Environ Sci Pollut Res
DOI 10.1007/s11356-017-9175-2

RESEARCH ARTICLE

The impacts of non-renewable and renewable energy on CO_2 emissions in Turkey

Umit Bulut[1]

Received: 28 February 2017 / Accepted: 1 May 2017

Abstract As a result of great increases in CO_2 emissions in the last few decades, many papers have examined the relationship between renewable energy and CO_2 emissions in the energy economics literature, because as a clean energy source, renewable energy can reduce CO_2 emissions and solve environmental problems stemming from increases in CO_2 emissions. When one analyses these papers, he/she will observe that they employ fixed parameter estimation methods, and time-varying effects of non-renewable and renewable energy consumption/production on greenhouse gas emissions are ignored. In order to fulfil this gap in the literature, this paper examines the effects of non-renewable and renewable energy on CO_2 emissions in Turkey over the period 1970–2013 by employing fixed parameter and time-varying parameter estimation methods. Estimation methods reveal that CO_2 emissions are positively related to non-renewable energy and renewable energy in Turkey. Since policy makers expect renewable energy to decrease CO_2 emissions, this paper argues that renewable energy is not able to satisfy the expectations of policy makers though fewer CO_2 emissions arise through production of electricity using renewable sources. In conclusion, the paper argues that policy makers should implement long-term energy policies in Turkey.

Keywords Greenhouse gas emissions · Carbon dioxide emissions · Renewable energy · Non-renewable energy · Fixed parameter and time-varying parameter estimation methods · Turkey

Responsible editor: Philippe Garrigues

✉ Umit Bulut
ubulut@ahievran.edu.tr

[1] Faculty of Economics and Administrative Sciences, Department of Economics, Ahi Evran University, 40100 Kırşehir, Turkey

Introduction

Even though standard growth models do not consider energy as an input for economic activities, energy is a basic factor of production in a modern economy (Rafiq and Salim 2009). Sadorsky (2009) denotes that energy consumption level is considered as a development indicator in the energy economics literature. Increases in economic activities and in industrialization and acceleration of urbanization result in increases in energy demand (Salim et al. 2008; Bilgili et al. 2016b). Hence, demand for energy sources rapidly increased in the last 50 years (Aslan et al. 2014). As British Petroleum (BP 2016) and World Bank (2016) exhibit, while the world primary energy demand grew by 17.7% from 2005 to 2013, the share of fossil energy sources, such as oil, natural gas and coal, in total primary energy demand was 81% in 2013. Put differently, the world counts on fossil energy sources, since most of the energy is produced through fossil energy sources (Salim et al. 2014). This dependence leads to major environmental problems, such as global warming, climate change and air pollution (Lau et al. 2012; Nejat et al. 2015; Kocak and Sarkgunesi 2017) because greenhouse gas emissions (GHGs), such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluorinated gases, arise from the usage of fossil sources. With regard to the World Bank (2016) and US Environmental Protection Agency (EPA 2017) data, global GHGs almost doubled from 1970 to 2012, and CO_2 had the greatest share in global GHGs with 76% in 2014. Therefore, CO_2 emissions seem to be the main reason of the environmental problems, especially global warming and climate change (Wuebbles et al. 2002; Lau et al. 2012; Saboori and Sulaiman 2013; Nejat et al.

Published online: 16 May 2017

2015; Bilgili et al. 2017). CO_2 intensity in the atmosphere has rapidly risen since the industrial revolution and has warmed the Earth (Maslin 2004; Narayan 2007; Swapnesh et al. 2014; Bilgili et al. 2017). One can observe that global CO_2 emissions increased by 45% from 2000 to 2013 through the World Bank (2016) data.

Since environmental pollution has become one of the largest global issues because of great increases in GHGs (Dogan and Seker 2016a), many meetings have been organized since 1970s in order to decrease environmental problems. The United Nations Conference on the Human Environment held in Stockholm in 1972, Rio de Janeiro Earth Summit in 1992, Kyoto Protocol shaped in 1997 and entered into force in 2005, and the 2015 United Nations Climate Change Conference in Paris were principal attempts to reduce environmental problems stemming from fossil energy sources.

After these attempts, policy makers have paid attention to renewable energy sources which are regarded as clean energy sources to decrease environmental problems and to ensure sustainable development (Bilgili and Ozturk 2015; Ozturk and Bilgili 2015; Bilgili et al. 2016b) because energy policies that can reduce the dependency on fossil sources and can decrease the environmental problems are needed for sustainable growth. Renewable energy sources are biomass, hydroelectric, geothermal, solar and wind. As Fang (2011) points out, policy makers have two expectations about renewable energy. First, renewable energy can meet energy needs for economic activities, and second, renewable energy is able to decrease environmental problems stemming from the usage of fossil energy sources. Hence, the need for renewable energy technologies and production has reshaped energy policies of countries, and production of renewable energy has been stimulated by many countries through tax incentives, sectoral subsidies, investment subsidies and other supports (Bilgili et al. 2016a; Kocak and Sarkgunesi 2017).

Today, China and the USA are the countries with the greatest CO_2 emissions in the world. With regard to the World Bank (2016) data, in 2013, the shares of China and the USA in global CO_2 emissions were 28.59 and 14.46%, respectively. During 1960–2013, China's CO_2 emissions annually grew by 5.98%, while the USA's CO_2 emissions annually grew by 1.36%. On the other hand, as an emerging market economy, the growth in CO_2 emissions of Turkey was higher than those of China and the USA during the same period. Turkey's CO_2 emissions annually grew by 6.87% during 1960–2013. Figure 1 presents CO_2 emissions with the base year 1960 (1960 = 100) for the world, the USA, China and Turkey.

As is seen from the figure, the increase in Turkey's CO_2 emissions is greater compared to the world, China and the USA during 1960–2013. As a result of this rapid increase, the share of Turkey in global CO_2 emissions reached 0.90% in 2013 while it was 0.39% in 1980. If growth rates of the Turkish economy increase in the following periods, the share of Turkey in global CO_2 emissions has the potential to increase.

