Journal of Social Sciences of Mus Alparslan University

anemon

Derginin ana sayfası: http://dergipark.gov.tr/anemon

Araştırma Makalesi ● Research Article

Biomass Energy Consumption, Economic Growth and CO_2 Emission in G-20 Countries

G-20 Ülkelerinde Biyokütle Enerji Tüketimi, Ekonomik Büyüme ve CO_2 Emisyonu

Mehmet Akif Destek [a], İlyas Okumuş [b,*]

[a] Arş. Gör. Dr., Gaziantep Üniversitesi, İktisadi ve İdari Bilimler Fakültesi, İktisat Bölümü, 27310, Gaziantep/Türkiye.
ORCID: 0000-0002-2514-9405

[b] Dr. Öğr. Üyesi, Hatay Mustafa Kemal Üniversitesi, İİBF, Maliye Bölümü, 31060, Hatay/Türkiye.
ORCID: 0000-0003-2225-4215

MAKALE BİLGİSİ

Makale Geçmişi:
Başvuru tarihi: 10 Haziran 2018
Düzeltme tarihi: 20 Ağustos 2018
Kabul tarihi: 28 Ağustos 2018

Anahtar Kelimeler:
Biyokütle Enerjisi Tüketimi
Ekonomik Büyüme
CO_2 Emisyonu
G-20 Ülkeleri

ÖZ

Bu çalışmada 1992-2013 yılları arasında G-20 ülkelerinde biyokütle enerjisi tüketimi, ekonomik büyüme, karbondioksit emisyonu ve doğal kaynak tükenmesi arasındaki ilişki incelenmektedir. Bu amaç doğrultusunda, panel birim kök, panel eşbütünleşme, panel FMOLS (fully modifies OLS) ve panel VECM Granger nedensellik yöntemleri kullanılmıştır. Sonuçlar, biyokütle enerjisi tüketiminin, ekonomik büyümenin, CO_2 emisyonunun ve doğal kaynak tükenmesinin eşbütünleşik olduğunu göstermektedir. Ayrıca, biyokütle enerjisi tüketiminin artması ekonomik büyümenin artmasına yol açmaktadır. Öte yandan, biyokütle enerji tüketimindeki artış CO_2 emisyonlarını azaltmaktadır. Ayrıca, büyüme hipotezini destekleyen biyokütle enerji tüketiminden GSYH büyümesine doğru tek yönlü bir nedensellik vardır. Son olarak, biyokütle enerji tüketimi ile CO_2 emisyonu arasında iki yönlü bir nedensellik ilişkisi vardır.

ARTICLE INFO

Article history:
Received June 10, 2018
Received in revised form August 20, 2018
Accepted August 28, 2018

Keywords:
Biomass Energy Consumption
GDP Growth
CO_2 Emission
G-20 Countries

ABSTRACT

This study investigates the relationship between biomass energy consumption, economic growth, carbon dioxide emissions, and natural resource depletion in G-20 countries from 1992 to 2013. For this purpose, we used panel unit root tests, the panel cointegration test, the panel fully modified OLS (FMOLS) method, and the panel VECM Granger causality method. The results reveal that biomass energy consumption, economic growth, CO_2 emissions, and natural resource depletion are cointegrated. In addition, increasing biomass energy consumption leads to increased economic growth. On the other hand, the increase in biomass energy consumption reduces CO_2 emissions. Moreover, a unidirectional causality exists from biomass energy consumption to GDP growth, supporting the growth hypothesis. Finally, a bidirectional causal relationship exists between biomass energy consumption and CO_2 emissions.

1. Introduction

Since the Industrial Revolution, economic development has been rooted in fossil fuel-oriented industries and mass production systems. This economic growth strategy has increased income and reduced poverty. However, such development has triggered some problems, such as environmental issues, global climate change, energy dependency, and limited supplies of fossil fuels (Ulucak and Erdem, 2017). Thus, the dependence on fossil fuels, or the conventional way of development, can no longer be sustained. Because of these serious problems and recent global crises, sustainable development and green, or environmentally sustainable, growth have become parts of a worldwide discourse driven by international treaties, global environmental organizations, and bodies such as the G-20. Due to these issues, countries are now seeking to replace fossil fuel energy sources with renewable and sustainable energy resources, such as biomass.

