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Renewable energy in Turkey: Great potential, low but increasing utilization, and an empirical analysis on renewable energy-growth nexus

Umit Bulut[a,*], Gonul Muratoglu[b]

[a] Kirsehir Ahi Evran University, Faculty of Economics and Administrative Sciences, Department of Economics, Turkey
[b] Ankara Haci Bayram Veli University, Faculty of Economics and Administrative Sciences, Department of Economics, Turkey

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ABSTRACT

Concerns about the exhaustion of fossil energy sources, energy security problems, and increasing environmental problems have led policy makers to pay greater attention to renewable energy sources all over the world. Additionally, high current account deficits stemming from energy import dependency make substitution of fossil energy with renewable energy a necessity for Turkey. Although Turkey has a great potential in terms of renewable energy, it has not begun to utilize this great potential until recent years. However, Turkey has many motives to utilize renewable energy further.

This paper aims to investigate whether renewable energy consumption raises GDP in Turkey. For this purpose, the paper uses data spanning the period 1990–2015 and employs cointegration and causality tests which can present efficient output in small samples. The findings indicate that GDP is not related to renewable energy consumption and there is no causality between GDP and renewable energy consumption in Turkey. In conclusion, the paper argues that these findings may stem from the low share of renewable energy in total energy and Turkey needs to utilize renewable energy sources further to (i) meet energy needs for economic activities, (ii) mitigate environmental problems, and (iii) reduce energy import dependency and current account imbalances.

1. Introduction

There has been a strong opinion in the literature and global political sphere about decreasing the use of fossil energy sources, i.e. oil, natural gas, and coal, in the past few decades. Main reasons of this fact are (i) concerns about depletion of fossil sources since they are non-renewable energy sources, (ii) the urgent need to take action against global climate change, (iii) other alarming environmental effects, air pollution in particular, and (iv) the volatility of their prices (Lau et al., 2012; Nejat et al., 2015; Bilgili et al., 2017a, 2017b; Bulut, 2017). In case of Turkey, there are two additional reasons against the predominant use of fossil energy sources: (i) high levels of energy imports which contribute to large trade deficits, and ii) low self-sufficiency of the country by means of current available energy sources. Turkey's energy production is not sufficient to meet the continuously increasing energy demand of the country. As a result, Turkey has been a net importer of energy and these imports contribute to significant trade deficits. Put differently, energy import dependency of Turkey is one of the essential reasons of high trade deficit and current account deficit. These issues have brought the necessity of a rapid shift towards renewable energy sources in Turkey.

Apart from these, environmental factors have become key issues for Turkey as they are for the rest of the world. Turkey has been suffering from air pollution which (i) affects human health negatively, (ii) causes many diseases some of which are fatal, and (iii) causes health expenditures to rise and significant losses of workdays. Air pollution is mostly caused by burning of fossil fuels. Actually, burning of fossil fuels is the main reason behind the global warming and all of the other alarming climate change phenomena.[1] Climate change represents an enormous long term threat to global ecosystems and national economies (Hansen and Skinner, 2005). Turkey is a Mediterranean country and is predicted to be impacted severely by climate change effects, such as water shortage, drought, difficulties in agriculture, and heat waves (Sen,

* Corresponding author.
E-mail addresses: ubulut@ahievran.edu.tr (U. Bulut), gonuld@gazi.edu.tr (G. Muratoglu).

[1] National Aeronautics and Space Administration (NASA) defines global warming "the upward temperature trend across the entire Earth since the early 20th century, and most notably since the late 1970s, due to the increase in fossil fuel emissions since the industrial revolution". On the other hand, climate change refers to "a broad range of global phenomena created predominantly by burning fossil fuels, which add heat-trapping gases to Earth's atmosphere. These phenomena include the increased temperature trends described by global warming, but also encompass changes such as sea level rise; ice mass loss in Greenland, Antarctica, the Arctic and mountain glaciers worldwide; shifts in flower/plant blooming; and extreme weather events" (NASA, 2018).

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2013; Sahin et al., 2016). These urgent matters obligate Turkey just like every country to take serious measures in order to mitigate negative environmental effects of fossil fuel usage. Renewable energy based energy systems and policies offer the most probable solution in this matter since they are green, sustainable, and affordable due to the rapid developments in this sector. Renewable energy sources, namely biomass, geothermal, hydroelectric, solar, and wind, have much less negative effects on environment. Moreover, these effects can be minimized by some production technologies, careful planning, and by application of control measures (Toklu, 2013). Considering economic, political, and environmental reasons altogether, domestic production of renewable energy to meet the major part of the country's energy requirements seems to be the most reasonable and eventually the imperative option for Turkey.

Turkey possesses an important potential to produce renewable energy which is sustainable on the contrary to exhaustible fossil fuels. In the literature, there are several studies suggesting that renewable energy sources must have a greater share in Turkey's energy mix and that Turkey's energy policy should be reconstructed with a special focus on renewable energy because of the concerns listed above (Ediger and Kentel, 1999; Kaygusuz and Sari, 2003; Ocak et al., 2004; Ozgur, 2008; Bilgen et al., 2008; Yuksel and Kaygusuz, 2011; Capik et al., 2012; Baris and Kucukali, 2012; Simsek and Simsek, 2013; Toklu, 2013; Sahin et. al, 2016; Ozcan, 2018). Turkey's oil and lignite coal reserves are far from meeting country's fuel needs. Turkey's energy imports account for more than half of its energy requirement. In other words, shortage of supply and increasing consumption are economic reasons behind the energy imports, which in turn cause high import dependency and great trade deficits. On the other hand, depending solely on fossil fuels and a few major fossil fuel exporting countries undermine self-sufficiency of Turkey (Ozcan, 2018). Turkey would benefit a great deal from diversification of energy sources which also indicates the necessity of domestic renewable energy production for the country.

As was denoted above, there are five main types of renewable energy sources in the world. Turkey has a significant potential in all these types of renewable energy sources. As a matter of fact, there is an awareness at governmental level about the potential of Turkey in renewables, the necessity of renewable energy production, and the need to increase the share of renewable energy in total energy production and consumption in Turkey. There have been some efforts to promote renewable energy sector and to shape legislative regulations accordingly. However, there is a need for a more immediate, comprehensive, and formidable approach and a breakthrough in order to achieve renewable energy goals of the country and to solve the economic and environmental problems associated with the use of fossil fuels.

In general, policy makers and public have two expectations about renewable energy as Fang (2011) remarks. The first one is to meet energy demand for continuity in economic activities while the second one is to mitigate environmental problems that stem from the use of fossil energy sources. As Turkey is an import dependent country in terms of energy, an additional third expectation shows up for Turkey. Accordingly, policy makers can expect renewable energy to reduce import dependency and trade deficit of Turkey as well. While one needs to estimate an empirical model to examine whether renewable energy can meet the first and second expectations, he/she does not need an econometric analysis to test whether more renewable energy can decrease import dependency and trade deficit of Turkey. Because, more energy production from renewable sources can reduce energy imports and directly improve trade balance of Turkey.

Based on the explanations above, this paper focuses on the first expectation for Turkey. Put differently, the paper investigates the effects of renewable energy consumption on GDP in Turkey using annual data over the period 1990–2015. The contributions of the paper to the energy economics literature are threefold. First, though there is an extending empirical literature on renewable energy-growth nexus, there are a few papers examining this relationship for Turkey. Moreover, only Dogan (2016) investigates the effects of both non-renewable and renewable energy consumption on GDP in Turkey. Therefore, one can argue that there seems to be a research gap in this field. Second, this paper estimates a Cobb-Douglas production function to remove model specification errors and potential omitted variable problem. While doing that, the paper employs a modern perspective on economic growth. Accordingly, the empirical model includes not only conventional factors of production, namely technology, capital, and labour, but also democracy as the indicator of the institutional quality. We add democracy to the model because institutional economics has taken place in the mainstream economics in the last decades and many papers have explored that economic growth is positively related to democracy (see Barro, 1996; Acemoglu et al., 2002, 2014; Baum and Lake, 2003; Doucouliagos and Ulubasoglu, 2008; Acemoglu and Robinson, 2012, among others). Moreover, the effects of institutional quality on economic growth are neglected in the papers focusing energy-economic growth nexus. Therefore, this paper also provides researchers with new perspectives for the energy-growth nexus. Third, unlike Dogan (2016), this paper employs two estimators and two bootstrap Granger causality tests in order to yield more reliable findings about the relationship between renewable energy consumption and GDP. All these methods are capable of presenting efficient output in small samples.

The rest of the paper is organized as follows: Section 2 presents the developments in renewable energy in Turkey. Literature review is given in Section 3. Section 4 introduces the model and data. Methodology is presented in Section 5. Section 6 reports the findings. Section 7 concludes the paper with a summary of main findings and some policy proposals.

2. Current state of renewable energy utilization in Turkey

Turkey is an emerging economy and energy consumption of Turkey has rapidly grown especially in recent years. For instance, with regard to International Energy Agency (2018) (hereafter IEA) data, while Turkey's energy consumption was 40,169 ktoe in 1990, it was 57,908 ktoe in 2000, and reached 85,545 ktoe in 2014. In Turkey, the rapid pace of urbanization, positive demographic trends, economic growth and increasing per capita income are boosting energy consumption and energy consumption of Turkey is estimated to increase around 4–6% per year up to the next decade (Kaplan, 2015). On the other hand, energy production of the country appears to be poor compared to energy consumption. As a result, Turkey's dependence on foreign energy level has shown a significant increase, especially since the early 1990 and has started to run around 70% since the early 2000s (Turkish Petroleum (TP), 2017; Ministry of Energy and Natural Resources (MENR), 2018).