Based on these figures, this paper focuses on the second expectation about renewable energy for Turkey. Put differently, this paper examines the effects of non-renewable and renewable energy on CO_2 emissions by using annual data from 1970 to 2013. The contribution of the paper to the empirical research is twofold. The first contribution arises from the sample. As a result of the rapid increases in Turkey's CO_2 emissions, renewable energy policies of Turkey along with the findings of the paper may be considerable for the rest of the world. As will be presented in the last section of the paper, the policy makers in Turkey have noticed this event and focused on renewable energy sources especially since 2005. Second, while other papers in literature estimate fixed parameters to specify the determinants of CO_2 emissions in Turkey, this paper employs not only fixed parameter estimation methods but also Kalman filter to observe time-varying parameters of non-renewable and renewable energy. Therefore, the main contribution of this paper to the energy economics literature is that this is the first paper that presents time-varying parameters of non-renewable and renewable energy for Turkey. Thus, this paper aims at presenting more reliable output about the relationship between energy consumption and CO_2 emissions.

The rest of the paper is planned as follows: "Brief literature" section presents empirical literature. "Model and data" section is devoted to reveal model and data. "Methodology and findings" section presents estimation methodology and reports findings. "Conclusion" section concludes the paper with a summary of main findings and some policy proposals.

Brief literature

When one examines the literature on the relationship between total, non-renewable, and/or renewable energy and CO_2 emissions, he/she will observe that many papers have been performed so far (see e.g. Soytas et al. 2007; Apergis and Payne 2009; Atici 2009; Chiu and Chang 2009; Apergis et al. 2010; Menyah and Wolde-Rufael 2010; Hossain 2011; Jalil and Feridun 2011; Pao and Tsai 2011; Pao et al. 2011; Chandran and Tang 2013; Omri 2013; Shahbaz et al. 2013; Boluk and Mert 2014; Cowan et al. 2014; Farhani and Shahbaz 2014; Lopez-Menendez et al. 2014; Shahbaz et al. 2014; Shafiei and Salim 2014; Ajmi et al. 2015; Al-Mulali et al. 2015a, b, c; Baek 2015; Farhani and Ozturk 2015; Kasman and Duman 2015; Tang and Tan 2015; Dogan and Seker 2016a, b; Dogan and Turkekul 2016; Jebli et al. 2016). Among these papers, Boluk and Mert (2014), Farhani and Shahbaz (2014), Shafiei and Salim (2014), Al-Mulali et al. (2015b), Dogan and Seker (2016a, b) and Jebli et al. (2016) examine the effects of both non-renewable and renewable energy on CO_2 emissions.

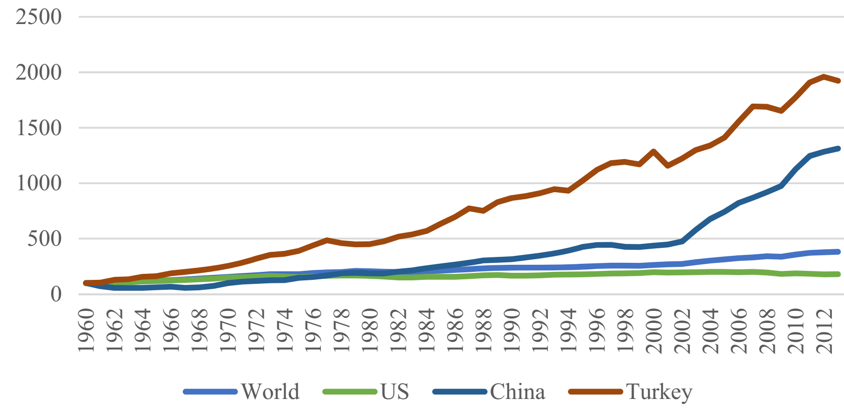


Fig. 1 CO_2 emissions (1960 = 100). Source: World Bank

Accordingly, Boluk and Mert (2014) and Farhani and Shahbaz (2014) explore that both non-renewable and renewable energy consumption increase CO_2 emissions in European Union countries and MENA countries, respectively. Shafiei and Salim (2014), Dogan and Seker (2016a), Dogan and Seker (2016b) and Jebli et al. (2016) find that non-renewable energy consumption raises CO_2 emissions while renewable energy consumption reduces CO_2 emissions in OECD countries, European Union countries, top renewable energy countries and OECD countries, respectively. In addition, Al-Mulali et al. (2015b) yield that non-renewable energy consumption enhances CO_2 emissions, while renewable energy consumption has no effects on CO_2 emissions in Vietnam.

Besides these papers, some papers examine the relationships between total, non-renewable, and/or renewable energy and CO_2 emissions for Turkey. For instance, Say and Yucel (2006) yield that total energy consumption affects CO_2 emissions positively using data from 1970 to 2002. Halicioglu (2009) employs data from 1960 to 2005 and examines the relationships between total energy consumption and CO_2 emissions. He yields that energy consumption has statistically significant impacts on CO_2 emissions and that there is bidirectional causality between variables. Soytas and Sari (2009) analyse the causal relationships between total energy consumption and CO_2 emissions using data from 1960 to 2000. They explore that there is unidirectional causality running from CO_2 emissions to energy consumption. Ozturk and Acaravci (2010) utilize data covering the period 1968–2005 to investigate the causal relationships between total energy consumption and CO_2 emissions. They yield that there is no causality between energy consumption and CO_2 emissions. Yavuz (2014) utilizes data covering the period 1960–2007 and finds that CO_2 emissions are positively related to total energy consumption. Boluk and Mert (2015) examine the impact of electricity production from renewable sources on CO_2 emissions using data from 1961 to 2010. They yield that electricity production from renewable sources has statistically significant and negative effects on CO_2 emissions. Seker et al. (2015), using data from 1974 to 2010, find that CO_2 emissions are positively related to total energy consumption and that there is unidirectional causality from CO_2 emissions to energy consumption.

Table 1 summarizes the empirical literature about the relationship between energy consumption and CO_2 emissions for Turkey.

One can observe, throughout the empirical literature for Turkey, that (i) there are no papers that examine the effects of non-renewable and renewable energy on CO_2 emissions one by one, and (ii) all papers examining the relationships between energy and CO_2 emissions employ fixed parameter estimation methods. This paper investigates the effects of both non-renewable and renewable energy on CO_2 emissions by employing both fixed parameter and time-varying parameter estimation methods. Hence, this paper tries to fulfil a considerable gap in the empirical literature.