This study focuses on the G-20 countries (Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Turkey, the United Kingdom, and the

* Sorumlu yazar/*Corresponding author*.
e-posta: ilyasokumus@mku.edu.tr

http://dx.doi.org/10.18506/anemon.453801

United States), excluding the European Union, which cause 78.6% of total global CO_2 emissions and consume 74.9% of total global renewable energy production (BP, 2014). Therefore, it is crucial to examine the directions of the causal relationships between biomass energy consumption, GDP, and CO_2 emissions.

Since the third G-20 summit in Pittsburgh, the countries have discussed issues surrounding energy, the volatility of fossil fuel prices, the environment, and climate change. The accepted opinion holds that in order to provide sustainable development, decrease the volatility of energy prices, and decrease environmental degradation, these countries must turn towards alternative renewable energy sources (Kang, 2012).

Based on the above, this study aims to investigate the relationship between biomass energy consumption, GDP, CO_2 emissions, and natural resource depletion in G-20 countries between 1992 and 2013. For this purpose, we employed panel unit root tests, the panel cointegration test, the panel fully modified OLS method, and the panel VECM Granger causality method. This study contributes to existing literature in some aspects. First, while most of previous studies focused on the effects of fossil fuel energy consumption on economic growth or environmental pollution, this study considers the relationship between biomass energy consumption and economic growth for G-20 countries. In addition, the study utilizes multivariate models by adding CO_2 emissions and natural resource depletion.

The rest of the paper is as following; Second section involves the literature review, Third section describes the data, model, methodology and empirical findings, Fourth section presents the conclusion and policy implications of the study.

2. Literature Review

In recent years, it seems that many studies examined the relationship between energy consumption and economic growth. Payne (2010) and Ozturk (2010) reviewed the existing literature and provided four testable hypotheses. First one is called growth hypothesis which indicates that unidirectional causality from energy consumption to economic growth. In such a situation, energy conservation policies are detrimental on economic growth. Second hypothesis is called conservation hypothesis. According to this hypothesis, there is unidirectional causality from economic growth to energy consumption and energy conservation policies may not be harmful on economic growth. Some studies found that bidirectional causality between energy consumption and economic growth which is called feedback hypothesis. If feedback hypothesis is exist then energy reduced policies would be detrimental on economic growth. Finally the last hypothesis is called neutrality hypothesis which implies that there is no causal relationship between energy consumption and economic growth. In such a situation, reducing the energy consumption is ineffective on economic growth.

In the literature, it seems that various hypotheses were supported about the causal linkage between renewable energy consumption and economic growth. These mixed results could be sourced from using different data sets, econometric techniques or different sample periods. For instance, the growth hypothesis was confirmed by some studies such as Aydın and Esen (2017) for Turkey; Esen and Bayrak (2017) for energy importing countries. The feedback hypothesis was supported in various studies such as Sadorsky (2009a) for emerging countries; Apergis and Payne (2010) for 20 OECD countries; Apergis and Payne (2010) for Eurasia; Apergis et al. (2010) for a group of 19 developed and developing countries; Apergis and Payne (2011) for 6 Central American countries; Tugcu et al. (2012) for G7 countries. The neutrality hypothesis was discovered in some studies such as Payne (2009) for US; Menagaki (2011) for 27 European countries. The conservation hypothesis was confirmed in number of studies such as Menyah and Rufael (2010) for US; Apergis and Payne (2011) for 16 emerging countries.

On the other hand, the studies about the relationship between biomass consumption and economic growth are less. Bildirici (2012) investigated the relationship between biomass energy consumption and economic growth in Argentina, Bolivia, Brazil, Chile, Colombia, Jamaica, and Guatemala for 1980-2009 periods. Using ARDL bound test approach; the findings showed that there is a unidirectional relationship from biomass energy consumption to GDP in these countries. Bildirici (2013) investigated the causality relation between biomass energy consumption and economic growth in the selected 10 developing and emerging countries by using ARDL approach of cointegration and error correction models for periods from 1980 to 2009. In the countries studied, there is a unidirectional relationship from biomass energy consumption to GDP.

