Biomass energy consumption and economic growth nexus in OECD countries: a panel analysis

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Highlights

- Investigation of relationship between biomass consumption and economic growth
- Focus on 26 OECD countries for 1980 to 2013
- Feedback hypothesis is confirmed
- Policy suggestion: promotion of biomass will enhance economic growth

Abstract

This paper investigates the relationship between biomass energy consumption and economic growth for 26 OECD countries for 1980 to 2013 period. This study used panel unit root analyses, panel cointegration analyses, dynamic OLS analyses, fully modified OLS analyses and panel VECM Granger causality to examine the relationship. The results reveal the presence of long-run equilibrium relationship between the variables supporting the feedback hypothesis. As policy implication, OECD countries have to improve the biomass energy infrastructure as an important source of renewable energy to promote economic growth.

Keywords: OECD; Biomass energy; economic growth; Dynamic OLS; Fully Modified OLS

JEL Classifications: C51, Q43, Q47.

Introduction

Depending on the World Meteorological Organization (WMO) greenhouse gas bulletin October 2017, the rise of atmospheric carbon dioxide (CO2) during the last 70 years is about 100 times. The record augmentation in CO2 emission from 2015 to 2016 was more important than augmentation observed from 2012 to 2013 with 3.3 ppm. This increase of CO2 emissions has concentrated interest in renewable energy to protect the environment to ease the impact of climate change. Thus, renewable energy, particularly biomass is considered as a new source of non-intermittent renewable energy for sustainable development in the world.

This paper analyses the relationship between biomass energy consumption and economic growth in 26 OECD countries. OECD countries consider biofuels principally as a device of reducing greenhouse gases, meeting clean air policies, stimulating rural development, creating jobs, reducing foreign oil dependence and saving foreign exchange. Biomass energy in OECD includes many sources as: wood wastes from forestry and industry; food and paper industries; residues from agricultural; animal manure and dedicated energy crops. For example, Finland has significant expertise with co-firing biomass with waste and fossil fuels. The OECD has about 1,544 Mha of forest, crop and woodland, of which about 460 Mha are cropland. The IEA reference scenario of the estimated biomass energy potential contribution for OECD economic growth is about 2 % as an annual average-for 2020 compared 3.1 % for the world. Also, the IEA projections for OECD report an expansion from 1.3% to some 3%-5% by 2050 for the biomass proportion in electricity production (IEA, 2006).

In recent years, the causal relationship between economic growth and Biomass energy consumption was examined in some countries and regions. However, no study related with the OECD countries that investigates relationship between biomass consumption and economic growth. This study, therefore, intends to fill the gap by examining the relationship biomass energy consumption and economic growth for 26 OECD countries by resorting to the long-run relationship using Dynamic Ordinary Least Squares (DOLS) and Fully Modified Ordinary Least Squares (FMOLS) techniques. The short-run dynamics are captured appropriately in order to capture the long-run cointegrating relationship among variables. Also, we perform the Granger causality test to focus on the causal relationship between biomass energy consumption and economic growth. Using annual data of per capita GDP and biomass energy consumption for OECD countries, we show evidence of significant long run bidirectional causality relationship between biomass energy consumption and economic growth supporting the feedback hypothesis.

The remainder of the article is organized as follows. Section 2 briefly reviews the related literature on the relationship between biomass energy consumption and economic growth. Section 3 presents the econometric methodology and data. Section 4 reports our main empirical results. Conclusion and policy implications of our findings are discussed in Section 5.

Literature review

The causality relationship between renewable energy consumption and economic growth has been investigated in many studies during last decade. However, works that explore the relationship between biomass energy consumption and economic growth are scare. Energy literature has a few numbers of studies which examines the relationship between biomass energy consumption and economic growth as shown in table 1. Results provide four types of hypothesis: (i) the neutrality hypothesis is supported if no causality relationship between economic growth and biomass energy. The meaning of the neutrality hypothesis is that biomass energy consumption does not affect economic growth (ii) the conservation hypothesis sustained unidirectional causality running from economic growth to biomass energy consumption meaning that the economic growth is the dynamic which causes the consumption of the biomass energy (iii) the feedback hypothesis sustained bidirectional relationship between economic growth and biomass energy consumption (iv) the growth hypothesis sustained unidirectional causality relationship from biomass energy consumption to economic growth. It means that biomass energy consumption plays a vital role in the economic growth process.