Turkey's import dependency of energy along with the price fluctuations of these imports make energy security one of the top priorities of the government. In the framework of energy security, commissioning of new energy production investments, ensuring the diversity of energy sources, and providing the highest level of energy efficiency stand out as important goals for Turkey. In order to avoid risks from high levels of energy dependence and to develop a sustainable energy model, the governments have made significant reforms in the last decade. For instance, due to liberalization of energy markets, many private entities participated in energy markets, which in turn created more competitive energy markets. Hence, the share of private entities in electricity generation increased to 75% in 2017 while it was 32% in 2002 (Invest in Turkey, 2018). Besides, Energy Exchange Istanbul (EXIST) was founded in 2015. Main objectives of EXIST are to manage energy markets and to provide all market participants with transparent and reliable market conditions (EXIST, 2018; Association of European Energy Exchanges (Europex), 2018). In addition, Turkish governments plan on promoting alternative solutions based on renewable energy. Over the last decade, Turkey has been pursuing an innovative energy policy for the future where renewable energy plays an important role. Turkey has proved international cooperation by signing Kyoto Protocol in 2009 and by declaring the "National renewable energy action plan for Turkey" in 2014 due to the EU's Renewable Energy Directive.

In this action plan, the redesigned energy policy of the government has been revealed which puts special emphasis on the role and the share of renewable energy. According to the plan, by 2023, Turkey aims to increase the share of renewable energy sources in electricity production and in total energy consumption to 37.6% and 20.5%, respectively. It is also aimed to reduce the energy intensity, which is calculated as units of energy consumption per unit of GDP by 2023 (MENR, 2014).

In Turkey, there have been some legislative efforts to organize and promote renewable energy production and utilization. The beginning of these legal arrangements are the laws which came into effect in 2001[2] and 2005,[3] respectively. The former is designed to encourage the electricity generation from renewable energy sources while the latter facilitates renewable energy sources such as biomass, geothermal, hydro, solar, and wind. The government, with this second law, aims to increase the share of renewable energy in electricity generation and to develop a manufacturing sector around renewables. Significant amendments were made to the electricity market law in 2008.[4] The law regarding the production of geothermal energy and the protection of natural water resources came into effect in 2007.[5] In the same year, another law to increase the efficient use of energy resources and to reduce the energy costs came into effect. This law titled 'Energy Efficiency Law'[6] also aims the protection of environment through decreasing levels of energy use. Then in 2011, 'Renewable Energy Law'[7] came into effect which introduced new and updated incentives for renewables. Within this framework, the government aimed to enhance renewable energy production using locally produced equipment. Research and development activities and some investment incentives are covered by the law such as the subsidies to companies that use solar power and/or biomass. In Turkey, government promotions of renewable energy, particularly electricity generation from renewable resources, included in these laws are licensing fees, connection to the grid, exemption from licensing and company establishment obligations and purchase obligations, feed-in-tariffs (until 2011), purchase guarantees, and land acquisitions (MENR, 2014; Baris and Kucukali, 2012; Capik et al., 2012; Simsek and Simsek, 2013).

Turkey has a great potential in terms of renewable energy sources. The geographic location of Turkey with humid and warm climate properties provide convenient circumstances to utilize renewable energy sources to a wide extent (Ediger and Kentel, 1999). The country's realizable renewable energy potential is equal to 13% of EU-27's total renewable energy potential. However, this potential in renewable energy sources has not been utilized properly. According to a study, Turkey has utilized approximately 70% of its existing economic hydropower potential, 8.9% of the wind power potential, 0.45% of the solar power potential, 30.7% of the geothermal potential, and 17.3% of its biomass potential (Ozcan, 2018). Hydroelectric power plants, biomass for heating, and geothermal energy have been the main renewable energy sources in Turkey contributing to the energy mix. In recent years, technologies such as production of electricity based on solar and wind energy have also started to be effective in the energy sector.

The data of Turkey's electricity generation by share of primary energy resources (Table 1) reveals some obvious facts about the energy mix of Turkey:

i) The share of fossil energy sources in electricity generation has always been high compared to renewable energy sources since 1970.

Table 1
Turkey's gross electricity generation by share of primary energy resources (%). Source: Turkish Electricity Transmission Company (2018) (hereafter TEIAS).

Year	Fossil Energy Sources	Hydro	Geothermal + Wind + Solar
1970	64.8	35.2	–
1980	51.2	48.8	–
1990	59.6	40.2	0.2
2000	75.2	24.7	0.1
2010	73.8	24.5	1.7
2016	67.7	24.5	7.8

ii) The share of renewables in electricity generation sharply declined from 1990 to 2000.
iii) In recent decades, the share of hydro has declined while the share of geothermal, wind, and solar has increased. The share of geothermal, wind, and solar summited with a value of 7.8 in 2016. Total share of renewables (hydro plus others) reached a level of 32.3% in 2016 which is the highest since 1990.

In conclusion, low level use of renewable energy sources requires a greater utilization of fossil fuels due to the increasing demand for energy in Turkey. Therefore, fossil energy imports lead to increases in the trade deficit. Risks arising from fossil energy supply and variability of fossil energy prices may be exposed and energy security problems may increase. Besides, economic activities may not achieve the expected development and low capacity utilization rates may show up. This can also prevent new employment opportunities as well. Last but not least, the low level use of renewable energy sources will require greater use of fossil energy sources that have negative environmental impacts which are already alarming.

3. Literature review

The energy consumption-economic growth nexus has been broadly examined in the energy economics literature since the pioneer study of Kraft and Kraft (1978). As Ozturk (2010) denotes, researchers have four hypotheses to be able to test the energy-growth nexus.

I) The first hypothesis is the growth hypothesis which is valid when there exists unidirectional causality running from energy consumption to GDP. The validity of this hypothesis means energy consumption has a role in the economic growth process. Hence, energy saving policies and measures can have a contractionary effect on GDP and an increase in energy consumption can increase GDP when this hypothesis dominates.
II) The second hypothesis is the feedback hypothesis which dominates when there occurs bidirectional causality between energy consumption and GDP. This hypothesis signifies the existence of a mutual relationship between energy consumption and GDP and imply that energy consumption and GDP affect each other.
III) The third one is the conservation hypothesis that prevails when there is unidirectional causality from GDP to energy consumption. When this hypothesis dominates, energy saving measures and policies have no effects on GDP and GDP has a positive effect on energy consumption.
IV) The last hypothesis is the neutrality hypothesis which indicates no causal relationship between energy consumption and GDP. This hypothesis implies that policies aiming to save energy have no significant effects on GDP and increases and/or decreases in GDP do not affect energy consumption.

This paper classifies the papers that examine the relationship between renewable energy consumption and GDP for Turkey under two groups. The first group of the papers examines the nexus between renewable energy consumption and GDP through a panel data framework. These

[2] Electricity Market Law (No: 4628).
[3] Law on Utilization of Renewable Energy Sources for the Purpose of Generating Electrical Energy (No: 5346).
[4] Amendments to the Electricity Market Law (No: 5784).
[5] Geothermal Resources and Natural Mineral Waters Law (No: 5686).
[6] Energy Efficiency Law (No: 5627).
[7] Amended law on Renewable Energy Law (No: 6094).

papers can be classified under two subgroups. The first subgroup of the papers (Sadorsky, 2009; Apergis and Payne, 2011, 2012; Pao et al., 2014; Shafiei and Salim, 2014) present the findings only for the whole panel. Put differently, they do not consider heterogeneity across countries while estimating the relationship between renewable energy consumption and GDP. Therefore, one cannot have direct information about the relationship between renewable energy consumption and GDP in Turkey by observing these papers' findings. The second subgroup of the papers considers heterogeneity across countries and present specific findings for Turkey. For instance, Salim and Rafiq (2012), who use data covering the period from 1980 to 2006, examine the nexus between renewable energy consumption and GDP in Brazil, China, India, Indonesia, Philippines, and Turkey. They yield findings in favour of the feedback hypothesis for Turkey. Besides, Kocak and Sarkgunesi (2017) investigate the relationship between renewable energy consumption and GDP for 9 Black Sea and Balkan countries including Turkey. They explore that the neutrality hypothesis dominates for the case of Turkey.

The second group of the papers investigates the renewable energy consumption-GDP nexus for Turkey through time series methods. For instance, Ocal and Aslan (2013) investigate the relationship between renewable energy consumption and GDP using data covering the period 1990–2010. They find out that the conservation hypothesis prevails for renewable energy consumption in Turkey. Dogan (2015) examines the relationship between renewable energy consumption and GDP using data for the period 1990–2012. He finds evidence in favour of the neutrality hypothesis. Finally, Dogan (2016) analyzes the renewable energy consumption-GDP nexus for the period 1988–2012 and yields the conservation hypothesis dominates for renewable energy consumption in Turkey.

As is seen, following the empirical literature on renewable energy consumption-GDP nexus for Turkey, one can observe that (i) Salim and Rafiq (2012) explore the validity of the feedback hypothesis, (ii) Ocal and Aslan (2013) and Dogan (2016) find the conservation hypothesis dominates, and (iii) Dogan (2015) and Kocak and Sarkgunesi (2017) find evidence in favour of the neutrality hypothesis.