Bildirici and Ozaksoy (2013) probed the relationship between biomass energy consumption and economic growth in some European countries, the results revealed that feedback hypothesis was valid in all these countries. Bildirici (2014) looked at the relationship between biomass energy and economic growth in transition countries. Using Pedroni (2000) panel cointegration and ARDL bound test, the evidence revealed that feedback hypothesis was existed in the all countries. Bildirici and Ersin (2014) considered the causality analysis among biomass energy consumption and economic growth in Austria, Canada, Germany, Great Britain, Finland, France, Italy, Mexico, Portugal and the U.S. for 1970-2013 periods by using ARDL method, Granger causality and Toda and Yamamoto non-causality test. For Austria, Germany, Finland and Portugal, the granger causality test determined the evidence that the conservation hypothesis is supported. In state of U.S., the feedback hypothesis highlights the interdependent relationship between biomass energy consumption and economic growth.

Ozturk and Bilgili (2015) explored the relationship between economic growth and biomass consumption by applying dynamic panel analyses for Sub-Sahara African countries for 1980–2009 periods. A significant and substantive influence of biomass energy consumption on economic growth was found. Bilgili and Ozturk (2015) used panel data method to investigate the relationship between biomass energy consumption and GDP growth in G7 countries for 1980-2009 periods. The result supported that there is unidirectional causality from biomass energy consumption to economic growth. Therefore, the growth hypothesis was supported. Similarly, the growth hypothesis of biomass energy is also validated by Destek (2017) and Aydın (2018).

Similarly, the results of the studies examining the relationship between renewable energy consumption and CO_2 emissions are mixed. Sadorsky (2009b) estimated an empirical model of renewable energy consumption in the G7 countries spanning the period 1980-2005. Panel cointegration estimates showed that in the long term, increasing CO_2 per capita is found to be major driver behind renewable energy consumption per capita. Menyah and Wolde-Rufael (2010) explored the causal relationship between CO_2 emissions, renewable and nuclear energy consumption in the US for the period 1960-2007. Using a modified version of the granger causality test, they found a unidirectional causality running from nuclear energy consumption to CO_2 emissions but no causality running from renewable energy to CO_2 emissions. Apergis and Payne (2014) investigated the relationship between renewable energy consumption and CO_2 emissions in Central America over the period 1980 to 2010. The bidirectional causality between the variables was found. Jebli et al. (2014) applied panel cointegration techniques and panel granger causality tests to investigate the nexus in Central and South America spanning the period 1995-2010. In the long-run, there is evidence of bidirectional causality between emissions and renewable energy consumption.

Rafiq et al. (2014) considered the dynamic relationships among carbon emission and renewable energy generation of India and China during the period 1972 to 2011 using vector error correction model (VECM). In the long run, bidirectional causality is found between carbon dioxide emissions and renewable energy generation. Zeb et al. (2014) utilized Granger causality test to explore the causal linkage between renewable energy production, CO_2 emissions, natural resource depletion in selected SAARC countries over a period of 1975-2010. The results show that increasing renewable energy production leads to decrease in CO_2 emissions. Apergis and Payne (2015) utilized panel cointegration techniques to estimate the causal dynamics between renewable energy consumption per capita, real gross domestic product (GDP) per capita, carbon dioxide emissions per capita, and real oil prices for a panel of 11 South American countries over the period 1980 to 2010. The results of the study revealed a feedback relationship among the variables.

There are few studies investigating the relationship between biomass energy consumption and CO_2 emissions. For instance, Bilgili (2012) utilized Hatemi-J (2008) and Gregory-Hansen (1996) cointegration tests to examine the possible impact of biomass energy consumption on CO_2 emissions for the period from January 1990 to September 2011 in the US, the results of study showed that biomass energy consumption affects CO_2 emissions negatively. Hayfa and Rania (2014) examined the impact of the biomass energy use on CO_2 emissions by using panel data model for 15 countries during the period 1991-2011. The results showed that the biomass reduces the CO_2 emissions.

3. Data and Method

This study utilizes annual data from 1992 to 2013 for the G-20 countries, excluding the European Union: Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Turkey, the United Kingdom, and the United States. Following the energy demand models of Sadorsky (2009), Salim and Rafiq (2012), and Zeb et al. (2014), biomass energy consumption operates as a function of real GDP, CO2 emissions, and natural resource depletion.

