Biomass energy consumption and economic growth: Evidence from top 10 biomass consumer countries

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ABSTRACT

This study aims to investigate the economic efficiency of biomass energy consumption for the period from 1980 to 2013 in top 10 biomass energy consumer countries. For this purpose, this study uses both augmented mean group (AMG) estimator and panel bootstrap causality method which are suitable for dependent and heterogeneous panels. The results of AMG estimator shows that economic growth is positively affected by biomass energy use in Brazil, China, Finland, Germany, Italy and Sweden. In addition, empirical findings from panel bootstrap causality test show that the growth hypothesis is valid for Brazil, Germany, India and Italy; the conservation hypothesis is supported in Sweden, the feedback hypothesis is confirmed in China and the US; the neutrality hypothesis is valid in Finland, Japan and the UK.

Keywords: Biomass; energy consumption; economic growth; dependency; heterogeneity; bootstrap causality

1.Introduction

Energy consumption is still regarded as the most crucial trigger for economic activity all over the world. However, scarcity of energy resources, fluctuations in energy prices and serious environmental concerns (global warming, climate change etc.) leads to the quest for alternative energy sources. Renewable energy sources especially biomass energy has become one of the major energy source for sustainable development. Some important reasons for preferring biomass energy are that reducing fossil-fuel energy dependency, reducing unemployment in underdeveloped countries due to labor intensive nature, and reducing CO_2 emissions (Bilgili and Ozturk, 2015).

In recent years, the economic aspects of biomass energy consumption have been investigated by many researchers based on different country classifications. The role of biomass energy use on economic growth is examined for regional categorization; West Africa by Adewuyi and Awodumi (2017), Sub-Saharan Africa by Ozturk and Bilgili (2015) and development level categorization; developing and emerging countries by Bildirici (2013), G-7 countries by Bilgili and Ozturk (2015), BRICS countries by Shahbaz et al. (2016). On the other hand, the real impact of biomass energy consumption on economic growth can be detected by focusing on the countries that consume the most biomass energy. According to the US Energy Information Administration, top 10 biomass energy consumer countries are the US, China, Germany, Brazil, Japan, the UK, India, Italy, Finland and Sweden, respectively. In 2014, the share of biomass energy consume of these countries is 75.8 % in global biomass energy consumption (EIA, 2017).

Based on above reasons, the main aims of this study are to investigate the effect of biomass energy consumption on economic growth using with Cobb-Douglas production function and to examine the causal relationship between biomass energy use and economic growth for the period of 1980-2013 in top 10 biomass energy consumer countries. It is also aimed to determine which energy-growth hypothesis is valid in these countries[1].

The contributions of this study to the existing literature are as follows; first, this is the first study to examine the biomass energy use and economic growth for the top biomass energy consumer countries. Second, as an estimation of a bivariate empirical model may lead to unreliable results, this study uses multivariate empirical model based on Cobb-Douglas function. Third, unlike previous studies, used methodologies in this study take into account the cross-sectional dependency and country-specific heterogeneity among countries. Moreover, the empirical findings of each country can be separated with used parameter estimator and causality procedure therefore obtained results will be more policy-oriented.

2.Data and methodology

In order to investigate the relationship between biomass energy use and economic growth, the annual data of the period from 1980 to 2013 is examined for top 10 biomass energy consumer countries: Brazil, China, Finland, Germany, India, Italy, Japan, Sweden, the UK and the US. Using with the Cobb-Douglas production function, the real GDP is described as a function of biomass energy use, gross fixed capital formation and total

[1] The growth hypothesis is valid in case of there is unidirectional causality from biomass energy consumption to economic growth; the conservation hypothesis is valid when there is evidence of the unidirectional causality from economic growth to biomass energy consumption; the feedback hypothesis is confirmed in situation of there is bidirectional causal linkage between biomass energy consumption and economic growth; and the neutrality hypothesis is supported when there is no any causal connection between biomass energy use and economic growth.

labor force. Moreover, all variables are converted into logarithmic form and the panel version of empirical model can be written as follows;

$$GDP_{it} = \delta_0 + \delta_1 BEC_{it} + \delta_2 K_{it} + \delta_3 L_{it} + \mu_{it} \quad (1)$$

where t, i and μ_{it} refer to time period, cross-section and residual term, respectively. In addition, GDP_{it} is the natural log of gross domestic product; BEC_{it} is the natural log of biomass energy consumption, K_{it} is the natural log of capital and L_{it} is the natural log of total labor force. The real gross domestic product is measured in constant 2010 US dollars; biomass energy consumption is measured in used extraction of biomass, capital formation is measured in gross fixed capital formation share of GDP. Furthermore, the data of *GDP* and *K* is obtained from World Development Indicators; the data of *BEC* is retrieved from Global Material Flow Database; and the data of *L* is downloaded from Penn World Table 9.0 database.