4. Model and data set

This paper employs a Cobb-Douglas type production function in order to investigate the impact of renewable energy consumption on GDP in Turkey. Hence, the model of the paper includes technology, capital, and labour as additional factors of production. The model also contains democracy, fossil energy consumption, and renewable energy consumption as was denoted in the first part. Based on these explanations, the production function in the paper is described as the following:

$$Y = A^{\beta_1}K^{\beta_2}L^{\beta_3}D^{\beta_4}F^{\beta_5}R^{\beta_6}e^{u} \tag{1}$$

where Y, A, K, L, D, F, R, and e denote GDP, technology, capital, labour, democracy, fossil energy consumption, total renewable energy consumption, and the error term, respectively. The returns to scale related to the variables are indicated by the parameters β. Shahbaz et al. (2015) remark that the non-linear description is not able to present consistent results and to help policy makers in order to design and implement effective energy policies. Therefore, this paper uses a log-linear specification to examine the relationships between GDP and the independent variables above. The log-linear type of the Cobb-Douglas production is defined as the following:

$$\ln Y_t = \beta_0 + \beta_1 \ln A_t + \beta_2 \ln K_t + \beta_3 \ln L_t + \beta_4 \ln D_t + \beta_5 \ln F_t + \beta_6 R_t + u_t \tag{2}$$

where Y denotes real GDP (constant 2010 US$), A describes gross domestic spending on R&D (million US$), K stands for gross fixed capital formation (constant 2010 US$), L implies employment (total employment ages 15 +), D denotes democracy index calculated as the arithmetic mean of political rights and civil liberties ratings that are based on 1–7 scale (with 1 representing the greatest degree of freedom and 7 indicating the lowest degree of freedom), F represents fossil energy consumption (ktoe), and R denotes total renewable energy consumption (ktoe). Lastly, u is the error term. The annual data cover the period 1990–2015. Data for GDP, capital, and employment are sourced from the World Bank (2018), while technology data are obtained from OECD (2018). Besides, democracy data are extracted from Freedom House (2018). Finally, energy consumption data are obtained from IEA (2018) and World Bank (2018).

5. Methodology

5.1. Unit root test with one structural break

Prior to the examination of the cointegration relationship in the model and the estimation of independent variables' coefficients, this paper first determines the order of integration of the series in the empirical model. Unit root tests produced by Dickey and Fuller (1981) (hereafter ADF), Phillips and Perron (1988, PP), and Kwiatkowski et al. (1992) (hereafter KPSS) are widely employed in econometric analyses. The primary shortcoming of these tests is that they do not consider structural breaks in series. However, one should consider structural breaks in series before investigating a long-term relationship between variables in the empirical model. This paper therefore employs the unit root test of Zivot and Andrews (1992) (hereafter ZA) with one structural break along with the conventional unit root tests stated above. ZA test has three models, namely Model A, Model B, and Model C, and these models are defined as follows:

Model A:

$$y_t = \hat{\mu}^A + \hat{\theta}^A \mathrm{DU}_t(\hat{\lambda}) + \hat{\beta}^A t + \hat{\alpha}^A y_{t-1} + \sum_{j=1}^{k} \hat{c}_j^A \Delta y_{t-j} + \hat{e}_t \tag{3}$$

Model B:

$$y_t = \hat{\mu}^B + \hat{\gamma}^B \mathrm{DT}_t^*(\hat{\lambda}) + \hat{\beta}^B t + \hat{\alpha}^B y_{t-1} + \sum_{j=1}^{k} \hat{c}_j^B \Delta y_{t-j} + \hat{e}_t \tag{4}$$

Model C:

$$y_t = \hat{\mu}^C + \hat{\theta}^C \mathrm{DU}_t(\hat{\lambda}) + \hat{\beta}^C t + \hat{\gamma}^C \mathrm{DT}_t^*(\hat{\lambda}) + \hat{\alpha}^C y_{t-1} + \sum_{j=1}^{k} \hat{c}_j^C \Delta y_{t-j} + \hat{e}_t \tag{5}$$

where t = 1, 2, 3, …, T indicates the period, TB exhibits the time of break, and $\hat{\lambda}$ = TB/T is the break point. Model A, Model B, and Model C allow the break in intercept, trend, and in intercept and in trend, respectively. The dummy variables in the equations, namely $\mathrm{DU}_t(\hat{\lambda})$ and $\mathrm{DT}_t^*(\lambda)$, show the break in intercept and in trend, respectively. The values of dummy variables are defined as below:

$$\mathrm{DU}_t(\hat{\lambda}) = \begin{cases} 1 \; if \; t > T\lambda \\ 0 \; if \; t \le T\lambda \end{cases}$$

$$\mathrm{DT}_t^*(\hat{\lambda}) = \begin{cases} t - T\lambda \; if \; t > T\lambda \\ 0 \; if \; t \le T\lambda \end{cases}$$

While applying the test, t-statistic obtained from the test is compared with the critical values constituted by Zivot and Andrews (1992). If test statistic is greater than the critical values, then the null hypothesis of a unit root is rejected.

5.2. ARDL approach

This paper performs the autoregressive distributed lag (ARDL) approach since this cointegration test has many advantages over other cointegration tests, such as Engle and Granger (1987) and Johansen and Juselius (1990). Accordingly, the ARDL method (i) uses only one equation while other cointegration tests estimate long-run parameters through a set of equations, (ii) can be made use of whether independent variables are I(0) or I(1) (Pesaran and Shin, 1999), (iii) can avoid serial correlation and endogeneity problems (Narayan, 2004), and (iv) can present efficient output for small samples (S. Narayan and P.K. Narayan, 2004). According to this approach, first, whether there exists a cointegration relationship in the model is examined via the bounds testing approach of Pesaran et al. (2001), and then, if such a long-run relationship is present, short- and long-run parameters are estimated through the ARDL approach of Pesaran and Shin (1999).

For a model in which Y is dependent and X is independent variables, the model with intercept and trend can be built up to investigate whether there is a cointegration relationship between variables as the following:

$$\Delta Y_t=\beta_0+\beta_1 Y_{t-1}+\beta_2 X_{t-1}+\beta_3 trend + \sum_{i=1}^{p}\delta_i\Delta Y_{t-i} +\sum_{i=1}^{p}\lambda_i\Delta X_{t-i}+\varepsilon_t \quad (6)$$

To test Eq. (6), F_{IV} and F_V statistics are utilized. While the F_{IV} statistic tests the null hypothesis of no cointegration expressed as H_0: $\beta_1 = \beta_2 = \beta_3 = 0$, the F_V statistic tests the null hypothesis of cointegration stated as H_0: $\beta_1 = \beta_2 = 0$. To determine the lag length for the bounds test, the Akaike Information Criterion (AIC) and/or Schwarz Bayesian Criterion (SBC) can be made use of. The lag length presenting the lowest AIC and/or SBC is utilized among the lag lengths without serial correlation. Narayan (2005) produces new lower and upper bound critical values (I(0) and I(1), respectively) for small samples as Pesaran et al. (2001) produce critical values for sample sizes of 500 or 1000 observations. If test statistics are greater than the upper bound critical values developed by Narayan (2005), the null hypothesis of no cointegration is rejected.

After one determines the existence of a long-run relationship, he/she can set up the ARDL model to estimate both short- and long-run parameters. The optimal lag length can be determined through SBC for the ARDL (p,q) model specified as:

$$Y_t= \alpha + \sum_{i=1}^{p}\alpha_i Y_{t-i} +\sum_{i=0}^{q}\beta_i X_{t-i}+u_t \quad (7)$$

Considering this model, one can estimate the long-run parameters as follows:

$$\alpha^* =\alpha/\left(1-\sum_{i=1}^{p}\alpha_i\right) \quad (8)$$

$$\beta^*=\left(\sum_{i=0}^{q}\beta_i\right)/\left(1-\sum_{i=1}^{p}\alpha_i\right) \quad (9)$$

Then, the cointegration model depending on these estimations can be stated as:

$$\hat{Y}_t=\alpha^*+\beta^* X_t \quad (10)$$

After calculating long-run parameters, the short-run relationship between variables can be estimated by employing the error correction model based on the ARDL approach. The error correction model can be expressed as the following:

$$\Delta Y_t=\theta_0+\theta_1 EC_{t-1} +\sum_{i=1}^{p}\delta_i\Delta Y_{t-i} +\sum_{i=0}^{q}\lambda_i\Delta X_{t-i}+u_t \quad (11)$$

In Eq. (11), the one-period lagged error correction term, namely EC_{t-1}, indicates how much deviation in the short run can be corrected in the long-run (i.e., the speed of adjustment). The coefficient of the EC_{t-1} term is expected to be statistically significant and negative.

5.3. DOLS estimator

If one determines the existence of a cointegration relationship among variables, he/she can estimate long-run parameters by employing the dynamic ordinary least squares (DOLS) method developed by Stock and Watson (1993) as well. S. Narayan and P.K. Narayan (2004), P.K. Narayan and S. Narayan (2004) point out that this technique is able to report efficient estimations in small samples. Additionally, one can check the robustness of the findings of the ARDL approach by exploiting this method.

Stock and Watson (1993) propound a long-run dynamic approach which can mend serial correlation and endogeneity problems in the OLS estimation (Esteve and Requena, 2006). The DOLS model can be expressed as below:

$$y_t=\alpha_0+\alpha_1 t +\alpha_2 x_t +\sum_{i=-q}^{q}\delta_i\Delta x_{t-i}+\varepsilon_t \quad (12)$$

where y, t, x, q, Δ, and ε denote dependent variable, time trend, independent variable(s), optimal leads and lags, the first difference operator, and the error term, respectively.

5.4. Hacker and Hatemi-J (2012) Granger causality test

To examine causal relationships between two variables, Hacker and Hatemi-J (2012) produce a Granger causality based on bootstrapping. This test (i) lets the optimal lag length be determined endogenously, (ii) can perform well in small samples, and (iii) is robust to autoregressive conditional heteroscedasticity (ARCH) effects.