Biomass energy consumption (BIO) is the dependent variable measured used in extraction per capita. The GNP per capita (Y) is measured in millions of constant 2005 US dollars. Carbon dioxide emissions (CO) are measured in metric tons per capita. Finally, natural resource depletion (NRD) is measured in natural resource depletion percentage of GNI. The data of Y, CO, and NRD are sourced from WDI (2015), and BIO is from the Global Material Flow database. The panel version of model can be shown as follows:

$$lnBIO_{it} = \beta_{0i} + \beta_{1i}lnY_t + \beta_{2i}lnCO_t + \beta_{3i}lnNRD_t + \varepsilon_{it} \quad (1)$$

where lnBIO, lnY, lnCO and lnNRD indicate the natural log of biomass consumption per capita, gross domestic product per capita, carbon dioxide emissions per capita and natural resource depletion respectively.

The crucial step of econometric analysis is to investigate the stationary properties of variables. We used two panel unit root test such as LLC unit root test developed by Levin, Lin, and Chu (2002) and IPS unit root test developed by Im, Pesaran, and Shin (2003) in order to determine the order of integration of the variables. The null hypothesis of both test indicate unit root process.

In order to examine the long-run relationship between variables, the panel cointegration test developed by Pedroni (1999) is utilized. Pedroni (1999) developed seven statistics to analyze the possible long-run relation and the test which is based on estimation of Eq 1.with estimation of $\delta_i\varepsilon_{it-1} + \sum_{k=1}^{K_i}\delta_{ik}\Delta\varepsilon_{it-k} + v_{it}$ regression model. The null hypothesis of test indicates that there is no cointegration between variables.

The next step is to examine the long-run coefficients of cointegrated variables. The long-run coefficients of variables are estimated with fully modified ordinary least squares (FMOLS) developed by Pedroni (2000). The estimation of FMOLS can be constructed as $\hat{\beta}_{GFMOLS} = N^{-1}\sum_{i=1}^{N}\beta_{FMOLS}$ where β_{FMOLS} is acquired from individual FMOLS estimation of Eq 1.

In case of the existence of the long-run relationship between variables, the causality connections between variables can be examined. We utilized with the panel Granger causality test which is based on vector error correction model (VECM) to investigate the directions of causal linkage between biomass energy consumption, GDP growth, CO_2 emissions and natural resource depletion. The panel VECM can be written as follows:

$$\begin{aligned}\Delta BIO_{it} = \delta_{1i} &+ \sum_{q=1}^{k}\delta_{11iq}\Delta BIO_{it-q} \\ &+ \sum_{q=1}^{k}\delta_{12iq}\Delta Y_{it-q} + \sum_{q=1}^{k}\delta_{13iq}\Delta CO_{it-q} \\ &+ \sum_{q=1}^{k}\delta_{14iq}\Delta NRD_{it-q} + \varphi_{1i}\varepsilon_{it-1} + v_{1it}\end{aligned} \quad (2)$$

$$\Delta Y_{it} = \delta_{2i} + \sum_{q=1}^{k} \delta_{21iq} \Delta Y_{it-q} + \sum_{q=1}^{k} \delta_{22iq} \Delta BIO_{it-q} + \sum_{q=1}^{k} \delta_{23iq} \Delta CO_{it-q} + \sum_{q=1}^{k} \delta_{24iq} \Delta NRD_{it-q} + \varphi_{2i}\varepsilon_{it-1} + v_{2it} \quad (3)$$

$$\Delta CO_{it} = \delta_{3i} + \sum_{q=1}^{k} \delta_{31iq} \Delta CO_{it-q} + \sum_{q=1}^{k} \delta_{32iq} \Delta BIO_{it-q} + \sum_{q=1}^{k} \delta_{33iq} \Delta Y_{it-q} + \sum_{q=1}^{k} \delta_{34iq} \Delta NRD_{it-q} + \varphi_{3i}\varepsilon_{it-1} + v_{3it} \quad (4)$$

$$\Delta NRD_{it} = \delta_{4i} + \sum_{q=1}^{k} \delta_{41iq} \Delta NRD_{it-q} + \sum_{q=1}^{k} \delta_{42iq} \Delta BIO_{it-q} + \sum_{q=1}^{k} \delta_{43iq} \Delta Y_{it-q} + \sum_{q=1}^{k} \delta_{44iq} \Delta CO_{it-q} + \varphi_{4i}\varepsilon_{it-1} + v_{4it} \quad (5)$$

where Δ is the lag operator, k is the lag length and ε_{it} is the residual terms.