Model and data

This paper follows time series analysis in order to examine the effects of non-renewable and renewable energy on CO_2 emissions in Turkey. Based on the explanations in the "Introduction" section and the empirical literature given in the "Brief literature" section, the paper employs a function in which CO_2 emissions are related to GDP, electricity production from non-renewable sources and electricity production from renewable sources. Since this paper essentially analyses the effects of non-renewable and renewable energy on CO_2 emissions, the empirical model in the paper uses GDP as the control variable, and the paper does not examine the validity of the environmental Kuznets curve hypothesis by following Say and Yucel (2006), Chang (2010), Hossain (2011), Alam et al. (2012), Farhani and Ben Rejeb (2012), Omri (2013), Park and Hong (2013) and Shahbaz et al. (2013). If

Table 1 Empirical literature on the energy-CO_2 emissions nexus for Turkey

Paper	Period	Finding(s)
Say and Yucel (2006)	1970–2002	TEC contributes to CO_2
Halicioglu (2009)	1960–2005	TEC contributes to CO_2, TEC↔CO_2
Soytas and Sari (2009)	1960–2000	CO2 → TEC
Ozturk and Acaravci (2010)	1968–2005	TEC ≠→CO_2
Yavuz (2014)	1960–2007	TEC contributes to CO_2
Boluk and Mert (2015)	1961–2010	EPRS reduces CO_2
Seker et al. (2015)	1974–2010	TEC contributes to CO_2, CO_2 → TEC

TEC, CO_2, EPRS, →, ↔ and ≠→ refer to the total energy consumption, CO_2 emissions, electricity production from renewable sources, unidirectional Granger causality, bidirectional Granger causality and no Granger causality, respectively.

natural logarithmic values of variables are used, the empirical model can be stated as the following:

$$\ln CO_{2t} = \beta_0 + \beta_1 \ln GDP_t + \beta_2 \ln EPNRS_t + \beta_3 nEPRS_t + \varepsilon_t \quad (1)$$

where $\ln CO_2$, lnGDP, lnEPNRS and lnEPRS stand for natural logarithmic forms of CO_2 emissions (kt), gross domestic product at market prices (constant 2010 USD), electricity production from non-renewable sources (GWh) and electricity production from renewable sources (GWh), respectively. Besides, ε denotes error term. Non-renewable energy sources are coal, liquid fuels and natural gas, while renewable energy sources are hydro, geothermal, solar, wind, solid biomass, biogas and waste. While data for CO_2 emissions and GDP are obtained from World Bank (2016), electricity production data are extracted from Turkish Statistical Institute (TSI 2016).

One can have initial observations of natural logarithms of the variables by observing Figs. 2, 3, 4 and 5. These figures present the line graphs and trends of the variables. As seen, all variables are fitted well with their polynomial trends. The variables $\ln CO_2$, lnGDP, lnEPNRS and lnEPRS follow the trends of [y = 7E − 06 × ^{3}–0.0008 × ^{2} + 0.0698× + 10.667], [y = 4E − 06 × ^{3}–0.0003 × ^{2} + 0.0465× + 25.656], [y = −5E − 05 × ^{3} + 0.0031 × ^{2} + 0.0303× + 8.8221] and [y = 6E − 05 × ^{3}–0.0054 × ^{2} + 0.2057× + 7.5828], respectively. The trend lines of the variables yield the goodness of fit measure R^2 of [0.9896], [0.9927], [0.9895] and [0.9484], respectively.

One observes from Figs. 2, 3, 4 and 5 that all variables tend to go upward from 1970 to 2013. The average slopes of $\ln CO_2$, lnGDP, lnEPNRS and lnEPRS are 0.054, 0.039, 0.270 and 0.082, respectively. Considering average slopes, one finds out that (i) lnEPNRS has the highest upward trend by far, (ii) lnEPRS has the second highest increasing rate throughout time, (iii) $\ln CO_2$ has the third upward trend and (iv) the smallest average slope belongs to lnGDP.

Whether or not lnGDP, lnEPNRS and lnEPRS have statistically significant impacts of $\ln CO_2$ in Turkey, they will be determined in the following section through fixed parameter and time-varying parameter estimation methods.

Methodology and findings

Preliminary tests: unit root and cointegration

Determining the order of integration of variables is the first step in time series analyses in order to avoid possible spurious regression problem. Unit root tests suggested by Dickey and

Fig. 2 CO_2 emissions of Turkey

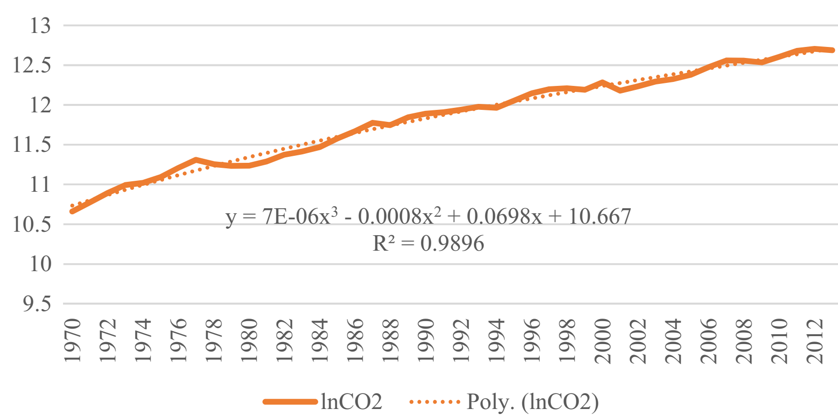
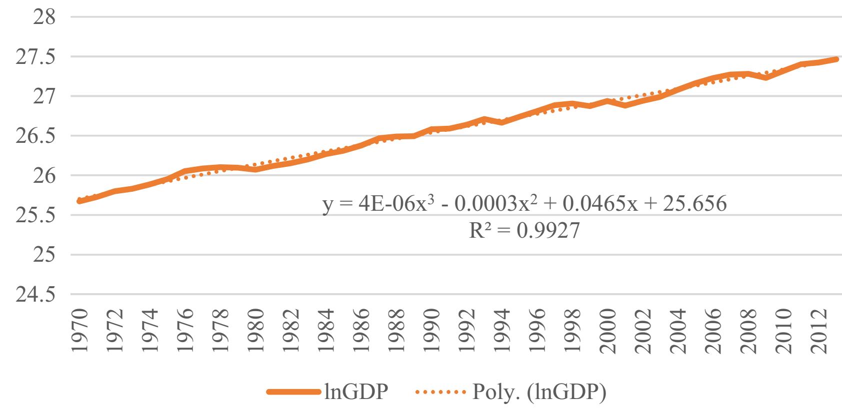


Fig. 3 GDP of Turkey



Fuller (1981, henceforth ADF) and by Phillips and Perron (1988, henceforth PP) are commonly conducted in econometric analyses to determine the order of integration of variables. In addition, the cointegration test produced by Johansen (1998, 1991) is widely performed in econometric analyses. Hence, this paper first conducts unit root and cointegration tests.