Payne (2011) analyzed the linkage between the biomass energy and growth for the United States using the Toda-Yamamoto causality test. He found a unidirectional causality running from biomass energy consumption to economic growth. However, Bildirici (2013) investigated the long run relationship between Biomass energy consumption and GDP for 10 developing and emerging countries using an ARDL and vector error-correction models. The empirical results revealed the presence of long-run dynamic relationship biomass energy consumption and economic growth for all countries excepting Paraguay. In addition, biomass energy consumption Granger causes economic growth found in Argentina, Bolivia, Cuba, Costa Rica, Jamaica, Nicaragua, Panama and Peru, and economic growth Granger causes biomass energy consumption in El Salvador.

Also, Bildirici and Özaksoy (2013) examined the relationship between biomass energy consumption and economic growth in 10 European countries (Austria, Finland, France, Hungary, Poland, Portugal, Romania, Spain, Sweden and Turkey) using an ARDL model over the period of 1960– 2010. The long-run estimates showed the existence of relationship for all countries. On the other hand, unidirectional causality is found from economic growth to biomass energy consumption for Austria and Turkey and unidirectional causality from biomass energy consumption to economic growth for Hungary and Poland. Also, a bidirectional causality is found for Spain, Sweden, and France. Ozturk and Bilgili (2015) used a dynamic panel analyses for 51 Sub-Sahara African countries. They find significant effect of biomass consumption on economic growth.

The study of Ozturk and Bilgili (2015) investigated the biomass energy-growth nexus in G7 countries by applying OLS and DOLS approaches. The empirical findings indicated that the unidirectional causality exists running from biomass energy consumption to economic growth. Bildirici and Ozaksoy (2016) employ ARDL framework to find a unidirectional causality running from Biomass energy consumption to GDP for Angola, Guinea-Bissau and Nigeria, from GDP to Biomass energy consumption for Seychelles. Also, they find a bidirectional causality relationship for Benin, Mauritania, Nigeria and South Africa. Shahbaz, Ghulam, Khalid, and Mantu (2016) find support for long-run equilibrium relationship between biomass energy consumption and economic growth for the case of BRICS countries.

Recently, Bildirici and Ozaksoy (2017) investigated the link between wood biomass energy consumption and real per capita GDP for some selected African countries using linear and nonlinear ARDL model. The empirical findings indicated that the unidirectional causality existed running from economic growth to woody biomass energy consumption for Botswana, Cameroon, Uganda, and Zambia and from woody biomass energy consumption to economic growth for Burkina Faso, Malawi, Central African Republic, Namibia, Côte d'Ivoire, Djibouti, Gabon and Zimbabwe. However, the bidirectional causality was supported for Kenya, Lesotho, Madagascar and Togo

From the literature survey, we notice that studies exploring the relationship between biomass energy consumption and economic growth are relatively scarce (see Table 1). In addition, no study has been focused on OCED countries to establish the Biomass energy consumption – economic growth nexus. In the same line, our work intends to fill this gap in the literature.

Table 1: Literature survey on Biomass consumption and economic growth relationships.