Because of the high degree of globalization and increasing economic and financial integration in the world economy, panel data methodologies which ignore the cross-sectional dependence may lead to unreliable results. Therefore, this study first examines the existence of cross-sectional dependence among countries using by LM test of Breusch and Pagan (1980), CD_{LM} and CD test of Pesaran (2004) and LM_{adj} test of Pesaran et al. (2008). In addition, slope homogeneity is examined with $\tilde{\Delta}$ and $\tilde{\Delta}_{adj}$ test of Pesaran and Yamagata (2008).

This study uses Augmented Mean Group (AMG) estimator developed by Eberhardt and Bond (2009); Bond and Eberhardt (2013) to take into account the cross-sectional dependence and country-specific heterogeneity among countries. The other advantage of using this methodology is that it allows to examining the parameters of non-stationary variables. Therefore, any pre-testing procedure (unit root or cointegration) is not required to use this approach. In the first step of testing procedure, the main panel model (Eq. 1) is estimated with first differenced form and *T-1* period dummy as follows;

$$\Delta GDP_{it} = \gamma_1 \Delta BEC_{it} + \gamma_2 \Delta K_{it} + \gamma_3 \Delta L_{it} + \sum_{t=2}^{T} p_t(\Delta D_t) + u_{it} \tag{2}$$

where ΔD_t is first differences *T-1* period dummies; p_t is the parameters of period dummies. In the second step, estimated p_t parameters are converted to φ_t variable which indicates common dynamic process as follows;

$$\Delta GDP_{it} = \gamma_1 \Delta BEC_{it} + \gamma_2 \Delta K_{it} + \gamma_3 \Delta L_{it} + d_i(\varphi_t) + u_{it} \tag{3}$$

$$\Delta GDP_{it} - \varphi_t = \gamma_1 \Delta BEC_{it} + \gamma_2 \Delta K_{it} + \gamma_3 \Delta L_{it} + u_{it} \tag{4}$$

Group-specific regression model is first adapted with φ_t and then the mean values of group-specific model parameters are computed. For instance, the parameter of biomass energy use (γ_1) can be computed as $\gamma_{1,AMG}$=1/N$\sum_{i=1}^{N} \gamma_{1,i}$.

In order to determine the causal relationship between biomass energy use and economic growth, this study utilize with panel bootstrap causality approach developed by Konya (2006). Similar to the AMG procedure, the panel bootstrap causality approach considers the cross-sectional dependence and country-specific heterogeneity among countries. This approach is based on seemingly unrelated regression (SUR) estimation of the set of equations with individual country specific bootstrap critical values. Following Konya (2006), to overcome the problem of determining the optimal lag length, the model is estimated for each possible lags by assuming from 1 lag to 4 lags. Then, the optimal lag length is chosen which minimizes Schwarz Bayesian Criterion. The system for the relationship between biomass energy use and economic growth can be written as follows;

$$GDP_{1t} = a_{11} + \sum_{i=1}^{p_1} \beta_{11i} GDP_{1t-i} + \sum_{i=1}^{p_1} \delta_{11i} BEC_{1t-i} + \varepsilon_{11t}$$
$$\vdots \qquad (5)$$
$$GDP_{Nt} = a_{1N} + \sum_{i=1}^{p_1} \beta_{1Ni} GDP_{Nt-i} + \sum_{i=1}^{p_1} \delta_{1Ni} BEC_{Nt-i} + \varepsilon_{1Nt}$$