4. Empirical Findings

In the first step of empirical analysis, the stationary process of variables are examined with panel unit root tests and test results are shown in Table 1. At a first glance, the null of unit root can't be rejected clearly at 1% percent level. When the difference operator is used, the null of unit root can be rejected strongly and all variables become stationary. The variables are integrated of order one therefore it seems there is possible long-run relationship between variables.

Table 1. The Results of Panel Unit Root Test

Variable	LLC		IPS	
	Constant	Constant&Trend	Constant	Constant&Trend
lnBIO	-0.8770 [0.1902]	-4.4233 [0.0000]	0.3331 [0.6305]	-1.8204 [0.0343]
lnY	-0.2845 [0.3380]	0.1918 [0.5761]	3.4409 [0.9997]	2.1209 [0.9830]
lnCO	1.8418 [0.9672]	-0.0443 [0.4823]	3.8275 [0.9999]	2.2419 [0.9875]
lnNRD	-1.9592 [0.0250]	-3.4219 [0.0003]	-0.1565 [0.4378]	-1.3763 [0.0844]
ΔlnBIO	-19.7641 [0.0000]	-17.9867 [0.0000]	-17.0624 [0.0000]	-14.8293 [0.0000]
ΔlnY	-10.4721 [0.0000]	-10.3147 [0.0000]	-5.1252 [0.0000]	-4.2660 [0.0000]
ΔlnCO	-11.5946 [0.0000]	-14.1715 [0.0000]	-9.9335 [0.0000]	-12.0506 [0.0000]
ΔlnNRD	-11.6496 [0.0000]	-10.2028 [0.0000]	-10.8139 [0.0000]	-8.2947 [0.0000]

Δ is the first difference operator. The maximum lag lengths were selected automatically using with Schwarz Information Criteria. Numbers in brackets are *p*-values. Newey-West bandwidth selection with Bartlett kernel is used for LLC test. Numbers in brackets are p-values.

In the second step, the panel cointegration test results are presented in Table 2. We used each variable as a dependent variable and investigated the cointegration relationship for four models. The results show that the null of no cointegration can be rejected for all models. Therefore, it can be said that the biomass consumption, economic growth, CO_2 emissions and natural resource depletion are cointegrated.

Table 2. The Results of Panel Cointegration Test

	Constant	Contant&Trend
Dependent variable: lnBIO		
Panel ν-statistic	1.1504	2.0975**
Panel ρ-statistic	- 0.0836	1.6232
Panel PP-statistic	- 6.1002***	- 7.8412***
Panel ADF-statistic	- 4.3176***	- 7.4777***
Group ρ-statistic	0.3060	2.2899
Group PP-statistic	- 6.0368***	- 9.6942***
Group ADF-statistic	- 5.5689***	- 7.3351***
Dependent variable: lnGDP		
Panel ν-statistic	-1.5406	5.6155***
Panel ρ-statistic	0.7403	1.7443
Panel PP-statistic	-0.3067	-1.6364*
Panel ADF-statistic	-0.5870	-2.5854***
Group ρ-statistic	1.9084	3.3449
Group PP-statistic	-1.8869**	-0.6715
Group ADF-statistic	-3.1048***	-1.7881**
Dependent variable: lnCO		
Panel ν-statistic	1.4931*	0.9777
Panel ρ-statistic	0.6493	1.8564
Panel PP-statistic	-1.0863	-1.7421**
Panel ADF-statistic	-1.4935*	-2.5461***
Group ρ-statistic	2.3136	2.3572
Group PP-statistic	-1.8041**	-4.7585***
Group ADF-statistic	-1.7910**	-5.7920***
Dependent variable: lnNRD		
Panel ν-statistic	0.5588	-1.2417
Panel ρ-statistic	-0.1924	1.3484
Panel PP-statistic	-4.9731***	-6.5361***
Panel ADF-statistic	-3.6507***	-3.6614***
Group ρ-statistic	2.3099	3.5072
Group PP-statistic	-5.0645***	-7.6100***
Group ADF-statistic	-4.0004***	-5.1886***

*,** and *** indicates statistically significance at 10, 5 and 1 percent level respectively.