Study	Period	Country	Methodology	Main results
Payne (2011)	1949-2007	USA	Todo-Yamamoto causality test	Biomass → GDP
Bildirici (2012)	1980-2009	7 Latin America countries.	ARDL model	GDP → biomass for Colombia. Biomass → GDP for Bolivia, Brazil and Chile. ↔ for Guatemala. LR ↔ for all countries.
Bildirici (2013)	1980-2009	10 developing and emerging countries.	ARDL model	Biomass → GDP for Argentina, Bolivia, Cuba, Costa Rica, Jamaica, Nicaragua, Panama and Peru. GDP → Biomass for El Salvador. LR ↔ for Argentina, Bolivia, Cuba, Costa Rica, El Salvador, Jamaica, Nicaragua, Panama and Peru.
Bildirici and Ozaksoy (2013)	1960-2010	10 European countries.	ARDL model	GDP → biomass for Austria and Turkey. Biomass → GDP for Hungary and Poland. ↔for Spain, Sweden and France. LR ↔ for all the countries.
Bildirici (2014)	1990-2011	Transition countries.	- Panel ARDL - Cointegration analysis -FMOLS method	Biomass → GDP
Bildirici and Ersin (2015)	1970-2013	10 countries	- ARDL model - Granger causality - Toda and Yamamato causality test	GDP → biomass for Austria, Germany, Finland and Portugal. ↔ for the US.
Öztürk and Bilgili (2015)	1980-2009	51 Sub-Sahara African countries	OLS and DOLS	Biomass → GDP
Bilgili and Öztürk (2015)	1980-2009	G7 countries	OLS and DOLS	Biomass → GDP
Bildirici and Ozaksoy (2016)	1980-2013	Sub-Saharan African countries	ARDL model	Woody Biomass → GDP for Angola, Guinea-Bissau and Niger. GDP → woody biomass for Seychelles. ↔ for Benin, Mauritania, Nigeria and South Africa.
Shahbaz et al. (2016)	1991Q1–2015Q4	BRICS countries	Panel analysis	biomass ↔ GDP
Bildirici and Ozaksoy (2017)	1980-2012	Selected African countries	ARDL and NARDL models	GDP → woody biomass for Botswana, Cameroon, Uganda and Zambia. Woody Biomass → GDP for Burkina Faso, Malawi, Central African Republic, Namibia, Côte d'Ivoire, Djibouti, Gabon and Zimbabwe. ↔ for Kenya, Lesotho, Madagascar and Togo.

Note: → indicates unidirectional causality, ↔ indicates bidirectional causality and LR indicates long-run relationship.

Model specification and data

The objective of this study is to investigate the effect of biomass energy consumption, capital use and trade openness on economic growth (GDP) for 26 OECD countries (see Appendix A) for the period 1980-2013. In modelling the relationship between GDP and biomass, Ozturk and Bilgili (2015) used population and openness while Bilgili and Ozturk (2015) used capital and labor and Shahbaz et al. (2016) used capital and openness as control variables. Our empirical model is in the same line of previous studies and be written as follows:

$GDP_{it} = f(biomass_{it}, K_{it}, O_{it})$

Where GDP_{it} is per capita gross domestic product, $biomass_{it}$ is biomass energy consumption, K_{it} is the capitalization measured by capital use and O_{it} is for trade openness and measured real trade (imports + exports). The variables are converted into per capita units by dividing series by total population series. The log linear form of the model is given by:

$$\ln GDP_{it} = \alpha_0 + \alpha_1 lnBiomass_{it} + \alpha_1 lnK_{it} + \alpha_1 lnO_{it} + \varepsilon_{it}$$

The data are obtained from the World Development Indicators for all variables excepting the data for Biomass which is extracted from Global Material Flow Data base[1].

Methodology

Our econometric analysis employs (i) panel unit root tests (ii) panel cointegration tests (iii) panel Dynamic OLS and Fully modified OLS and (iv) panel Granger causality test.

Panel unit root tests

We start with the panel unit root tests to identify the order of integration of each variable. Therefore, two kinds of panel unit root tests are conducted: the Maddala and Wu (1999) based on Fisher (1932) and the Im, Pesaran, and Shin (2003) which allow for individual unit root processes for each cross-section units.

[1] www.materialflows.net

Based on combining the p-value of the test statistic for a unit root in each cross-sectional unit, the Maddala and Wu's test (ADF-Fisher) is nonparametric and has Chi-square distribution.

Following Maddala and Wu (1999) proposed a Fisher type test:

$$P = -2\sum_{i=1}^{N} \log(pi) \qquad (1)$$

Where pi denotes the p-value from the ADF unit root test. P is distributed as χ 2 with 2N degrees of freedom. The null hypothesis of existing panel unit root will be rejected when pi closes to 0. However, null hypothesis is not rejected when pi closes to 1.