Hacker and Hatemi-J (2012) deal with the following vector autoregressive model VAR (k) of order k in order to test Granger causality:

$$y_t=B_0+B_1 y_{t-1}+\ldots+B_k y_{t-k}+u_t \quad (13)$$

where y_t, B_0, and u_t stand for vectors with dimensions $n \times 1$ and B_i, respectively and $i \geq 1$ is a parameter matrix with n x n dimensions. The error vector, u_t, has a zero-expected value and is supposed to be independent and identically distributed with a non-singular covariance matrix Ω which carries out the condition for some $\lambda > 0$, with u_{it} being the element of u_t. There exists non-Granger causality from the rth element of y_t to the jth element of y_t if the following expression is accurate:

$$H_0: \text{ the element in } B_i's \text{ row } j, \text{ column r is zero for } i = 1, \ldots, k \quad (14)$$

The lag order k is detected by minimizing an information criterion. Hatemi-J (2008) suggests a new information criterion that is an alternative to other criteria, such as SBC and AIC. He calls this criterion the Hatemi-J criterion (HJC). HJC is defined as:

$$HJC = \ln(\det\hat{\Omega}_j)+j2^{-1}T^{-1}(n^2\ln T + 2n^2\ln(\ln T)) \quad j = 0, \ldots, k. \quad (15)$$

where $\det\hat{\Omega}_j$ describes the determinant of the estimated maximum likelihood variance-covariance matrix of the residuals in the VAR (j) model. While n is the number of the variables, T is the sample size and ln states natural logarithm. Then, it is possible to express the VAR model as follows:

$$Y = DZ + \delta \quad (16)$$

The following step is to estimate δ_U. The variance-covariance of these residuals is computed as $S_u = (\delta_U \delta S_U')/(T-(1+nk))$, where $1 + nk$ denotes the number of estimated parameters. It is possible to clarify $\beta = vec(B_0, B_1, \ldots, B_k)$ or $\beta = vec(D)$, where vec indicates the column-stacking operator and to accept $\hat{\beta}$ as the ordinary least squares estimate of β. The Wald (W) test statistic used to test the null hypothesis of non-Granger causality is illustrated as

$$Wald = (Q\hat{\beta})'[Q((Z'Z)^{-1} \otimes S_U)Q']^{-1}(Q\hat{\beta}) \sim \chi_k^2 \quad (17)$$

where ⊗ stands for the Kronecker product, and Q denotes a k x n(1 + nk) matrix. Each of Q's k rows is related to a zero restriction on one of β's parameters. Each element in row of Q is given the value of one if the relevant parameter within the vector β is zero, given that the null hypothesis of non-causality is correct, and it is given a zero value, otherwise. By making use of these notations, the null hypothesis of non-Granger causality can also be expressed as:

$$H_0: Q\beta = 0 \quad (18)$$

If the Wald statistic is greater than the bootstrap critical values, the null hypothesis of non-Granger causality can be rejected.

5.5. Hatemi-J (2012) asymmetric Granger causality test

To test whether a variable causes another variable has greatly attracted researchers since the pioneer study by Granger (1969) on causality. Hatemi-J (2012) points out that previous papers on causality have posited positive and negative shocks have same impacts while positive and negative shocks can have different causal impacts. Starting from this, he produces an asymmetric causality test. This test not only has the same advantages as the Hacker and Hatemi-J (2012) causality test has but also allows researchers to examine asymmetric causal relationships between variables.

Hatemi-J (2012) first assumes that we have two integrated variables, y_1 and y_2, as in Eqs. (19) and (20).

$$y_{1t}=y_{1t-1}+\varepsilon_{1t}=y_{10}+\sum_{i=1}^{t}\varepsilon_{1i} \tag{19}$$

$$y_{2t}=y_{2t-1}+\varepsilon_{2t}=y_{20}+\sum_{i=1}^{t}\varepsilon_{2i} \tag{20}$$

where t = 1,2,…,T, the constants y_{10} and y_{20} denote the initial values, and the variables ε_{1i} and ε_{2i} exhibit white noise disturbance terms. This notation is used to identify positive and negative shocks: $\varepsilon_{1i}^{+} = \max(\varepsilon_{1i}, 0)$, $\varepsilon_{2i}^{+} = \max(\varepsilon_{2i}, 0)v$, $\varepsilon_{1i}^{-} = \min(\varepsilon_{1i}, 0)$, $\varepsilon_{2i}^{-} = \min(\varepsilon_{2i}, 0)$, respectively. Then, one can state $\varepsilon_{1i} = \varepsilon_{1i}^{+} + \varepsilon_{1i}^{-}$, and $\varepsilon_{2i} = \varepsilon_{2i}^{+} + \varepsilon_{2i}^{-}$. It follows that

$$y_{1t} = y_{1t-1} + \varepsilon_{1t} = y_{10} + \sum_{i=1}^{t}\varepsilon_{1i}^{+} + \sum_{i=1}^{t}\varepsilon_{1i}^{-} \tag{21}$$

$$y_{2t} = y_{2t-1} + \varepsilon_{2t} = y_{20} + \sum_{i=1}^{t}\varepsilon_{2i}^{+} + \sum_{i=1}^{t}\varepsilon_{2i}^{-} \tag{22}$$

The positive and negative shocks of each variable can be described in a cumulative form as $y_{1t}^{+} = \sum_{i=1}^{t}\varepsilon_{1i}^{+}$, $y_{1t}^{-} = \sum_{i=1}^{t}\varepsilon_{1i}^{-}$, $y_{2t}^{+} = \sum_{i=1}^{t}\varepsilon_{2i}^{+}$, $y_{2t}^{-} = \sum_{i=1}^{t}\varepsilon_{2i}^{-}$. Positive and negative shocks have permanent impacts on the variable. The next stage is to test for the causal relationship between these variables. If it is assumed that $y_t^{+} = (y_{1t}^{+}, y_{2t}^{+})$, the causality test can be applied by using the following vector autoregressive model of order p, VAR (p):

$$y_t^{+} = \nu + A_1\, y_{t-1}^{+} + \ldots + A_p\, y_{t-1}^{+} + u_t^{+} \tag{23}$$

where y_t^{+} denotes the 2 × 1 vector of variables, v stands for the 2 × 1 vector of intercepts, and u_t^{+} is a 2 × 1 vector of error terms. The matrix A_r represents a 2 × 2 matrix of parameters for lag order r (r = 1, …, p). The optimal lag order can be specified by using the HJC.

After detecting the optimal lag order, the null hypothesis that kth element of y_t^{+} does not Granger cause the ωth element of y_t^{+} is tested. This hypothesis is defined as the following:

$$H_0: \text{the row } \omega, \text{ column k element in } A_r \text{ is equal to zero for } r = 1, \ldots, p \tag{24}$$

The Wald test statistic can be used to test the null hypothesis of non-Granger causality defined as H_0: $C\hat{\beta} = 0$:

$$\text{Wald} = (C\beta)'[C((Z'Z)^{-1}\otimes S_U)C']^{-1}(C\beta) \tag{25}$$

where β = vec(D) and vec stands for the column-stacking operator, ⊗ indicates the Kronecker product, and C denotes a p x n(1 + np) indicator matrix. S_U stands for the estimated variance-covariance matrix of the unrestricted VAR model estimated as $S_U = \frac{\hat{\delta}_U'\hat{\delta}_U}{T-q}$, where q is the number of parameters in each equation of the VAR model. If the calculated Wald statistic is greater than the bootstrap critical values, the null hypothesis of non-Granger causality is rejected.

Table 2
Unit root tests without structural breaks[a].

Variable		ADF	PP	KPSS
lnY	Level	0.679	0.735	0.752[b]
	1st difference	− 4.939[b]	− 4.939[b]	0.146
lnA	Level	− 0.642	− 0.643	0.752[b]
	1st difference	− 6.194[b]	− 6.194[b]	0.044
lnK	Level	− 0.245	− 0.156	0.724[c]
	1st difference	− 5.426[b]	− 5.426[b]	0.082
lnL	Level	− 0.463	0.021	0.472[c]
	1st difference	− 3.032[c]	− 3.032[c]	0.233
lnD	Level	− 1.510	− 1.726	0.257
	1st difference	− 3.635[c]	− 3.635[c]	0.176
lnF	Level	− 0.588	− 0.416	0.751[c]
	1st difference	− 6.801[b]	− 11.593[b]	0.500[c]
lnR	Level	− 2.906	− 2.798	0.152
	1st difference	− 6.670[b]	− 6.697[b]	0.219

[a] Critical values for ADF and PP tests are −3.824, −2.986, and −2.632 at 1%, 5%, and 10% levels of significance, respectively. Critical values for KPSS test are 0.739, 0.463, and 0.347 at 1%, 5%, and 10% levels of significance, respectively.
[b] Indicates 1% statistical significance.
[c] Indicates 5% statistical significance.

6. Findings

To examine the order of integration of the variables, the paper first employs ADF, PP, and KPSS unit root tests. While ADF and PP methods test for the null hypothesis of the existence of a unit root, the null hypothesis of KPSS test indicates a stationary variable.

The findings of these unit root tests are reported in Table 2. As is seen, lnY, lnA, lnK, lnL, and lnF are stationary at first difference with regard to all unit root tests. Put differently, these variables are integrated of order 1 (I(1)). Besides, while lnD and lnR are stationary at first difference with regard to ADF and PP unit root tests, KPSS test indicates that these variables are stationary at level (I(0)). Put differently, unit root tests show mixed evidence for lnD and lnR.

Table 3 presents the results of the ZA unit root test with one structural break. One can observe from the table that lnA and lnD are stationary at level while lnY, lnK, and lnL are stationary at first difference. He/she can also observe that ZA unit root test exhibits mixed evidence for lnF and lnR. Hence, unit root tests explore that the ARDL approach should be employed to examine the cointegration relationship in the empirical model.