Table 2 reports the results of the unit root and cointegration tests. As is seen from the table, both unit root tests reveal that the null hypothesis of a unit root can be rejected at first differences for all variables. In other words, the unit root tests explore that all variables are integrated of order one. Therefore, whether there is a cointegration relationship in the model that can be investigated by way of the Johansen (1998, 1991) cointegration test, this cointegration test depicts that there is a cointegration relationship among variables in the model with regard to trace and max-eigen statistics.

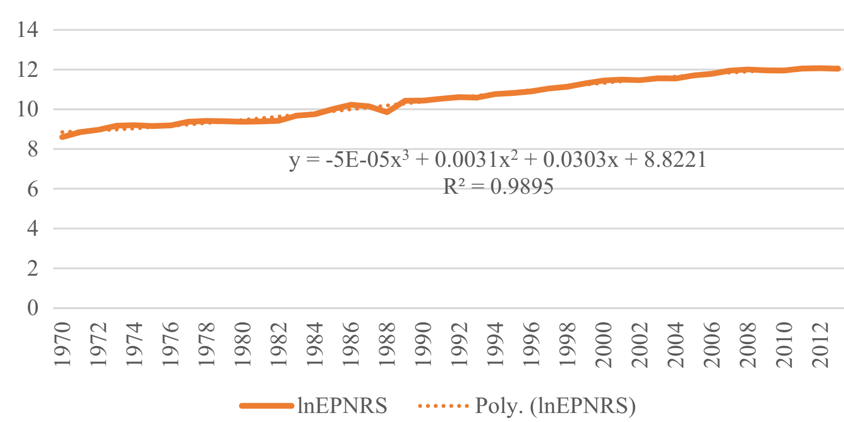
Unit root and cointegration tests without structural breaks may present biased and inefficient output when there exist structural breaks. This paper therefore employs relatively new unit root and cointegration tests considering structural breaks by following Salim and Bloch (2009) and Salim et al. (2014) before estimating coefficients of independent variables. Accordingly, the paper employs the unit root test developed by Narayan and Popp (2010) and the cointegration test produced by Maki (2012).

Narayan and Popp (2010) develop a unit root test with two structural breaks that are endogenously determined. They suggest two models allowing for two structural breaks. The first model, namely M1, allows for two structural breaks in intercept, while the second model, namely M2, allows for two structural breaks in intercept and trend. Maki (2012) develops a cointegration test considering up to five structural breaks. Since the data set consists of 44 observations, the paper lets two breaks and considers level shifts for the Maki (2012) cointegration test.

Table 3 presents the results of the Narayan and Popp (2010) unit root test and Maki (2012) cointegration test.

Table 3 presents the results of the Narayan and Popp (2010) unit root and Maki (2012) cointegration tests. As is seen, the null hypothesis of a unit root can be rejected at first differences for all variables. Put differently, all variables are integrated of order one. Besides, there is a cointegration relationship among variables as the test statistic is greater than 5% critical value with regard to the Maki (2012) cointegration test. Hence, the level values of the series can be used in order to estimate the independent variables' coefficients.

Fig. 4 Electricity production from non-renewable sources in Turkey



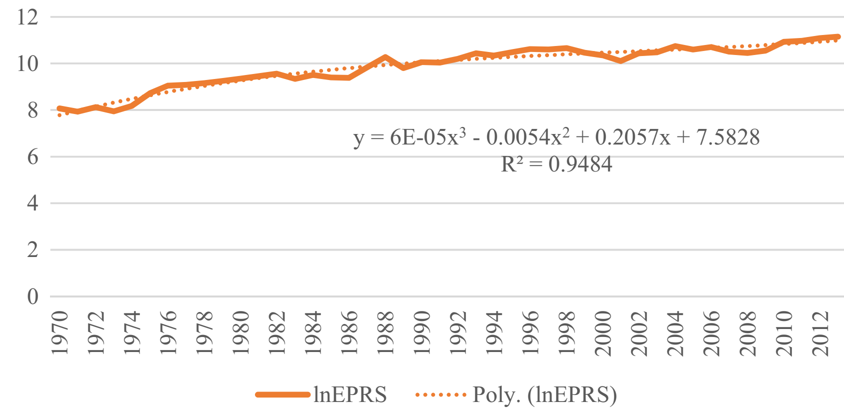


Fig. 5 Electricity production from renewable sources in Turkey

Prior to presenting long-term coefficients, this paper remarks the break dates obtained from these tests, since these break dates correspond to considerable periods for the Turkish economy. Accordingly, the second oil crises triggered by the Iranian Revolution may account for the break detected in 1979, while the efforts to liberalise the Turkish economy may account for the breaks detected in 1980s. Besides, the breaks detected in 1993 and 2000 correspond to the years before 1994 and 2001 crises, respectively.

Fixed parameter estimation methods: fully modified ordinary least squares and dynamic ordinary least squares estimators

If there is a cointegration relationship among variables, long-term coefficients can be estimated by performing the fully modified ordinary least squares (FMOLS) method produced by Phillips and Hansen (1990) and the dynamic ordinary least squares (DOLS) approach suggested by Stock and Watson (1993). As Narayan and Narayan (2004a, b) point out, these methods are able to present reliable output in small samples. Besides, the employment of both methods provides a check for the robustness of the findings.