Next, the results of panel group FMOLS estimation are reported in Table 3. The panel group FMOLS estimation results show that the increase in CO_2 emissions by 1% will increase biomass energy consumption by 0.3098%. In addition, the increase in natural resource depletion by 1% will decrease biomass energy consumption by 0.0249%. It also shows that the increase in biomass consumption, CO_2 emissions and natural resource depletion by 1% will increase GDP growth by 0.2164%, 0.6748% and 0.0481% respectively. Moreover, the increase in biomass energy consumption by 1% will decrease CO_2 emissions by 0.2565% and the increase in GDP growth by 1% will increase in CO_2 emissions by 0.5686%. The results also reveal that the increase in biomass energy consumption by 1% will decrease natural resource depletion by 0.8801% and the increase in GDP growth by 1% will increase natural resource depletion by 1.9618%.

lnCO	-0.3544	-0.6457

Table 3. The Results of Panel Group FMOLS Estimation

Variables	Coefficients	*t*-statistics
Dependent variable: *lnBIO*		
lnY	-0.1130	-1.6415
lnCO	0.3098***	3.5625
lnNRD	-0.0249*	-1.8266
Dependent variable: *lnY*		
lnBIO	0.2164***	3.2729
lnCO	0.6748***	11.6129
lnNRD	0.0481***	5.2642
Dependent variable: *lnCO*		
lnBIO	-0.2565***	-3.5711
lnY	0.5686***	13.2177
lnNRD	-0.0134	-1.0703
Dependent variable: *lnNRD*		
lnBIO	-0.8801*	-1.7795
lnY	1.9618***	5.0005

Finally, Table 4 represents the panel granger causality test results. In the short-run, there is a unidirectional causality from biomass energy consumption to GDP growth. Furthermore, there is bidirectional causality between biomass energy consumption and CO_2 emissions. In addition, the unidirectional causal relationship exists from GDP growth to CO_2 emissions. In the long-run, on the one hand, the biomass energy consumption, CO_2 emissions and natural resource depletion causes GDP growth. On the other hand, GDP growth, CO_2 emissions and natural resource depletion do not cause the biomass energy consumption. To sum up, the unidirectional causality from the biomass energy consumption to GDP growth indicates that the growth hypothesis is supported in G-20 countries for both of the short-run and the long-run. Similarly, the biomass energy consumption causes the CO_2 emissions for both of the short-run and the long-run.

Table 4. The Results of Panel Granger Causality Test

	Independent Variables					
	Short-run causality				Long-run causality	
	ΔlnBIO	ΔlnY	ΔlnCO	ΔlnNRD	ECT(-1)	
ΔlnBIO	-	2.1017	6.4717**	0.4013	-0.0080	[-1.4079]
ΔlnY	6.5240***	-	2.8637	0.3592	-0.0011***	[-4.4650]
ΔlnCO	4.8450*	6.5899**	-	1.0656	-0.0019***	[-4.2692]
ΔlnNRD	1.0751	2.6185	0.4630	-	-0.0015	[-0.5337]

*,** and *** indicates statistically significance at 10, 5 and 1 percent level respectively. Numbers in brackets are *t*-statistics. The optimal lag length is selected with using Schwarz Information Criteria.

5. Conclusions and Policy Implications

This study empirically investigate the relationship between biomass energy consumption, GDP growth, CO_2 emissions, and natural resource depletion in G-20 countries excluding the European Union, from 1992 to 2013. We applied panel unit root tests, the panel cointegration test, the panel FMOLS method, and panel VECM Granger causality methods in order to examine the nexus.

The results of the panel cointegration test reveal that biomass energy consumption, GDP growth, CO_2 emissions, and natural resource depletion are cointegrated. In addition, the panel FMOLS estimation results demonstrate that an increase in CO_2 emissions by 1% increases biomass energy consumption by 0.3098%. Furthermore, an increase in natural resource depletion by 1% decreases biomass energy consumption by 0.0249%. An increase in biomass consumption, CO_2 emissions, and natural resource depletion by 1% increases GDP growth by 0.2164%, 0.6748%, and 0.0481%, respectively. Moreover, an increase in biomass energy consumption by 1% decreases CO_2 emissions by 0.2565%, while an increase in GDP growth by 1% increases CO_2 emissions by 0.5686%. An increase in biomass energy consumption by 1% decreases natural resource depletion by 0.8801%, and an increase in GDP growth by 1% increases natural resource depletion by 1.9618%. The panel VECM Granger causality test results indicate that unidirectional causality exists from biomass energy consumption to GDP growth and from GDP growth to CO_2 emissions. In addition, bidirectional causality exists between biomass energy consumption and CO_2 emissions.