On the other hand, the break dates indicated by the ZA unit root test correspond to some considerable periods for Turkey. Therefore, some of them should be clarified before applying the cointegration test. Accordingly, the economic crises in 2000/2001 may account for the break dates detected in 1999–2001 while the high growth performance of the Turkish economy may account for the breaks in 2002–2007. Finally, the global financial crisis may account for the breaks in detected in 2008 and 2009.

Table 4 presents the results of the ARDL test. Panel A of Table 4 depicts whether there exists a cointegration relationship in the model. The results of the bounds test indicate that both test statistics are greater than the upper bound critical values, implying there is a cointegration relationship among variables in the model. Therefore, the ARDL model can be performed to estimate both long- and short-run coefficients of the variables. The long-run parameters are reported in Panel B of Table 4. As is seen, the coefficients of lnA, lnK, lnL, and lnF are positive and statistically significant, with values of 0.107, 0.351, 0.502, and 0.137, respectively, while the coefficient of lnD is negative and statistically significant with the value of −0.045. Additionally, the coefficient of lnR is 0.024 and statistically insignificant.

Appendix A depicts the findings of long- and short-run ARDL estimates. The most remarkable finding is that the one-period lagged error correction term is negative and statistically significant (-1.026). This

Table 3
ZA unit root test[a].

Variable		Model A	Model B	Model C
lnY	Level	−3.496 (1999)	−2.992 (2002)	−4.748 (2001)
	1st difference	−5.196[c]	−4.986[b]	−5.085[c]
lnA	Level	−6.824[b] (2007)	−6.457[b] (1995)	−6.336[b] (2007)
	1st difference	−7.171[b]	−6.164[b]	−7.804[b]
lnK	Level	−3.432 (1999)	−3.172 (2002)	−3.835 (2004)
	1st difference	−5.767[b]	−5.242[b]	−5.739[b]
lnL	Level	−2.417 (2010)	−1.917 (2005)	−3.962 (2004)
	1st difference	−4.624[d]	−5.262[b]	−5.061[d]
lnD	Level	−7.137[b] (2002)	−4.242[d] (2005)	−4.944[d] (2002)
	1st difference	−5.267[c]	−5.323[b]	−5.931[b]
lnF	Level	−4.289 (2013)	−4.306[d] (2008)	−5.136[c] (2006)
	1st difference	−7.168[b]	−6.592[b]	−6.985[b]
lnR	Level	−4.778[d] (2000)	−4.171[d] (2009)	−4.524 (2000)
	1st difference	−7.273[b]	−6.909[b]	−7.103[b]

[a] In model A, critical values for 1%, 5%, and 10% significance levels are −5.34, −4.80, and −4.58, respectively. In model B, critical values for 1%, 5%, and 10% significance levels are −4.93, −4.42, and −4.11, respectively. In model C, critical values for 1%, 5%, and 10% significance levels are −5.57, −5.08, and −4.82, respectively.
[b] Indicates 1% statistical significance.
[c] Indicates 5% statistical significance.
[d] Indicates 10% statistical significance.

Table 4
ARDL estimations.

Panel A: The results of the bounds test			
Test Statistics			
F_{IV}		F_V	
4.103[a]		4.303[a]	
10% critical values[b]			
I(0)	I(1)	I(0)	I(1)
2.781	3.941	2.977	4.260
Panel B: Long-run parameters			
Variable	Coefficient	Std. error	t-statistic
lnA	0.107[c]	0.017	6.157
lnK	0.351[c]	0.012	28.275
lnL	0.502[c]	0.054	9.166
lnD	− 0.045[d]	0.023	− 1.907
lnF	0.137[c]	0.035	3.881
lnR	0.024	0.021	1.126

[a] Indicates the rejection of the null hypothesis of no cointegration.
[b] Critical values are obtained from Narayan (2005).
[c] Illustrates 1% statistical significance.
[d] Illustrates 10% statistical significance.

finding concurs with the results depicted in Panel A part of Table 4, which indicate there exists a cointegration relationship, showing the short-run deviations are mended in the long run. In addition, the value of the error correction term means the speed of adjustment to reach the long-run cointegration at the current period. Then, one can argue that a short-run deviation from equilibrium is corrected in 0.97 year (1/1.026).

Lastly, stability of the parameters in long- and short-run models are tested via the CUSUM and CUSUM-Q tests produced by Brown et al. (1975). If CUSUM and CUSUM-Q statistics appear in the critical bounds, one can determine the estimated parameters are stable. The results of CUSUM and CUSUM-Q tests for long- and short-run models are presented in Appendix B. One can note that CUSUM-Q statistic in the long-run model exhibits a small deviation from the upper critical bound and then takes part in the critical bounds, while other statistics take part in the critical bounds over the sample period. Hence, the findings of CUSUM and CUSUM-Q tests show that the parameters in the long- and short-run models seem to be stable over the period 1990–2015.

The findings of the DOLS estimator are depicted in Table 5. Accordingly, the DOLS estimator explores that lnA, lnK, lnL, lnD, lnF, and lnR have the estimations of 0.096, 0.293, 0.483, −0.030, 0.245, and −0.033, respectively. Among these coefficients, the coefficients of lnD and lnR are statistically insignificant while other coefficients are statistically significant.

Table 5
DOLS estimates.

Variable	Coefficient	Std. error	t-statistic
lnA	0.096[a]	0.027	3.514
lnK	0.293[a]	0.028	10.363
lnL	0.483[a]	0.089	5.382
lnD	− 0.030	0.033	− 0.932
lnF	0.245[a]	0.067	3.641
lnR	− 0.033	0.061	− 0.453

[a] Illustrates 1% statistical significance.

At this stage, it should be reminded that the negative and statistically significant coefficient of democracy index indicates that democracy index positively affects GDP since a decrease in democracy index shows an improvement in level of democracy. Accordingly, the ARDL approach explores that GDP is positively related to technology, capital, labour, democracy index, and fossil energy consumption and is not related to renewable energy consumption. Besides, the DOLS estimator reveals that GDP is positively related to technology, capital, labour, and fossil energy consumption and is not related to democracy index and renewable energy consumption.

Then, the findings of the ARDL model and the DOLS estimator are compatible with neo-classical and endogenous growth models, focusing on technology, capital, and labour as the determiners of economic growth. Besides, while the findings of the ARDL model regarding democracy concur with those of the papers mentioned in the first part, the findings of the DOLS estimator for democracy exhibit no relationship between democracy and economic growth (see Gerring et al., 2005 for a historical perspective on democracy-economic growth nexus).

Table 6 exhibits the results of the Hacker and Hatemi-J (2012) bootstrap Granger causality tests. As is seen from the table, the only causal relationship runs from lnY to lnD with regard to this causality test. Accordingly, the null hypothesis of no causality from lnY to lnD can be rejected at 10% significance level while other null hypotheses can not be rejected at any significance levels. This finding implies that democratic demands in Turkey increase when incomes of people rise. Table 6 therefore reports that neither fossil energy consumption nor renewable energy consumption Granger cause GDP in Turkey.

Table 7 demonstrates the results of the Hatemi-J (2012) asymmetric causality test. As is presented, the only causal relationship runs from lnL^- to lnY^-. According to this, the null hypothesis that a negative shock in lnL does not cause a negative shock in LY can be rejected at 10% significance level while other null hypotheses can not be rejected at any significance

Table 6
Hacker and Hatemi-J (2012) causality test[a].

Null hypothesis	Wald statistic	Critical values[b]		
		1%	5%	10%
lnA does not Granger cause lnY	0.162	9.365	4.518	3.098
lnY does not Granger cause lnA	0.782	9.186	4.761	3.207
lnK does not Granger cause lnY	1.325	8.260	4.339	2.955
lnY does not Granger cause lnK	1.179	8.425	4.307	2.967
lnL does not Granger cause lnY	0.073	9.062	4.663	3.150
lnY does not Granger cause lnL	0.038	10.193	5.278	3.566
lnD does not Granger cause lnY	1.514	8.187	4.450	2.977
lnY does not Granger cause lnD	3.546[c]	8.278	4.486	3.017
lnF does not Granger cause lnY	0.213	8.566	4.414	3.037
lnY does not Granger cause lnF	0.035	9.607	5.083	3.426
lnR does not Granger cause lnY	0.820	8.439	4.397	2.993
lnY does not Granger cause lnR	0.032	8.297	4.478	3.118

[a] HJC is utilized to specify the optimal lag length.
[b] Critical values are calculated using 10,000 bootstrap replications.
[c] Indicates 10% statistical significance.

Table 7
Hatemi-J (2012) asymmetric causality test[a].