The Im, Pesaran, and Shin (2003) test is characterized by the combining of individual unit root tests to derive a panel-specific result. The Im, Pesaran, and Shin (2003) test start by specifying a separate ADF regression for each cross section:

$$\Delta y_{it} = \alpha_i + \rho_i \Delta y_{it-1} + \sum_{j=1}^{p_i} \beta_{ij} \Delta y_{it-j} + \varepsilon_{it} \qquad (2)$$

The null hypothesis is $H_0 : \rho_i = 0$ for all i against the alternative hypothesis $H_1 : \rho_i < 0$ for each individual i. The test is based on the test statistic:

$$t_{\rho_i} = \hat{\rho}_i / \sigma(\hat{\rho}_i)$$

Where $\hat{\rho}_i$ is the OLS estimate of ρ_i in equation (2) and $\sigma(\hat{\rho}_i)$ is its standard error.

Panel cointegration tests

As each variable presents a panel unit root, the next step is to test for panel cointegration to examine the long-run equilibrium between economic growth and biomass energy consumption. Two panel cointegration tests were applied, namely Kao (1999) and Pedroni (1999, 2004).

Pedroni panel cointegration tests:

Pedroni (1999, 2004) proposed two types of cointegration tests: (i) the panel tests based on the within dimension method which include four statistics (panel-v, panel-ϱ, panel-ϱϱ and panel-ADF) (ii) the group tests based on the between dimension method which include three statistics (group rho-statistic, group PP-statistic and group ADF- statistic). These seven statistics are asymptotically distributed as normal.

The formula of the Pedroni panel cointegration test can be expressed as:

$$y_{it} = \alpha_i + \delta_i t + \sum_{j=1}^{m} \beta_{ji} X_{j,it} + \varepsilon_{it} \qquad t = 1, \dots, T,\ i = 1, \dots, N \tag{3}$$

where T represents the number of observations over time, N denotes the number of individual units, m is the number of regression variables and, y_{it} and β_{ji} are integrated on the order one.

The null hypothesis of no cointegration is H_0: $\rho_i = 0, \forall i$. The alternative hypothesis is given by H_0: $\rho_i = \rho < 1, \forall i$ where ρ_i can be given by the following equation:

$$\hat{\varepsilon}_{i,t} = \rho_i \hat{\varepsilon}_{i,t-1} + \mu_{i,t} \tag{4}$$

All these seven statistics have a standard asymptotic distribution.

Kao panel cointegration test

Kao (1999) presented an Augmented Dickey-Fuller panel cointegration test in which the null hypothesis indicates the absence of panel cointegration.

In the bivariate case Kao consider the following model:

$$y_{i,t} = \alpha_i + \beta x_{i,t} + \varepsilon_{i,t}, \qquad i = 1, \dots, N,\ t = 1, \dots, T \tag{5}$$

where $y_{i,t} = y_{i,t-1} + u_{i,t}$ and $x_{i,t} = x_{i,t-1} + e_{i,t}$

where α_i are the fixed effect varying across the cross-section observations, β is the slope parameter, y_{it} and x_{it} are independent random walks for all *i*.

The ADF test is applied to the estimated residual:

$$\hat{\varepsilon}_{i,t} = \rho \hat{\varepsilon}_{i,t-1} + \sum_{j=1}^{p} \delta_i \Delta\, \hat{\varepsilon}_{i,t-j} + v_{i,tp} \tag{6}$$

Where ρ is chosen so that the residual $v_{i,tp}$ are not correlated under the null hypothesis of the absence of cointegration. The ADF test statistic can be given by,

$$ADF = \frac{t_{ADF} + (\sqrt{6N}\hat{\sigma}_v/\hat{\sigma}_{0v})}{\sqrt{(\hat{\sigma}_{0v}^2/2\hat{\sigma}_v^2) + (3\hat{\sigma}_v^2/10\hat{\sigma}_{0v}^2)}} \quad \rightarrow \quad N(0,1) \qquad (7)$$

where t_{ADF} is the t-statistic in the ADF regression, and the estimated variance is $\hat{\sigma}_v^2 = \hat{\sigma}_u^2 - \hat{\sigma}_{ue}^2 \hat{\sigma}_e^{-2}$ with estimated long run variance $\hat{\sigma}_{0v}^2 = \hat{\sigma}_{0u}^2 - \hat{\sigma}_{0ue}^2 \hat{\sigma}_{0e}^{-2}$.