These empirical findings suggest some policy implications. Since the growth hypothesis is supported, the G-20 countries should increase investments in the production of biomass energy and increase the share of biomass consumption of total energy consumption. Using biomass energy plays a crucial role in reducing pollution and providing sustainable development. Moreover, investment in biomass energy should be encouraged because an increase in biomass energy consumption leads to a decrease in natural resource depletion. In summary, biomass energy is an appropriate energy source to reduce countries' dependence on energy import energy dependency, to avoid energy price volatility, and to provide green growth sustainability for the G-20 countries.

Kaynakça

Apergis, N., & Payne, J. E. (2010). Renewable energy consumption and growth in Eurasia. *Energy Economics*, *32*(6), 1392-1397.

Apergis, N., & Payne, J. E. (2010). Renewable energy consumption and economic growth: evidence from a panel of OECD countries. *Energy policy*, 38(1), 656-660.

Apergis, N., & Payne, J. E. (2011). Renewable and non-renewable electricity consumption–growth nexus: evidence from emerging market economies. *Applied Energy*, 88(12), 5226-5230.

Apergis, N., & Payne, J. E. (2014). Renewable energy, output, CO 2 emissions, and fossil fuel prices in Central America: evidence from a nonlinear panel smooth transition vector error correction model. *Energy Economics*, 42, 226-232.

Apergis, N., & Payne, J. E. (2015). Renewable energy, output, carbon dioxide emissions, and oil prices: evidence from South America. *Energy Sources, Part B: Economics, Planning, and Policy*, *10(3), 281-287*.

Apergis, N., Payne, J. E., Menyah, K., & Wolde-Rufael, Y. (2010). On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth. *Ecological Economics*, 69(11), 2255-2260.

Aydın, C., & Esen, Ö. (2017). Does Too Much Energy Consumption Harm Economic Growth for Turkish Republics in The Transition Process? New Evidence on Threshold Effects. *International Journal of Energy Economics and Policy*, 7(2), 34-43.

Aydın, F. F. (2018). D-8 Ülkelerinde Biyokütle Enerjisi Tüketimi ile Ekonomik Büyüme Arasındaki İlişki. *Anemon Muş Alparslan Üniversitesi Sosyal Bilimler Dergisi*, 6(3), 371-377.

Ben Jebli, M., Ben Youssef, S., & Apergis, N. (2014). The dynamic linkage between CO2 emissions, economic growth, renewable energy consumption, number of tourist arrivals and trade.

Bildirici, M. E. (2012). The relationship between economic growth and biomass energy consumption. *Journal of Renewable and Sustainable Energy*, 4(2), 023113.

Bildirici, M. E. (2013). Economic growth and biomass energy. *Biomass and bioenergy*, 50, 19-24.

Bildirici, M. E. (2014). Relationship between biomass energy and economic growth in transition countries: panel ARDL approach. *Gcb Bioenergy*, 6(6), 717-726.

Bildirici, M. E., & Özaksoy, F. (2013). The relationship between economic growth and biomass energy consumption in some European countries. *Journal of renewable and sustainable energy*, 5(2), 023141.

Bildirici, M., & Ersin, Ö. (2015). An Investigation of the Relationship between the biomass energy consumption, economic growth and oil prices. *Procedia-Social and Behavioral Sciences*, 210, 203-212.

Bilgili, F. (2012). The impact of biomass consumption on CO2 emissions: cointegration analyses with regime shifts. *Renewable and Sustainable Energy Reviews*, 16(7), 5349-5354.

Bilgili, F., & Ozturk, I. (2015). Biomass energy and economic growth nexus in G7 countries: Evidence from dynamic panel data. *Renewable and Sustainable Energy Reviews*, 49, 132-138.