Null hypothesis	Wald statistic	Critical values[b]		
		1%	5%	10%
$\ln A^{+}$ does not Granger cause $\ln Y^{+}$	2.430	191.439	34.789	16.330
$\ln A^{-}$ does not Granger cause $\ln Y^{-}$	7.142	145.119	28.900	14.231
$\ln Y^{+}$ does not Granger cause $\ln A^{+}$	5.474	197.015	40.027	19.463
$\ln Y^{-}$ does not Granger cause $\ln A^{-}$	0.044	209.477	41.519	19.503
$\ln K^{+}$ does not Granger cause $\ln Y^{+}$	2.889	184.649	38.255	17.734
$\ln K^{-}$ does not Granger cause $\ln Y^{-}$	5.566	247.166	40.890	18.272
$\ln Y^{+}$ does not Granger cause $\ln K^{+}$	7.019	218.638	38.131	17.306
$\ln Y^{-}$ does not Granger cause $\ln K^{-}$	3.644	130.538	26.938	13.599
$\ln L^{+}$ does not Granger cause $\ln Y^{+}$	2.090	18.941	7.416	4.440
$\ln L^{-}$ does not Granger cause $\ln Y^{-}$	5.078[c]	18.732	6.543	3.992
$\ln Y^{+}$ does not Granger cause $\ln L^{+}$	0.009	15.278	6.317	3.980
$\ln Y^{-}$ does not Granger cause $\ln L^{-}$	3.122	16.490	6.730	4.075
$\ln D^{+}$ does not Granger cause $\ln Y^{+}$	0.451	185.879	37.509	17.494
$\ln D^{-}$ does not Granger cause $\ln Y^{-}$	0.388	19.576	6.549	3.848
$\ln Y^{+}$ does not Granger cause $\ln D^{+}$	0.005	185.494	31.587	14.357
$\ln Y^{-}$ does not Granger cause $\ln D^{-}$	4.529	27.015	8.460	4.825
$\ln F^{+}$ does not Granger cause $\ln Y^{+}$	1.104	242.692	49.849	24.135
$\ln F^{-}$ does not Granger cause $\ln Y^{-}$	1.664	181.614	32.555	15.919
$\ln Y^{+}$ does not Granger cause $\ln F^{+}$	1.673	180.951	36.246	16.565
$\ln Y^{-}$ does not Granger cause $\ln F^{-}$	3.405	184.804	37.022	17.921
$\ln R^{+}$ does not Granger cause $\ln Y^{+}$	0.681	158.334	31.681	14.995
$\ln R^{-}$ does not Granger cause $\ln Y^{-}$	7.649	240.681	50.593	23.547
$\ln Y^{+}$ does not Granger cause $\ln R^{+}$	8.643	276.722	51.312	24.068
$\ln Y^{-}$ does not Granger cause $\ln R^{-}$	0.404	211.714	39.773	18.865

[a] HJC is used to detect the optimal lag length.
[b] Critical values are generated via 10,000 bootstrap replications.
[c] Indicates 10% statistical significance.

levels. One can therefore detect that neither fossil energy consumption nor renewable energy consumption Granger cause GDP in Turkey.

Based on the findings obtained from the ARDL cointegration method, the DOLS estimator, the Hacker and Hatemi-J (2012) bootstrap Granger causality test, and the Hatemi-J (2012) bootstrap Granger causality test, the paper yields that the growth hypothesis prevails for the case of fossil energy consumption and the neutrality hypothesis dominates for the case of renewable energy consumption in Turkey. Therefore, the findings of this paper for renewable energy consumption appear to concur with those of Dogan (2015) and Kocak and Sarkgunesi (2017). Moreoever, if one considers the findings of Ocal and Aslan (2013) and Dogan (2016) which are in favour of the conservation hypothesis, he/she can argue that all these papers along with this paper explore that saving policies and measures for renewable energy have no effects on GDP in Turkey.

7. Conclusion and policy proposals

Considering worrisome concerns about climate change along with economic and politic problems arising from the use of fossil fuels, a renewable energy focused approach has stood out to handle the dual pressure of climate change and increasing consumption levels of energy (Hansen and Skinner, 2005). Turkey has a significant potential for the production and deployment of most of the renewable energy sources. However, when one observes energy data for Turkey, he/she can observe that the share of renewable energy in total energy is still very low compared to fossil energy even though the share of renewable energy in electricity production has increased in Turkey in the last years.

Policy makers around the world expect renewable energy to (i) meet energy needs for sustainable development, (ii) decrease environmental problems, such as air pollution, global warming, and climate change, stemming from the use of fossil sources, and (iii) provide energy security. Policy makers in Turkey have two more expectations regarding renewable energy. Accordingly, substitution of fossil energy with renewable energy can decrease energy import dependency and improve current account balance of Turkey.

This paper tests whether renewable energy can meet the first expectation denoted above. Put differently, this paper examines the relationships between renewable energy consumption and GDP in Turkey using data over the period 1990–2015 within a Cobb-Douglas production function framework including a democracy index. The paper also adds fossil energy consumption to the empirical model to make a comparative analysis. It employs time series techniques which can present efficient output in small samples. The findings show the growth hypothesis dominates for the case of fossil energy consumption while the neutrality hypothesis prevails for the case of renewable energy consumption. Then, the findings of the paper majorly conform to those of other papers which investigate the renewable energy consumption-GDP nexus for Turkey.

In the energy economics literature, some papers try to explain the possible reasons of the neutrality hypothesis. For instance, Ghali and El-Sakka (2004) remark that when an economy grows, its production structure is likely to shift from industry sector to information and service sectors, which are not energy intensive sectors. Besides, Apergis and Payne (2009), Belloumi (2009), and Menegaki (2011) reveal similar arguments about the dominance of the neutrality hypothesis for renewable energy. Accordingly, while Apergis and Payne (2009) and Belloumi (2009) assert that the neutrality hypothesis can be valid when renewable energy is a little component of GDP, Menegaki (2011) specifies that the neutrality hypothesis can prevail due to early stages of development of renewable energy and thus insufficient utilization of renewable energy sources. According to the Central Bank of the Republic of Turkey (2018) data, the share of industrial sector in GDP has increased during 1998–2017 in Turkey (from 19% to 21.6%). Therefore, Turkey's production structure did not change too much over the last two decades. As was presented in Section 2, in order to utilize great potential in terms of renewable energy, the Turkish governments (i) made some significant legislative arrangements for renewable energy, (ii) implemented many policies towards renewable energy, and (iii) made energy sector more competitive. As a result, the share of renewable energy in total energy has begun to increase in recent years. However, it still low compared to fossil energy. Therefore, in accordance with the views of Apergis and Payne (2009), Belloumi (2009), and Menegaki (2011), this paper argues that the low share of renewable energy may lead to the validity of the neutrality hypothesis for renewable energy in Turkey. This paper therefore contends that renewable energy can satisfy expectations regarding economic growth if the share of renewable energy increases in Turkey. Moreover, it advocates that renewable energy can (i) mitigate environmental problems, (ii) contribute to energy security, (iii) decrease energy import dependency, and (iv) improve current account balance. This paper also argues that production of more energy from renewable sources can improve allocation of resources in Turkey. Accordingly, if current account balance of Turkey can be improved through more utilization of renewable energy sources, then more resources can be allocated for renewable energy along with technology and capital, which in turn affect economic growth positively. Hence, this paper supports the substitution of fossil energy with renewable energy and asserts that renewable energy can meet the expectations above if the Turkish government provides more incentives and becomes more active for renewable energy.

There are a number of studies in the literature that emphasize the role of the government in Turkey in the production and consumption of renewable energy. Some of these studies are Simsek and Simsek (2013), Kaygusuz (2002), Kaygusuz and Sari (2003), Baris and Kucukali (2012), Toklu (2013), and Ozcan (2018). It is widely agreed that government needs to form a more comprehensive and efficient energy policy along with an uncompromising implementation of it. Within this framework, some policy recommendations can be suggested as follows:

- It is indeed very important for the government to design upgraded energy policies with a special focus on production and the widespread use of renewable energy sources in Turkey.

- To this end, energy policies should aim to attract both the private sector and foreign investors. In this way, funds for investments in this sector would be mobilized by domestic and foreign private firms.
- Government funds should be directed to speed infrastructure investments up since a well-established and strong infrastructure would reduce production costs, make production available, and therefore attract more private firms to renewable energy sector.
- Renewable energy production is a relatively new area. Obtaining the most efficient and cost-friendly production technologies of renewables are of crucial importance. For this reason, Turkish government should prioritize to invest in developing brand new renewable energy production technologies. This means increasing research and development expenditures and all sorts of scientific activities funded by government agencies.
- Upgraded and updated subsidies need to be transferred to the renewable energy sector for further and enhanced development. Current subsidies on fossil fuels should gradually be transferred to renewable energy sources. Besides, other incentive mechanisms need to be accompanied by regulatory policies to promote production and the widespread use of renewables.
- Negative effects of renewables on the environment are much fewer than those of fossil fuels and renewable energy is supposed to be green and clean. However, both production and utilization of renewables may also have some negative environmental effects although they are small. It is important to eliminate or minimize these potential negative effects of renewable energy sources by proper calibration of production technologies and meticulous planning of the government.
- Extensive afforestation programs must be executed in Turkey. In addition to this, exploitation of the forests need to be controlled more efficiently.
- Evaluation of economic analysis criteria of hydroelectric power plants need to be carried out according to current conditions.
- It has been mentioned that hydropower is the major renewable energy source in Turkey. Government should not solely depend on this type of electricity generation among all renewable energy sources. Other renewable energy sources in Turkey need to be utilized to the fullest extent.
- The work required to strengthen the electricity transmission systems to allow for the interconnection of plants with intermittent production, such as more wind and solar energy power plants, should be accelerated.
- Continuation of regeneration of geothermal resources in accordance with conservation principles should be carried out.
- It is not enough for governments to support the development of renewable energy technologies. They must also support their commercial application all over the country.
- More comprehensive and continuously updated measures to reduce greenhouse gas emissions are needed.
- Imposing carbon taxes on fossil fuels to create a fund which can be used to incentivize and increase the deployment of renewables in Turkey should be considered. This would also allow renewable energy sources to compete with fossil fuels under more fair circumstances (Ozcan, 2018).
- Informing the public and organizing training campaigns on the utilization of renewable energy would contribute to the efficient and widespread use of renewables. Organization of these activities and events need to be prioritized in the agenda of related government agencies.

Appendix A

See Table A1.

Table A1
Long-run and short-run ARDL models.