Panel FMOLS and DOLS estimates

When the cointegration relationship between variables is found, the next step is to estimate the long-run parameters. However, classical OLS estimation in presence of cointegration leads to spurious parameters. As alternative methods, the panel Dynamic OLS (DOLS) and Fully modified OLS (FMOLS) methods proposed by Kao and Chiang (2000) and Pedroni (2001), respectively. These estimators provided the between-dimension "group mean" and allow for more flexibility in the presence of heterogeneity of the cointegrating vectors.

Consider the following cointegrated simple panel regression model:

$$y_{i,t} = \alpha_i + \beta_i x_{i,t} + \varepsilon_{i,t} \qquad (8)$$

$$x_{i,t} = x_{i,t-1} + v_{i,t}$$

where the variables $y_{i,t}$ and $x_{i,t}$ are cointegrated with slopes β_i, α_i allows the cointegrating relationship to include individual specific effects.

Pedroni (2001) introduced the group mean FMOLS estimator to solve the problem of endogeneity between regressors. The FMOLS estimates are given by:

$$\hat{\beta}_{FMOLS} = \frac{1}{N}\sum_{i=1}^{N}\left(\sum_{i=1}^{T}\left(x_{i,t} - \bar{x}_i\right)^2\right)^{-1}\left(\sum_{i=1}^{T}\left(x_{i,t} - \bar{x}_i\right)y_{i,t}^{*} - T\hat{\gamma}_i\right) \qquad (9)$$

$\hat{\gamma}_i$ correct the serial correlation term due to the heterogeneity dynamics and $y_{i,t}^{*}$ is the transformation of $y_{i,t}$ for eliminating endogeneity problem.

In same way, the DOLS technique can eliminate the correlation between regressors and error term by including delayed values in the cointegrated relationship. The dynamic OLS estimator is given by:

$$\hat{\beta}_{DOLS} = \frac{1}{N}\sum_{i=1}^{N}\left(\sum_{i=1}^{T} Z_{i,t}Z'_{i,t}\right)^{-1}\left(\sum_{i=1}^{T} Z_{i,t}\left(y_{i,t} - \bar{y}_i\right)\right) \quad (10)$$

where $Z_{i,t}$ represents $2(K+1) \times 1$ vector of explanatory variables including $(x_{i,t} - \bar{x}_i, \Delta x_{i,t-k}, \ldots, \Delta x_{i,t+k})$.

Granger causality test

The long-run and short-run relationships can be investigated using a panel vector error correction model (Pesaran, Shin, & Smith, 1999). The panel Granger causality model with dynamic error correction is given by:

$$\Delta lnGDP_{it} = \beta_{1i} + \sum_{k} \beta_{11ik} lnGDP_{i,t-k} + \sum_{k} \beta_{12ik} lnBiomass_{i,t-k} + \sum_{k} \beta_{13ik} lnK_{i,t-k} + \sum_{k} \beta_{14ik} lnO_{i,t-k} + \lambda_{1i} ECT_{it-1} + e_{it}$$

Where Δ denotes the first differences; β_{1i} represents the fixed country effects; λ_{1i} represents the adjustment coefficient and, e_{it} are the disturbance term.

Table 2: Descriptive statistics

Parameters	variables			
	GDP	Biomass	K	O
Mean	4.431	0.652	3.820	4.232
Median	4.480	0.608	3.863	4.226
Maximum	4.943	1.515	4.332	5.549
Minimum	3.461	-0.263	2.503	3.125
Std. Dev.	0.259	0.350	0.280	0.438
Skewness	-1.253	-0.003	-1.391	0.069
Kurtosis	4.813	3.502	6.040	3.229
observations	884	884	884	884

Results and discussion

Summary statistics of the panel data are presented in Table 2. We note more deviation is noted in openness trade compared to economic growth and less deviation have be found in capital use compared to openness trade OECD countries.