The FMOLS estimator has two advantages. First, it corrects for possible endogeneity and serial correlation problems. Second, it asymptotically removes the sample bias. In a general form, the FMOLS model can be stated as follows:

$$y_t = \alpha_0 + \alpha_1 x_t + \varepsilon_t \tag{2}$$

where y_t denotes an I(1) variable and x_t stands for a (kx1) vector of I(1) regressors. By assumption, x_t has the following

Table 2 Unit root and cointegration tests without breaks

Panel A: unit root tests					
Variable	ADF test statistic		PP test statistic		
	Level	1st difference	Level	1st difference	
$lnCO_2$	−2.118	−5.827[a]	−2.272	−5.795[a]	
lnGDP	−0.612	−6.535[a]	−0.620	−6.625[a]	
lnEPNRS	−1.159	−7.895[a]	−1407	−9.332[a]	
lnEPRS	−1.476	−7.211[a]	−1.691	−7.447[a]	
Panel B: Johansen (1998, 1991) cointegration test[c, d]					
Null hypothesis	Alternative hypothesis	Trace statistic	Null hypothesis	Alternative hypothesis	Max-eigen statistic
r = 0	r > 0	51.184[b]	r = 0	r = 1	27.955[b]
r = 1	r > 1	23.229	r = 1	r = 2	11.761
r = 2	r > 2	11.467	r = 2	r = 3	10.874
r = 3	r > 3	0.592	r = 3	r = 4	0.592

[a] 1% statistical significance

[b] 5% statistical significance

[c] The number of the cointegrating vectors

[d] Optimal lag length without serial correlation is determined through Schwarz Bayesian Criterion (SBC) and is found 2.

Table 3 Unit root and cointegration tests with breaks

Panel A: Narayan and Popp (2010) unit root test[a, b]

Variable	M1 test statistic		M2 test statistic	
	Level	1st difference	Level	1st difference
$lnCO_2$	−2.247 (1984, 2000)	−5.760[d]	−4.190 (1988, 2000)	−5.627[e]
lnGDP	−3.423 (1979, 2000)	−6.278[d]	−3.534 (1993, 2000)	−6.306[d]
lnEPNRS	−3.169 (1988, 1990)	−6.217[d]	−2.023 (1984, 2000)	−9.243[d]
lnEPRS	−2.421 (1987, 1989)	−6.687[d]	−4.017 (1982, 1988)	−6.921[d]
Panel B: Maki (2012) cointegration test[c]				
Model	Test statistic		Break dates	
Level shift	−5.829[e]		1990, 2009	

[a] For M1, critical values for 1, 5 and 10% levels of significance are −5.259, −4.514 and −4.143, respectively. For M2, critical values for 1, 5 and 10% levels of significance are −5.949, −5.181 and −4.789, respectively

[b] Break dates are reported in parentheses

[c] Critical values for 1, 5 and 10% levels of significance are −5.984, −5.517 and −5.272, respectively

[d] 1% statistical significance

[e] 5% statistical significance

first difference stationary process:

$$\Delta x_t = \gamma + \beta_t \tag{3}$$

where γ signifies a kx1 vector of drift parameters, and β is a kx1 vector of I(0) variables.

Stock and Watson (1993) estimate a long-run dynamic equation which includes explanatory variables along with the leads and lags of differences of explanatory variables. This method can correct the possible endogeneity and serial correlation problems in the OLS estimation (Esteve and Requene 2006). The DOLS model can be written as is stated in Eq. (4):

$$y_t = \alpha_0 + \alpha_1 t + \alpha_2 x_t + \sum_{i=q}^{q} \delta_i \Delta x_{t-i} + \varepsilon_t \tag{4}$$

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

Table 4 reports the results of the FMOLS and DOLS estimators. As is seen, all variables' coefficients are statistically significant with regard to both estimators. Besides, the results of the FMOLS estimator are similar to those of the DOLS estimator. Accordingly, for the FMOLS estimator, GDP, electricity production from non-renewable sources, and electricity production from renewable sources have the estimations of 0.367, 0.236 and 0.161, respectively. Besides, for the DOLS estimator, GDP, electricity production from non-renewable sources and electricity production from renewable sources have the estimations of 0.396, 0.216 and 0.194, respectively. The findings obtained from the FMOLS and DOLS estimators therefore indicate that CO_2 emissions are positively related to GDP, electricity production from non-renewable sources and electricity production from renewable sources. Another important finding explored through the FMOLS and DOLS estimators is that the coefficient of electricity production from renewable sources is lower than that of electricity production from non-renewable sources. Put differently, fewer CO_2 emissions arise when electricity is produced through renewable energy sources.

Time-varying parameter estimation method: Kalman filter

The state space form is a powerful tool that enables researchers to handle a large number of time series models (Harvey 1989). The Kalman filter is a state space model which uses recursive estimation algorithms to examine the dynamic relationships among variables.

A linear state space presentation of the dynamics of the nx1 vector y_t is depicted by the system of equations as follows:

$$y_t = c_t + Z_t \alpha_t + \epsilon_t \tag{5}$$

$$\alpha_{t+1} = d_t + T_t \alpha_t + \upsilon_t \tag{6}$$

where α_t is the mx1 vector of unobserved state variables, c_t, Z_t, d_t and T_t are the conformable vectors and matrices and ϵ_t and υ_t are the vectors of mean zero and Gaussian disturbances. As is seen in Eq. (6), it is assumed that the unobserved state vector moves over time as a first-order autoregressive process (AR(1)).

The disturbance vectors, ϵ_t and υ_t, are assumed to be serially independent and to have contemporaneous variance structure:

$$\Omega_t = \mathrm{var}\begin{bmatrix} \epsilon_t \\ \upsilon_t \end{bmatrix} = \begin{bmatrix} H_t & G_t \\ G_t' & Q_t \end{bmatrix} \tag{7}$$

where H_t is an nxn symmetric variance matrix, Q_t is an mxm symmetric variance matrix and G_t is an nxn matrix of covariances.

Table 4 FMOLS and DOLS estimators

Regressor	FMOLS estimator			DOLS estimator		
	Coefficient	Std. error	Prob. value	Coefficient	Std. error	Prob. value
lnGDP	0.367[c]	0.207	0.083	0.396[b]	0.180	0.037
lnEPNRS	0.236[a]	0.079	0.005	0.216[a]	0.074	0.007
lnEPRS	0.161[a]	0.041	0.000	0.194[a]	0.028	0.000

Optimal lengths are determined through Akaike Information Criterion (AIC). Accordingly, for the DOLS estimator, optimal lead and lag is 3 and 0, respectively. For the FMOLS estimator, optimal lag is 3.

[a] 1% statistical significance

[b] 5% statistical significance

[c] 10% statistical significance

Using the Kalman filter, Eq. (1) can be re-written as follows:

$$\ln CO_{2t} = \beta_0 + \beta_{1,t}\ln GDP_t + \beta_{2,t}\ln EPNRS_t + \beta_{3,t}\ln EPRS_t + \varepsilon_t \quad (8)$$

$$\beta_{i,t+1} = \beta_{i,t} + \upsilon_{i,t} \quad (9)$$

where $\beta_{i,t}$ shows the time-varying parameters that are used to examine the dynamic relationships among variables.