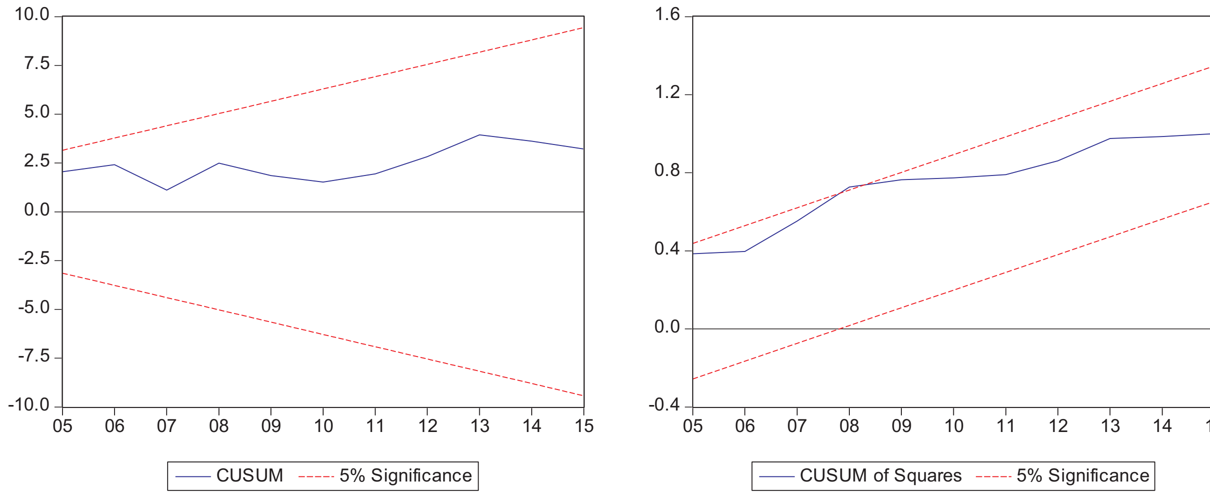
Panel A: Long-run ARDL model[a]			
Variable	Coefficient	Std. error	t-statistic
lnA[c]	0.048	0.017	2.722
lnA(−1)	− 0.002	0.017	− 0.159
lnA(−2)[b]	0.061	0.009	6.453
lnK[b]	0.284	0.015	18.143
lnK(−1)[b]	0.066	0.011	5.825
lnL[b]	0.358	0.060	5.887
lnL(−1)[c]	− 0.181	0.079	− 2.288
lnL(−2)[b]	0.325	0.055	5.862
lnD[b]	− 0.108	0.020	− 5.398
lnD(−1)[b]	0.062	0.019	3.199
lnF[b]	0.137	0.035	3.880
lnR	0.024	0.021	1.126
Diagnostic tests			
R^2 = 0.99, $\bar{R}^2$ = 0.99, F-ist = 6732.273 (0.000), χ^2_{RR} = 0.182 (0.678), χ^2_{BG} = 1.367 (0.303)			
χ^2_{WH} = 1.077 (0.454)			
Panel B: Short-run ARDL model[a]			
Variable	Coefficient	Std. error	t-statistic
dlnA[b]	0.048	0.011	4.350
dlnA(−1)[b]	− 0.063	0.011	− 5.498
dlnK[b]	0.284	0.010	28.174
dlnL[b]	0.361	0.041	8.788
dlnL(−1)[b]	− 0.337	0.061	− 5.481
dlnD[b]	− 0.110	0.017	− 6.172
dlnF[b]	0.138	0.034	4.059
dlnR[c]	0.028	0.013	2.243
EC(−1)[b]	− 1.026	0.134	− 7.653
Diagnostic tests			
R^2 = 0.99, $\bar{R}^2$ = 0.99, F−ist = 264.026(0.000) , χ^2_{RR} = 0.022(0.883) , χ^2_{BG} = 1.677(0.227)			
χ^2_{WH} = 1.409 (0.272)			

Notes: [a] χ^2_{RR}, χ^2_{BG}, and χ^2_{WH} stand for Ramsey Reset test for statistic for regression specification error, Breusch-Godfrey LM test statistic for no serial correlation, and White's test statistic for no heteroscedasticity. Values in parentheses are prob. values. [b] Illustrates 1% statistical significance. [c] Illustrates 5% statistical significance.

Appendix B. CUSUM and CUSUM-Q tests

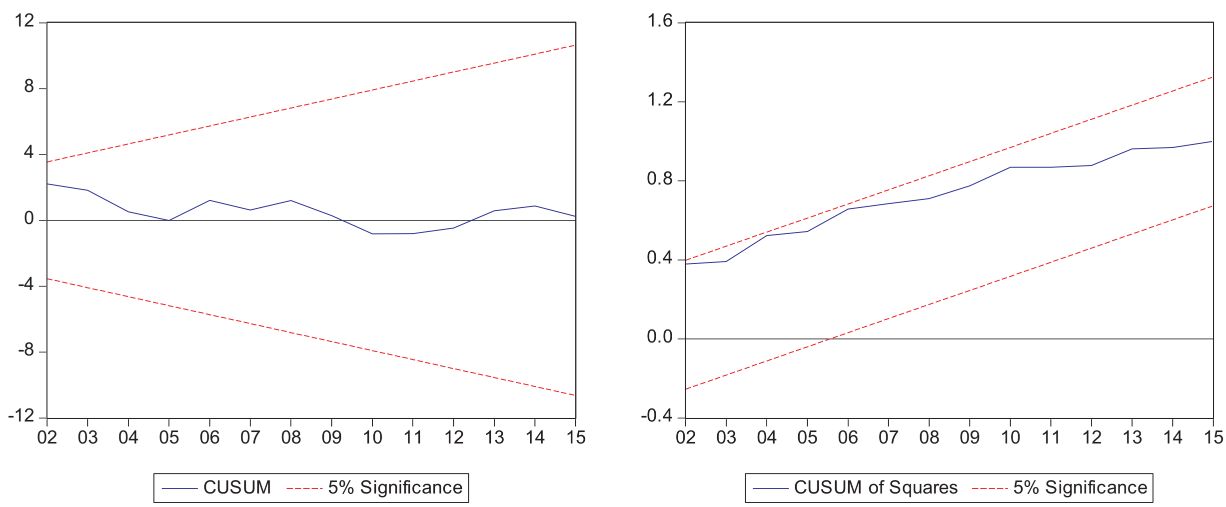
Appendix B1

Results for the long-run ARDL model



Appendix B2

Results for the short-run ARDL model



References

Acemoglu, D., Johnson, S., Robinson, J.A., 2002. Reversal of fortune: geography and institutions in the making of the modern world income distribution. Q. J. Econ. 117, 1231–1294.

Acemoglu, D., Robinson, J.A., 2012. Why Nations Fail: the Origins of Power, Prosperity, and Poverty. Crown Publishers, New York.

Acemoglu, D., Naidu, S., Restrepo, P., Robinson, J.A., 2014. Democracy does cause growth. National Bureau Econ. Res. 20004.

Apergis, N., Payne, J.E., 2009. Energy consumption and economic growth in Central America: evidence from a panel cointegration and error correction model. Energy Econ. 31, 211–216.

Apergis, N., Payne, J.E., 2011. On the causal dynamics between renewable and non-renewable energy consumption and economic growth in developed and developing countries. Energy Syst. 2, 299–312.

Apergis, N., Payne, J.E., 2012. Renewable and non-renewable energy consumption-growth nexus: evidence from a panel error correction model. Energy Econ. 34, 733–738.

Baris, K., Kucukali, S., 2012. Availibility of renewable energy sources in Turkey: current situation, potential, government policies and the EU perspective. Energy Policy 42, 377–391.

Barro, R.J., 1996. Democracy and growth. J. Econ. Growth 1, 1–27.

Baum, M.A., Lake, D.A., 2003. The political economy of growth: democracy and human capital. Am. J. Political Sci. 47, 333–347.

Belloumi, M., 2009. Energy consumption and GDP in Tunisia: cointegration and causality analysis. Energy Policy 37, 2745–2753.

Bilgen, S., Keles, S., Kaygusuz, A., Sari, A., Kaygusuz, K., 2008. Global warming and renewable energy sources for sustainable development: a case study in Turkey. Renew. Sustain. Energy Rev. 12, 372–396.

Bilgili, F., Kocak, E., Bulut, U., Kuloglu, A., 2017a. The impact of urbanization on energy intensity: panel data evidence considering cross-sectional dependence and heterogeneity. Energy 133, 242–256.

Bilgili, F., Kocak, E., Bulut, U., Kuskaya, S., 2017b. Can biomass energy be an efficient policy tool for sustainable development? Renew. Sustain. Energy Rev. 71, 830–845.

Brown, R.L., Durbin, J., Evans, J.M., 1975. Techniques for testing the constancy of regression relationships over time. J. R. Stat. Soc. 37, 149–192.

Bulut, U., 2017. The impacts of non-renewable and renewable energy on CO_2 emissions in Turkey. Environ. Sci. Pollut. Res. 24, 15416–15426.

Capik, M., Yılmaz, A.O., Cavusoglu, I., 2012. Present situation and potential role of renewable energy in Turkey. Renew. Energy 46, 1–13.

CBRT, 2018. Electronic data delivery system. ⟨https://evds2.tcmb.gov.tr/⟩ (Accessed 1 August 2018).

Dickey, D.A., Fuller, W.A., 1981. Likelihood ratio statistics for autoregressive time series with a unit root. Econometrica 49, 1057–1072.