Panel unit root tests results

We first performed Madalla and Wu (1999) (Fisher-ADF) and Im, Pesaran, and Shin (2003) panel unit root tests to test the hypothesis that each panel data series has a common unit root process. Table 3 presents the results of panel unit roots tests for each variable in levels and in first differences. The results from the panel unit root tests indicate that the variables are found to be first difference stationary, i.e. the presence of unit root in the data. This implies that there may potentially be a cointegrating relationship among the variables.

Table 3: Panel unit root tests results

	GDP	Biomass	K	O
ADF – Fisher Chi-square				
level	55.180 (0.355)	57.450 (0.280)	48.996 (0.594)	20.709 (0.989)
First difference	215.810*** (0.000)	459.389*** (0.000)	305.73*** (0.000)	404.01*** (0.000)
Im, Peasaran and Shin W-stat				
level	-0.2524 (0.400)	-0.066 (0.473)	0.139 (0.555)	3.495 (0.999)
First difference	-10.5558*** (0.000)	-21.039*** (0.000)	-14.842 *** (0.000)	-19.07*** (0.000)

Note: the values in parentheses are the probabilities of rejecting the null of unit root. The asterisk *** indicates significance at the 1%. Lag selection (automatic) is based on Schwarz Information Criteria (SIC).

Panel cointegration tests results

Stationary panel tests show that all variables are integrated of order (1) and become stationary in first differences. As variables are non-stationary in levels, then there is the possibility that variables under investigation are cointegrated. Then, we use the standard panel cointegration tests of Pedroni (1999, 2004) and Kao (1999).

Table 4: Panel cointegration tests results

Pedroni cointegration test					
Within-dimension			Between-dimension		
	Statistic test	Prob		Statistic test	Prob
Panel *v*-stat	2.696***	0.0035	Group *r*-stat	1.5038	0.9337
Panel *r*-stat	-0.078	0.4688	Group *PP*-stat	-2.9915***	0.0014
Panel *PP*-stat	-2.555***	0.0053	Group *ADF*-stat	-1.9357**	0.0309
Panel *ADF*-stat	-2.857***	0.0029			
Kao cointegration test					
t-Statistic	Prob				
-3.1512	0.0008***				

Note: The asterisks *, ** and *** indicate rejection of the null hypothesis of no cointegration at the 10%, 5% and 1% levels, respectively.

The proposed statistics test the null hypothesis of no cointegration versus the alternative of cointegration. Table 4 yields panel cointegration analyses' results. The results of the tests show that, there exists a cointegrating relationship between economic growth, biomass energy consumption, capital use and trade openness.

Panel FMOLS and DOLS estimates results

To estimate the long - run relationship, we use the group-mean FMOLS and DOLS estimators suggested by Pedroni (2001).

Table 5: Panel FMOLS and DOLS estimates

	FMOLS			DOLS		
	Coefficient	t-Statistic	Prob	Coefficient	t-Statistic	Prob
Biomass	0.9349	12.0178	0.0000***	1.0372	10.4276	0.0000***
K	0.6919	22.2329	0.0000***	0.6581	17.5243	0.0000***
O	0.2775	10.6662	0.0000***	0.2944	9.4232	0.0000***

Note: The asterisk *** indicate significance at the 1% level.

From the Table 5 it can be concluded that in the long run the coefficient of Biomass is positive and statistically significant at the 1% level. By using the FMOLS method the elasticity of GDP with respect to Biomass is 0.9349. This means that a one percent increase in Biomass will foster economic growth for the panel of 26 countries of OECD by about 0.9349%. By using the DOLS method the elasticity of GDP with respect to Biomass is 1.0372. This means that a one percent increase in Biomass will foster economic growth for the panel of the 26 countries of OECD by about 1.0372%. So a downward shock to Biomass leads to economic growth.

