0130 (3.010)	0.701
Group 2		
0.8965 (1.869)	0.7570 (2.259)	0.785

Source: Authors.

Table 10. Results of Granger causality.

Group 1			
	Short-run causality	Long-run causality	Strong causality
E.C.M. (t-stat.)	$\Delta bc \rightarrow \Delta y$	E.C.M. $\rightarrow \Delta bc$	Δbc, E.C.M. $\rightarrow \Delta y$
	$\Delta y \rightarrow \Delta bc$	E.C.M. $\rightarrow \Delta y$	Δy, E.C.M. $\rightarrow \Delta bc$
−0.441 (−4.002)	0.7869	8.7580**	4.0123***
	8.9865**	1.0190	9.8569***
Group 2			
−0.504 (−2.896)	6.7035**	1.1110	8.9680**
	1.0246	8.6640**	10.5260***

Note: The values in parentheses are *t*-values. Significance levels: * $p < 0.05$; ** $p < 0.01$; and *** $p < 0.001$.
For the co-joint test, we used the Wald-test (χ^2). In this table, the symbol $\rightarrow$ shows the direction of causality.
Source: Authors.

For Groups 1 and 2, the calculated Chi-square statistics are above the critical value with 2 degrees of freedom, suggesting a rejection of the null hypothesis of no Granger causality between biomass consumption and economic growth at 5% significance level. It was determined from the evidence to reject the null hypothesis for the one-direction causal relationship between variables for Groups 1 and 2. In Group 2, there is unidirectional causality from biomass consumption to economic growth as a result of the short- and long-run Granger causality supporting the growth hypothesis. The results of the growth hypothesis are similar to the results obtained for Bulgaria and Romania by Granger Causality method. However, in strong causality, there is evidence to reject the null hypothesis for bidirectional causality between biomass consumption and economic growth. In Group 1, there is unidirectional causality from economic growth to biomass consumption as a result of short- and long-run Granger causality, supporting the conservation hypothesis. Similarly, in strong causality there is evidence to reject the null hypothesis for bidirectional causality between biomass consumption and economic growth.

Strong Granger causality results in Groups 1 and 2 show the importance of biomass energy consumption for the two groups. Energy conservation policies may decrease economic growth performance and the changes in economic growth may decrease energy consumption. An energy policy focused on diminishing biomass energy consumption negatively affects the countries' economic growth. F.M.O.L.S. results denote biomass energy as normal good in Group 2. The A.R.D.L. results support the feedback hypothesis in the context of strong causality results. These findings are supported by Bildirici and Ozaksoy's (2014) results for Hungary, Bulgaria, Romania, Slovenia, Croatia and Slovakia.

5. Conclusion

This paper focuses on investigation of the relationship between biomass energy consumption and economic growth, which was tested by time series (A.R.D.L. and Granger Causality) and Panel methods (Panel Cointegration: Pedroni-Panel Johansen test and Panel Granger models). A.R.D.L. and Granger Causality methods were applied for Albania, Romania and Bulgaria. The short-run causality results indicate evidence of uni-directional causality from economic growth to biomass energy consumption for Albania. However, for Bulgaria and Romania, the causality results show evidence of uni-directional causality from biomass energy consumption to economic growth, which promotes the growth hypothesis. The feedback hypothesis is found in strong causality results for all of the analysed countries.

A second method was applied to Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Macedonia, Romania, Slovak Republic and Slovenia. According to Panel Granger causality test results, both in the short-run and long-run, there is evidence of uni-directional causality from economic growth to biomass energy consumption in Bosnia and Herzegovina, Czech Republic, Hungary, Macedonia and Slovak Republic. These findings support the conservation hypothesis for these countries. Short-run and long-run causality test results prove uni-directional causality from biomass energy consumption to economic growth, which supports the growth hypothesis not only for Croatia, Slovenia, Estonia and Latvia, but also for Bulgaria and Romania. However, strong causality test results signal bidirectional causality between biomass energy consumption and economic growth, which emphasises the feedback hypothesis in all these countries.

Regarding our empirical results, for the analysed countries, development of the biomass energy infrastructure and encouragement of biomass energy consumption are important energy policy tools as they promote economic growth, while also being affected by it. In this context, biomass energy consumption should be enhanced for these countries. Biomass energy consumption has direct and indirect effects on economic growth. If energy needs are obtained from biomass energy resources, energy dependence on fossil fuels from exporter countries will decrease. On the one hand, modern biomass energy is a way of decreasing foreign oil dependency while, on the other hand, modern biomass energy can benefit rural employment.

As a result, transition countries must encourage biomass energy consumption to enable sustainable economic growth and development. Furthermore, environmental protection necessarily meets part of a country's needs, promotes energy security and reduces poverty.

Disclosure statement

No potential conflict of interest was reported by the authors.

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