Figure 6 presents time-varying parameters based on the estimation of Eq. (8). At first glance, one may observe that all parameters except the parameter of lnEPRS in the beginning of 1970s are positive throughout time. When one observes the parameters one by one, he/she will observe that (i) the coefficient of lnGDP has a tendency to increase after a decrease at the beginning of the observed period, (ii) the coefficient of lnEPNRS has decreased since 1973 after a sharp increase during the period 1970–1973 and (iii) the coefficient of lnEPRS appears to be steady and does not show great fluctuations since 1974. It is with no doubt that the most important findings presented in Fig. 6 are that (i) all variables' coefficients are positive, (ii) the coefficient of lnEPNRS is greater than that of lnEPRS throughout the observed period and (iii) the coefficient of lnEPRS does not become negative except 1 year. Therefore, the findings obtained from the Kalman filter are majorly consistent with the findings obtained from the FMOLS and DOLS estimators. Accordingly, all methods find that all coefficients are positive and the coefficient of lnEPNRS is greater than that of lnEPRS. The only exception is that the coefficient of lnEPNRS is usually greater than that of lnGDP in the time-varying parameter estimation method.

Hence, the findings of this paper obtained from fixed parameter and time-varying parameter estimation methods concur with those of Boluk and Mert (2014) and Farhani and Shahbaz (2014) within the scope of the effects of non-renewable and renewable energy sources on CO_2 emissions. On the other hand, the findings of this paper conflict with those of Shafiei and Salim (2014), Dogan and Seker (2016a, b) and Jebli et al. (2016), which indicate CO_2 emissions are positively related to non-renewable energy consumption and are negatively related to renewable energy consumption.

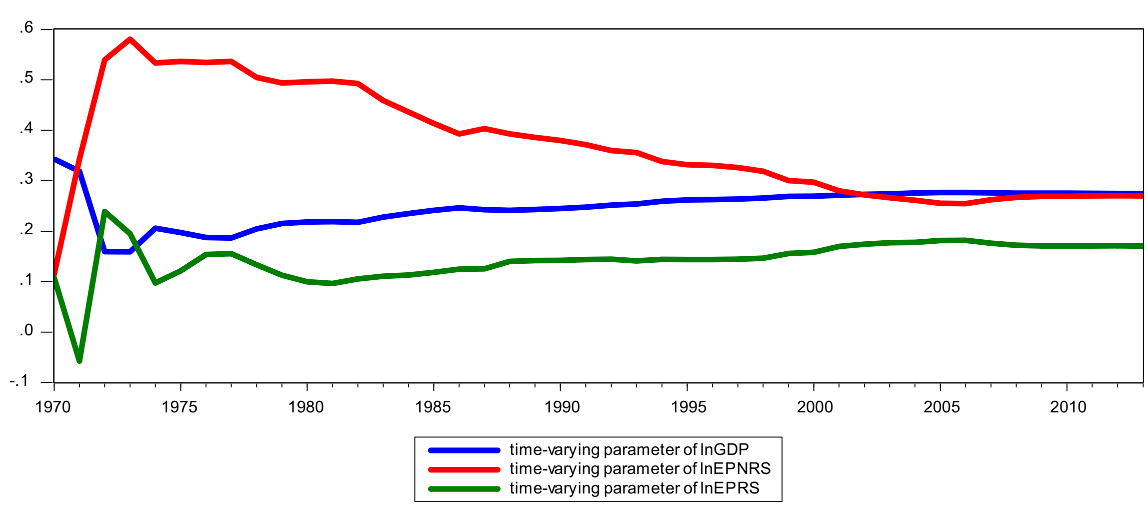


Fig. 6 Time-varying parameters. While Figs. 1–5 are generated through Microsoft Excel, Fig. 6 is produced using Eviews 9

Besides, the findings of this paper are inconsistent with those of Boluk and Mert (2015), which indicates electricity production from renewable sources that reduces CO_2 emissions in Turkey.

Conclusion

The world faces major environmental problems, such as air pollution, global warming and climate change today since (i) the world depends on fossil energy sources and (ii) GHGs, such as CO_2, CH_4, N_2O and fluorinated gases, arise from the usage of fossil sources. Policy makers consider renewable energy sources regarded as clean energy sources to reduce environmental problems. Hence, many global meetings have been organized, and renewable energy production and consumption have been encouraged in many countries in recent years. These developments have inevitably affected the energy literature, and many papers have been conducted in order to examine the effects of renewable energy consumption and/or production on GHGs. When one analyses these papers, he/she will observe that they employ fixed parameter estimation methods and ignore time-varying parameters of the determinants of GHGs. Therefore, there seems to be a research gap about the time-varying effects of non-renewable and renewable energy consumption/production on GHGs.

To fulfil this gap to a certain extent, this paper investigates the effects of electricity production from non-renewable and renewable sources on CO_2 emissions in Turkey by employing both fixed parameter and time-varying parameter estimation methods over the period 1970–2013. To this end, the paper, first, performs unit root and cointegration tests and explores that the variables are integrated of order one and that there is a cointegration relationship among variables. Then, the paper employs the FMOLS and DOLS estimators and the Kalman filter. The findings obtained from the methods yield that CO_2 emissions are positively related to GDP, electricity production from non-renewable sources and electricity production from renewable sources. Another important finding that the methods present is that the coefficient of electricity production from renewable sources is lower than that of electricity production from non-renewable sources. Put differently, electricity production from renewable sources leads to fewer CO_2 emissions than electricity production from non-renewable sources does. On the other hand, one can observe from the figure which presents time-varying parameters that the break dates indicated by Narayan and Popp (2010) unit root and Maki (2012) cointegration tests do not have considerable effects on time-varying parameters. In other words, time-varying parameters did not exhibit radical and/or permanent changes after the breaks. That is to say, the breaks did not have considerable effects on the relationships among variables.