$$BEC_{1t} = a_{21} + \sum_{i=1}^{p_2} \beta_{21i} GDP_{1t-i} + \sum_{i=1}^{p_2} \delta_{21i} BEC_{1t-i} + \varepsilon_{21t}$$
$$\vdots \qquad (6)$$
$$BEC_{Nt} = a_{2N} + \sum_{i=1}^{p_2} \beta_{2Ni} GDP_{Nt-i} + \sum_{i=1}^{p_2} \delta_{2Ni} BEC_{Nt-i} + \varepsilon_{2Nt}$$

where *N* implies the number of countries, *t* implies the time period and *i* refers to optimal lag length. In panel bootstrap causality procedure, different causal connections can be detected. For instance, it can be concluded that *BEC* causes *GDP* if not all δ_{1i} are zero, but all β_{2i} are zero; *GDP* causes *BEC* if all δ_{1i} are zero, but not all β_{2i} are zero. Moreover, there is bidirectional causality between *GDP* and *BEC* if neither δ_{1i} nor β_{2i} is zero and there is no causal relation between *GDP* and *BEC* if both δ_{1i} and β_{2i} is zero.

3.Empirical results

In the first step of analysis, the cross-sectional dependence and country-specific heterogeneity is examined and the empirical findings are shown in Table 1. According to the results, the null of there is no any dependence among countries is rejected for all tests. This means a shock occurred in one of sample country may be spill-over other countries. In addition, the homogeneity test results show that there is country-specific heterogeneity among countries.

[INSERT TABLE 1 HERE]

[INSERT TABLE 2 HERE]

In the second step of our analysis, the effect of biomass energy use, capital and labor on economic growth is investigated with AMG estimator. According to the results of Table 2, it seems economic growth is positively affected by biomass energy consumption in Brazil, China, Germany, Italy and Sweden. On the other hand, the parameter of biomass energy use is statistically insignificant in India, Japan, the UK and the US. This result shows that biomass energy use has not predictive power on economic activities in these countries. Moreover, increasing capital formation leads to increase in the real GDP in all countries except of Italy. The positive effect of total labor force on economic growth is also found in China, Germany, India, Japan and the US. When the group panel estimation results are evaluated, it can be seen that biomass energy consumption positively affects economic activities of top 10 biomass consumer countries.

[INSERT TABLE 3 HERE]

[INSERT TABLE 4 HERE]

In the third step of analysis, the causal relation between biomass energy consumption and economic growth is examined with panel bootstrap causality method. The results are illustrated in Table 3 and Table 4. According to Table 3, the unidirectional causality from biomass energy consumption to economic growth is valid in Brazil, China, Germany, India, Italy and the US. However, there is no any causality from biomass energy use to economic growth in Finland, Japan, Sweden and the UK. In addition, as a shown in Table 4, the unidirectional causality from economic growth to biomass energy consumption is confirmed in China, Sweden and the US. Based on these findings, it is concluded that the growth hypothesis for biomass energy use is supported in Brazil, Germany, India and Italy; the conservation hypothesis is supported in Sweden, the feedback hypothesis is confirmed in China and the US; the neutrality hypothesis is valid in Finland, Japan and the UK.

4.Conclusions and policy implications

This study aims to examine the relationship between biomass energy consumption and economic growth for the period from 1980 to 2013 in top 10 biomass energy consumer countries: Brazil, China, Finland, Germany, India, Italy, Japan, Sweden, the UK and the US. For this purpose, this study uses panel AMG estimator based on the Cobb-Douglas production function to investigate the effects of biomass energy consumption, capital and labor force on the real GDP. In addition, the causal relationship between biomass energy consumption and economic growth is searched using with panel bootstrap causality procedure. Because of both methods are suitable to investigate the relationship between variables in case of cross-sectional dependence and country-specific heterogeneity, we first test the dependence and slope homogeneity among countries.

According to the AMG estimator results, it is concluded that biomass energy use, total labor force and capital positively affects the economic growth in panel of sample countries. When the estimator results of each country are evaluated, we found the positive effect of biomass energy consumption on economic growth is valid in Brazil, China, Germany, Italy and Sweden. Moreover, the panel bootstrap causality test results show that the growth hypothesis for biomass energy use is supported in Brazil, Germany, India and Italy; the conservation hypothesis is supported in Sweden, the feedback hypothesis is confirmed in China and the US; the neutrality hypothesis is valid in Finland, Japan and the UK.

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