The results based on FDOLS method show that the impact of Biomass on economic growth is similar to those of DOLS method. This long-run finding is consistent with the recent studies of Payne (2011) for US economy, Bildirici and Özaksoy (2013) for European countries, Bildirici (2013) for Bolivia, Brazil, Chile, Colombia, and Guatemala, Bildirici (2014) for transition economies and, Ozturk and Bilgili (2015) for Sub-Saharan African countries, Shahbaz et al. (2016) for BRICS countries and Bildirici and Ozaksoy (2017) for selected African countries.

Also, results reveal a positive and significative link between economic growth and capital use at 1% level. A 1% increase in capital use leads economic growth by 0.6919% (respectively 0.6581%) based on FMOLS (respectively DOLS) estimation results. In the same way, a 1% increase in trade openness increases economic growth by 0.2775% (respectively 0.2944%) in case of OECD countries. This empirical result is similar with Shahbaz et al. (2016) for BRICS countries.

Granger causality test results

Table 6 reports the results of the short – run and long-run Granger causality tests. The long-run coefficient with its negative sign is statistically significant and explains how quickly variables converge to equilibrium. It shows a bidirectional long-run causality between economic growth and biomass energy consumption supporting feedback hypothesis.

Table 6: Granger causality test results

Dependent variable	Short-run relationship				Long-run relationship
	ΔGDP	ΔBiomass	ΔK	ΔO	ECT
ΔGDP	-	-0.0131 (0.3498)	-0.0243 (0.0183)**	-0.0222 (0.3177)	-0.0133*** (0.0000)
ΔBiomass	-0.1419 (0.0002) ***	-	0.0342 (0.0621)*	0.0347 (0.5183)	-0.0209*** (0.0000)
ΔK	0.7771 (0.0000) ***	-0.0625 (0.1538)	-	0.0887 (0.2027)	0.0453 (0.4015)
ΔO	0.5054 (0.0001) ***	-0.0052 (0.8688)	-0.0433 (0.2232)	-	-0.0266 (0.0001) ***

Note: The asterisks * , ** and *** indicate significance at the 10%, 5% and 1% levels, respectively. Probability values are reported in parentheses.

Our finding confirm the results of Bildirici and Özaksoy (2013) and Shahbaz et al. (2016) that reported the existence of feedback hypothesis between biomass energy consumption and GDP. However, it is contradictory with the result of Payne (2011) who reported that GDP is outcome of biomass energy consumption. Also, we note the presence of bidirectional relationship between trade openness and economic growth and between trade openness and biomass energy consumption which is contradictory with the result of Shahbaz et al. (2016) who noted unidirectional causality running from trade openness to economic growth, biomass energy consumption and capital use. On other hand, results suggest unidirectional causality running from capital use to economic growth, biomass energy consumption and capital use.

For short run results, we report an unidirectional causality running from economic growth to biomass energy consumption which found to be contradictory with the result of Shahbaz et al. (2016) and Bildirici and Ozaksoy (2017) who reported bidirectional causality between biomass energy consumption and economic growth. Moreover, the feedback relationship exists between capital use and economic growth. The unidirectional causality is noted running from economic growth to trade openness.

Conclusion and policy implications

This paper investigates the relationship between biomass energy consumption and economic growth for the panel of 26 OECD countries from 1980 to 2013. To this end, the panel unit root analyses, panel cointegration analyses, the long-run relationship using Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) techniques are conducted. Also, we perform the Granger causality test to supplement the findings of the long-run cointegration relationship. The long-run results determine that there is bidirectional causality between biomass energy consumption and economic growth for our panel of data. The feedback hypothesis emphasizes that energy conservation policies which reduce biomass energy consumption may impact on economic growth. In other words, biomass energy consumption plays an important role in the economic growth process.

The findings suggest that policy option to promote biomass energy consumption in 26 OECD countries under investigation helps to achieve sustainable development goal in long- run meaning that OECD economies should promote the availability of biomass energy for sustaining long-run economic growth and development. To this aim, OECD countries should improve energy policies which improve the biomass energy infrastructure and biomass supply to promote economic growth and reducing the greenhouse gas emissions (carbon dioxide emissions).

Appendix A. list of countries

Australia, Austria, Belgium, Canada, Chile, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Portugal, South Korea, Spain, Sweden, Switzerland, United Kingdom, United States of America.

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