Based on the findings of the paper, a question appears to be important for Turkey: Can renewable energy satisfy the expectations since fewer CO_2 emissions arise when electricity is produced through renewable sources? The answer of the question is negative, because policy makers stimulate production and consumption of renewable energy, since they expect renewable energy to decrease CO_2 emissions. A report titled "National Renewable Energy Action Plan for Turkey" and published by the Republic of Turkey Ministry of Energy and Natural Resources (2014) reveals that the Turkish governments have focused on renewable energy especially since 2005 in order to reduce CO_2 emissions and other GHGs. This report remarks that the Turkish government aims to increase the share of renewable sources in electricity production from 28.9 to 37.6% during the period 2013–2023 by implementing or planning to implement many policies towards renewable energy, such as feed-in tariff scheme, investment incentives program, financial support for geothermal exploration and drilling activities, land usage fee incentives, biofuels tax exemption and incentives for energy crops. Findings obtained from the Kalman filter can be exploited by the policy makers in Turkey in this regard. Accordingly, this paper argues that policy makers in Turkey should have a long-term horizon and implement long-term energy policies, since the breaks did not change the effects of non-renewable and renewable energy on CO_2 emissions, because the findings explore that rather than liberalization efforts, economic crises and the second oil crisis, the general trend of GDP and energy production and consumption policies have effects on CO_2 emissions in Turkey. This paper also remarks that renewable energy may reduce CO_2 emissions if the Turkish government achieves targets towards renewable energy in the following periods. Therefore, the paper suggests the future empirical research goes on focusing the impacts of renewable energy production/consumption on CO_2 emissions in Turkey.

References

Ajmi AN, Hammoudeh S, Nguyen DK, Sato JR (2015) On the relationships between CO_2 emissions, energy consumption and income: the importance of time variation. Energy Econ 49:629–638

Alam MJ, Begum IA, Buysse J, Van Huylenbroeck G (2012) Energy consumption, carbon emissions and economic growth nexus in Bangladesh: cointegration and dynamic causality analysis. Energy Policy 45:217–225

Al-Mulali U, Weng-Wai C, Sheau-Ting L, Mohammed AH (2015a) Investigating the environmental Kuznets curve (EKC) hypothesis by utilizing the ecological footprint as an indicator of environmental degradation. Ecol Indic 48:315–323

Al-Mulali U, Saboori B, Ozturk I (2015b) Investigating the environmental Kuznets curve hypothesis in Vietnam. Energy Policy 76:123–131

Al-Mulali U, Ozturk I, Lean HH (2015c) The influence of economic growth, urbanization, trade openness, financial development, and renewable energy on pollution in Europe. Nat Hazards 79:621–644

Apergis N, Payne JE (2009) CO_2 emissions, energy usage, and output in Central America. Energy Policy 37:3282–3286

Apergis N, Payne JE, Menyah K, Wolde-Rufael Y (2010) On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth. Ecol Econ 69:2255–2260

Aslan A, Apergis N, Yildirim S (2014) Causality between energy consumption and GDP in the US: evidence from wavelet analysis. Front Energy 8:1–8

Atici C (2009) Carbon emissions in Central and Eastern Europe: environmental Kuznets curve and implications for sustainable development. Sustain Dev 17:155–160

Baek J (2015) Environmental Kuznets curve for CO_2 emissions: the case of Arctic countries. Energy Econ 50:13–17

Bilgili F, Ozturk I (2015) Biomass energy and economic growth nexus in G7 countries: evidence from dynamic panel data. Renew Sust Energ Rev 49:132–138

Bilgili F, Kocak E, Bulut U (2016a) The dynamic impact of renewable energy consumption on CO_2 emissions: a revisited Environmental Kuznets Curve approach. Renew Sust Energ Rev 54:838–845

Bilgili F, Ozturk I, Kocak E, Bulut U, Pamuk Y, Mugaloglu E, Baglitas HH (2016b) The influence of biomass energy consumption on CO_2 emissions: a wavelet coherence approach. Environ Sci Pollut Res 23:19043–19061

Bilgili F, Kocak E, Bulut U, Kuskaya S (2017) Can biomass energy be an efficient policy tool for sustainable development? Renew Sust Energ Rev 71:830–845

Boluk G, Mert M (2014) Fossil & renewable energy consumption, GHGs (greenhouse gases) and economic growth: evidence from a panel of EU (European Union) countries. Energy 74:439–446

Boluk G, Mert M (2015) The renewable energy, growth and environmental Kuznets curve in Turkey: an ARDL approach. Renew Sust Energ Rev 52:587–595

British Petroleum (BP) (2016) BP statistical review of world energy June 2016 https://www.bp.com/content/dam/bp/pdf/energy-economics/statistical-review-2016/bp-statistical-review-of-world-energy-2016-full-report.pdf. Accessed 24 November 2016.

Chandran VGR, Tang CF (2013) The impacts of transport energy consumption, foreign direct investment and income on CO_2 emissions in ASEAN-5 economies. Renew Sust Energ Rev 24:445–453

Chang CC (2010) A multivariate causality test of carbon dioxide emissions, energy consumption and economic growth in China. Appl Energy 87:3533–3537

Chiu CL, Chang TH (2009) What proportion of renewable energy supplies is needed to initially mitigate CO_2 emissions in OECD member countries? Renew Sust Energ Rev 13:1669–1674

Cowan WN, Chang T, Inglesi-Lotz R, Gupta R (2014) The nexus of electricity consumption, economic growth and CO_2 emissions in the BRICS countries. Energy Policy 66:359–368

Dickey DA, Fuller WA (1981) Likelihood ratio statistics for autoregressive time series with a unit root. Econometrica 49:1057–1072

Dogan E, Seker F (2016a) Determinants of CO_2 emissions in the European Union: the role of renewable and non-renewable energy. Renew Energy 94:429–439

Dogan E, Seker F (2016b) The influence of real output, renewable and non-renewable energy, trade and financial development on carbon emissions in the top renewable energy countries. Renew Sust Energ Rev 60:1074–1085

Dogan E, Turkekul B (2016) CO_2 emissions, real output, energy consumption, trade, urbanization and financial development: testing the EKC hypothesis for the USA. Environ Sci Pollut Res 23: 1203–1213

Esteve V, Requena F (2006) A cointegration analysis of car advertising and sales data in the presence of structural change. Int J Econ Bus 13:111–128

Fang Y (2011) Economic welfare impacts from renewable energy consumption: the China experience. Renew Sust Energ Rev 15:5120–5128

Farhani S, Ben Rejeb J (2012) Energy consumption, economic growth and CO2 emissions: evidence from panel data for MENA region. Int J Energy Econ Policy 2:71–81

Farhani S, Ozturk I (2015) Causal relationship between CO_2 emissions, real GDP, energy consumption, financial development, trade openness, and urbanization in Tunisia. Environ Sci Pollut Res 22:15663–15676