Dogan, E., 2015. The relationship between economic growth and electricity consumption

from renewable and non-renewable sources: a study of Turkey. Renew. Sustain. Energy Rev. 52, 534–546.
Dogan, E., 2016. Analyzing the linkage between renewable and non-renewable energy consumption and economic growth by considering structural break in time-series data. Renew. Energy 99, 1126–1136.
Doucouliagos, H., Ulubasoglu, M.A., 2008. Democracy and economic growth: a meta-analysis. Am. J. Political Sci. 52, 61–83.
Ediger, V.S., Kentel, E., 1999. Renewable energy potential as an alternative to fossil fuels in Turkey. Energy Convers. Manag. 40, 743–755.
Engle, R.F., Granger, C.W.J., 1987. Co-integration and error correction: representation, estimation, and testing. Econometrica 55, 251–276.
Esteve, V., Requena, F.A., 2006. Cointegration analysis of car advertising and sales data in the presence of structural change. Int. J. Econ. Bus. 13, 111–128.
Europex, 2018. ⟨https://www.europex.org/members/epias-energy-exchange-istanbul/⟩ (Accessed 1 August 2018).
EXIST, 2018. ⟨https://www.epias.com.tr/en/corporate/about-us⟩ (Accessed 1 August 2018).
Fang, Y., 2011. Economic welfare impacts from renewable energy consumption: the China experience. Renew. Sustain. Energy Rev. 15, 5120–5128.
Freedom House, 2018. ⟨https://freedomhouse.org/report-types/freedom-world⟩ (Accessed 28 July 2018).
Gerring, J., Bond, P., Barndt, W.T., Moreno, C., 2005. Democracy and economic growth: a historical perspective. World Polit. 57, 323–364.
Ghali, K.H., El-Sakka, M.I., 2004. Energy use and output growth in Canada: a multivariate cointegration analysis. Energy Econ. 26, 225–238.
Granger, C.W.J., 1969. Investigating causal relations by econometric models and cross-spectral methods. Econometrica 37, 424–438.
Hansen, C.J., Skinner, R., 2005. Nuclear Power and Renewables: Strange Bedfellows? ⟨https://www.oxfordenergy.org/publications/nuclear-power-and-renewables-strange-bedfellows/⟩ (Accessed 23 April 2018).
Hacker, S., Hatemi-J, A., 2012. A bootstrap test for causality with endogenous lag length choice: theory and application in finance. J. Econ. Stud. 39, 144–160.
Hatemi-J, A., 2008. Forecasting properties of a new method to determine optimal lag order in stable and unstable VAR models. Appl. Econ. Lett. 15, 239–243.
Hatemi-J, A., 2012. Asymmetric causality tests with an application. Empir. Econ. 43, 447–456.
IEA, 2018. Statistics. ⟨http://www.iea.org/statistics/⟩ (Accessed 23 April 2018).
Invest in Turkey, 2018. Energy and renewables. ⟨http://www.invest.gov.tr/en-US/sectors/Pages/Energy.aspx⟩ (Accessed 1 August 2018).
Johansen, S., Juselius, K., 1990. Maximum likelihood estimation and inference on cointegration-with applications to the demand for money. Oxf. Bull. Econ. Stat. 52, 169–210.
Kaplan, D., 2015. Renewable energy Turkey: opportunity? ⟨https://www.rvo.nl/sites/default/files/2015/10/Renewable%20Energy%20Turkey.pdf⟩ (Accessed 15 February 2018).
Kaygusuz, K., 2002. Environmental impacts of energy utilisation and renewable energy policies in Turkey. Energy Policy 30, 689–698.
Kaygusuz, K., Sari, A., 2003. Renewable energy potential and utilization in Turkey. Energy Convers. Manag. 44, 459–478.
Kocak, E., Sarkgunesi, A., 2017. The renewable energy and economic growth nexus in Black Sea and Balkan countries. Energy Policy 100, 51–57.
Kraft, J., Kraft, A., 1978. Relationship between energy and GNP. J. Energy Dev. 3, 401–403.
Kwiatkowski, D., Phillips, P.C., Schmidt, P., Shin, Y., 1992. Testing the null hypothesis of stationarity against the alternative of a unit root: how sure are we that economic time series have a unit root? J. Econom. 54, 159–178.
Lau, L.C., Lee, K.T., Mohamed, A.R., 2012. Global warming mitigation and renewable energy policy development from the Kyoto Protocol to the Copenhagen Accord-A comment. Renew. Sustain. Energy Rev. 16, 5280–5284.
Menegaki, A.N., 2011. Growth and renewable energy in Europe: a random effect model with evidence for neutrality hypothesis. Energy Econ. 33, 257–263.
MENR, 2014. National renewable energy action plan for Turkey. ⟨http://www.eie.gov.tr/duyurular_haberler/h_2015_ulusal_enerji.aspx⟩ (Accessed 1 February 2018).
MENR, 2018. Energy statistics report 2017. ⟨http://www.enerji.gov.tr/tr-TR/EIGM-Raporlari⟩ (Accessed 1 March 2018).
Narayan, P.K., 2004. Fiji's tourism demand: the ARDL approach to cointegration. Tour. Econ. 10, 193–206.
Narayan, S., Narayan, P.K., 2004a. Determinants for demand for Fiji's exports: an empirical investigation. Dev. Econ. 42, 95–112.
Narayan, P.K., Narayan, S., 2004b. The J-curve: evidence from Fiji. Int. Rev. Appl. Econ. 18, 369–380.
Narayan, P.K., 2005. The saving and investment nexus for China: evidence from cointegration tests. Appl. Econ. 37, 1979–1990.
NASA, 2018. What's in a name? Weather, global warming and climate change. ⟨https://climate.nasa.gov/resources/global-warming/⟩ (Accessed 21 May 2018).
Nejat, P., Jomehzadeh, F., Taheri, M.M., Gohari, M., Majid, M.Z.A., 2015. A global review of energy consumption, CO_2 emissions and policy in the residential sector (with an overview of the top ten CO_2 emitting countries). Renew. Sustain. Energy Rev. 43, 843–862.
Ocak, M., Ocak, Z., Bilgen, S., Keles, S., Kaygusuz, K., 2004. Energy utilization, environmental pollution and renewable energy sources in Turkey. Energy Convers. Manag. 45, 845–864.
Ocal, O., Aslan, A., 2013. Renewable energy consumption–economic growth nexus in Turkey. Renew. Sustain. Energy Rev. 28, 494–499.
OECD, 2018. ⟨https://data.oecd.org/⟩ (Accessed 27 July 2018).
Ozcan, M., 2018. The role of renewables in increasing Turkey's self-sufficiency in electrical energy. Renew. Sustain. Energy Rev. 82, 2629–2639.
Ozgur, M.,A., 2008. Review of Turkey's renewable energy potential. Renew. Energy 33, 2345–2356.
Ozturk, I., 2010. A literature survey on energy–growth nexus. Energy Policy 38, 340–349.
Pao, H.T., Li, Y.Y., Fu, H.C., 2014. Clean energy, non-clean energy, and economic growth in the MIST countries. Energy Policy 67, 932–942.
Pesaran, M.H., Shin, Y., 1999. An autoregressive distributed lag modelling approach to cointegration analysis. In: Strom, S. (Ed.), Econometrics and Econometric Theory in the 20th Century: the Ragnar Frisch Centennial Symposium. Cambridge University Press, Cambridge, pp. 371–413.
Pesaran, M.H., Shin, Y., Smith, R.J., 2001. Bounds testing approach to the analysis of level relationships. J. Appl. Econom. 16, 289–326.
Phillips, P.C., Perron, P., 1988. Testing for a unit root in time series regression. Biometrika 75, 335–346.
Sadorsky, P., 2009. Renewable energy consumption and income in emerging economies. Energy Policy 37, 4021–4028.
Salim, R.A., Rafiq, S., 2012. Why do some emerging economies proactively accelerate the adoption of renewable energy? Energy Econ. 34, 1051–1057.
Sen, O.L., 2013. A holistic view of climate change and its impacts in Turkey. ⟨http://ipc.sabanciuniv.edu/wp-content/uploads/2013/12/IklimDegisikligiRapor.06.12.13.rev1_.pdf⟩ (Accessed 1 May 2018).
Shafiei, S., Salim, R.A., 2014. Non-renewable and renewable energy consumption and CO_2 emissions in OECD countries: a comparative analysis. Energy Policy 66, 547–556.
Shahbaz, M., Loganathan, M., Zeshan, M., Zaman, K., 2015. Does renewable energy consumption add in economic growth? An application of auto-regressive distributed lag model in Pakistan. Renew. Sustain. Energy Rev. 44, 576–585.
Simsek, H.A., Simsek, N., 2013. Recent incentives for renewable energy in Turkey. Energy Policy 63, 521–530.
Sahin, U., Asici, A.A., Acar, S., Gedikkaya-Bal P., Karababa, A.O., Kurnaz, L., 2016. Coal report: Turkey's coal policies related to climate change, economy and health. ⟨http://ipc.sabanciuniv.edu/wp-content/uploads/2016/01/Coal-Report-Turkeys-Coal-Policies-Related-to-Climate-Change-Economy-and-Health.pdf⟩ (Accessed 23 April 2018).
Stock, J.H., Watson, M., 1993. A simple estimator of cointegrating vectors in higher order integrated systems. Econometrica 61, 783–820.
TEIAS, 2018. Turkey's gross electricity generation by share of primary energy resources. ⟨https://www.teias.gov.tr⟩ (Accessed 3 March 2018).
Toklu, E., 2013. Overview of potential and utilization of renewable energy sources in Turkey. Renew. Energy 50, 456–463.
TP, 2017. Crude Oil and Natural Gas Sector Report (in Turkish). ⟨http://www.tpao.gov.tr/tp5/docs/rapor/sektorrapor3105.pdf⟩ (Accessed 15 January 2018).
World Bank, 2018. World Bank Open Data. ⟨https://data.worldbank.org/⟩ (Accessed 23 April 2018).
Yuksel, I., Kaygusuz, K., 2011. Renewable energy sources for clean and sustainable energy policies in Turkey. Renew. Sustain. Energy Rev. 15, 4132–4144.
Zivot, E., Andrews, D.W.K, 1992. Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis. J. Bus. Econ. Stat. 10, 251–270.