BP (2014). British Petroleum Statistical Review of World Energy. (Accessed on 10/05/2018), http://www.bp.com/statisticalreview

Destek, M. A. (2017). Biomass energy consumption and economic growth: Evidence from top 10 biomass consumer countries. *Energy Sources, Part B: Economics, Planning, and Policy*, 12(10), 853-858.

Esen, Ö., & Bayrak, M. (2017). Does more energy consumption support economic growth in net energy-importing countries?. *Journal of Economics, Finance and Administrative Science*, 22(42), 75-98.

Global Material Flow Database (2012). Dittrich M. Global material flow database. (Accessed on 10/05/2018), www.materialflows.net

Gregory, A. W., & Hansen, B. E. (1996). Residual-based tests for cointegration in models with regime shifts. *Journal of Econometrics*, 70(1), 99-126.

Hatemi-J, A. (2008). Tests for cointegration with two unknown regime shifts with an application to financial market integration. *Empirical Economics*, 35(3), 497-505.

Hayfa, E., & Rania, B. H. (2014). The impact of the biomass energy use on CO 2 emissions: A Panel data model for 15 countries. In*: Renewable Energy Congress (IREC)*, 2014 5th International (pp. 1-6). IEEE.

Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of econometrics*, 115(1), 53-74.

Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control*, 12(2-3), 231-254.

Kang, S. J. (2012). Green growth and sustainable development in G 20: performance and prospects. Special Report of Korean Development Institute (KDI), *Seoul Google Scholar*.

Levin, A., Lin, C. F., & Chu, C. S. J. (2002). Unit root tests in panel data: asymptotic and finite-sample properties. *Journal of Econometrics*, 108(1), 1-24.

Menegaki, A.N. (2011). Growth and renewable energy in Europe: a random effect model with evidence for neutrality hypothesis. *Energy Economics*, 33:257-63.

Menyah, K., & Wolde-Rufael, Y. (2010). CO2 emissions, nuclear energy, renewable energy and economic growth in the US. *Energy Policy*, 38(6), 2911-2915.

Ozturk, I. (2010). A literature survey on energy–growth nexus. *Energy Policy*, 38(1), 340-349.

Ozturk, I., & Bilgili, F. (2015). Economic growth and biomass consumption nexus: Dynamic panel analysis for Sub-Sahara African countries. *Applied Energy*, 137, 110-116.

Payne, J. E. (2009). On the dynamics of energy consumption and output in the US. *Applied Energy*, 86(4), 575-577.

Payne, J.E. 2009 On the dynamics of energy consumption and output in the US. Applied Energy, 86(4):575-7.

Pedroni, P. (1999). Critical values for cointegration tests in heterogeneous panels with multiple regressors. Oxford Bulletin of Economics and statistics, 61(S1), 653-670.

Pedroni, P. (2000). Fully modified OLS for heterogeneous cointegrated panels. *Adv. Econ*. 15, 93–130.

Rafiq, S., Bloch, H., & Salim, R. (2014). Determinants of renewable energy adoption in China and India: a comparative analysis. *Applied Economics*, 46(22), 2700-2710.

Sadorsky, P. (2009a). Renewable energy consumption and income in emerging economies. *Energy Policy*, 37, 4021-8.

Sadorsky, P. (2009b). Renewable energy consumption, CO2 emissions and oil prices in the G7 countries. *Energy Economics*, 31(3), 456-462.

Salim, R. A., & Rafiq, S. (2012). Why do some emerging economies proactively accelerate the adoption of renewable energy?. *Energy Economics*, 34(4), 1051-1057.

The World Bank (2015). World Development Indicators, Washington DC. (Accessed on 25.08.2015), http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators

Tugcu, C. T., Ozturk, I., & Aslan, A. (2012). Renewable and non-renewable energy consumption and economic growth relationship revisited: evidence from G7 countries. *Energy economics*, 34(6), 1942-1950.

Ulucak, R., & Erdem, E. (2017). Ekonomik büyüme modellerinde çevre: ekolojik ayak izini esas alan bir uygulama. *Hacettepe Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, 35(4), 115-147.

Zeb, R., Salar, L., Awan, U., Zaman, K., & Shahbaz, M. (2014). Causal links between renewable energy, environmental degradation and economic growth in selected SAARC countries: progress towards green economy. *Renewable Energy*, 71, 123-132.