Farhani S, Shahbaz M (2014) What role of renewable and non-renewable electricity consumption and output is needed to initially mitigate CO_2 emissions in MENA region? Renew Sust Energ Rev 40:80–90

Halicioglu F (2009) An econometric study of CO_2 emissions, energy consumption, income and foreign trade in Turkey. Energy Policy 37:1156–1164

Harvey AC (1989) Forecasting, structural time series models and the Kalman filter. Cambridge University Press, New York

Hossain MS (2011) Panel estimation for CO_2 emissions, energy consumption, economic growth, trade openness and urbanization of newly industrialized countries. Energy Policy 39:6991–6999

Jalil A, Feridun M (2011) The impact of growth, energy and financial development on the environment in China: a cointegration analysis. Energy Econ 33:284–291

Jebli MB, Youssef SB, Ozturk I (2016) Testing environmental Kuznets curve hypothesis: the role of renewable and non-renewable energy consumption and trade in OECD countries. Ecol Indic 60:824–831

Johansen S (1991) Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. Econometrica 59:1551–1580

Johansen S (1998) Statistical analysis of cointegration vectors. J Econ Dyn Cont 12:231–254

Kasman A, Duman YS (2015) CO_2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: a panel data analysis. Econ Model 44:97–103

Koçak E, Sarkgunesi A (2017) The renewable energy and economic growth nexus in Black Sea and Balkan countries. Energy Policy 100:51–57

Lau LC, Lee KT, Mohamed AR (2012) Global warming mitigation and renewable energy policy development from the Kyoto Protocol to the Copenhagen Accord—a comment. Renew Sust Energ Rev 16: 5280–5284

Lopez-Menendez AJ, Perez R, Moreno B (2014) Environmental costs and renewable energy: re-visiting the Environmental Kuznets Curve. J Environ Manag 145:368–373

Maki D (2012) Tests for cointegration allowing for an unknown number of breaks. Econ Model 29:2011–2015

Maslin M (2004) Global warming: a very short introduction. Oxford University Press, Oxford

Menyah K, Wolde-Rufael Y (2010) CO_2 emissions, nuclear energy, renewable energy and economic growth in the US. Energy Policy 38: 2911–2915

Narayan R (2007) Rationale, drivers, standards and technology for biobased materials. In: Graziani M, Fornasiero P (eds) Renewable resources and renewable energy: a global challenge. CRC Press-Taylor and Francis Group Boca Raton, Florida, pp 3–18

Narayan PK, Narayan S (2004a) The J-curve: evidence from Fiji. Int Rev Appl Econ 18:369–380

Narayan S, Narayan PK (2004b) Determinants of demand for Fiji's exports: an empirical investigation. Dev Econ 42:95–112

Narayan PK, Popp S (2010) A new unit root test with two structural breaks in level and slope at unknown time. J Appl Stat 37:1425–1438

Nejat P, Jomehzadeh F, Taheri MM, Gohari M, Majid MZA (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 Sustainable Energy Rev 43:843–862

Omri A (2013) CO_2 emissions, energy consumption and economic growth nexus in MENA countries: evidence from simultaneous equations models. Energy Econ 40:657–664

Ozturk I, Acaravci A (2010) CO_2 emissions, energy consumption and economic growth in Turkey. Renew Sust Energ Rev 14:3220–3225

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

Pao HT, Tsai CM (2011) Multivariate Granger causality between CO_2 emissions, energy consumption, FDI (foreign direct investment) and GDP (gross domestic product): evidence from a panel of BRIC (Brazil, Russian Federation, India, and China) countries. Energy 36:685–693

Pao HT, Yu HC, Yang YH (2011) Modeling the CO_2 emissions, energy use, and economic growth in Russia. Energy 36:5094–5100

Park J, Hong T (2013) Analysis of South Korea's economic growth, carbon dioxide emission, and energy consumption using the Markov switching model. Renew Sust Energ Rev 18:543–551

Phillips PCB, Hansen BE (1990) Statistical inference in instrumental variables regression with I(1) processes. Rev Econ Stud 57:99–125

Phillips PCB, Perron P (1988) Testing for a unit root in time series regression. Biometrika 75:335–346

Rafiq S, Salim RA (2009) Temporal causality between energy consumption and income in six Asian emerging countries. Appl Econ Quart 55:335–350

Saboori B, Sulaiman J (2013) Environmental degradation, economic growth and energy consumption: evidence of the environmental Kuznets curve in Malaysia. Energy Policy 60:892–905

Sadorsky P (2009) Renewable energy consumption and income in emerging economies. Energy Policy 37:4021–4028

Salim RA, Bloch H (2009) Business expenditures on R&D and trade performances in Australia: is there a link? Appl Econ 41:351–361

Salim RA, Rafiq S, Hassan AK (2008) Causality and dynamics of energy consumption and output: evidence from non-OECD Asian countries. J Econ Dev 33:1–26

Salim RA, Hassan K, Shafiei S (2014) Renewable and non-renewable energy consumption and economic activities: further evidence from OECD countries. Energy Econ 44:350–360

Say NP, Yucel M (2006) Energy consumption and CO_2 emissions in Turkey: empirical analysis and future projection based on an economic growth. Energy Policy 34:3870–3876

Seker F, Ertugrul HM, Cetin M (2015) The impact of foreign direct investment on environmental quality: a bounds testing and causality analysis for Turkey. Renew Sust Energ Rev 52:347–356

Shafiei S, Salim RA (2014) Non-renewable and renewable energy consumption and CO_2 emissions in OECD countries: a comparative analysis. Energy Policy 66:547–556

Shahbaz M, Solarin SA, Mahmood H, Arouri M (2013) Does financial development reduce CO_2 emissions in Malaysian economy? A time series analysis. Econ Model 35:145–152

Shahbaz M, Khraief N, Uddin GS, Ozturk I (2014) Environmental Kuznets curve in an open economy: a bounds testing and causality analysis for Tunisia. Renew Sust Energ Rev 34:325–336

Soytas U, Sari R (2009) Energy consumption, economic growth, and carbon emissions: challenges faced by an EU candidate member. Ecol Econ 68:1667–1675

Soytas U, Sari R, Ewing BT (2007) Energy consumption, income, and carbon emissions in the United States. Ecol Econ 62:482–489

Stock JH, Watson M (1993) A simple estimator of cointegrating vectors in higher order integrated systems. Econometrica 61:783–820

Swapnesh A, Srivastava VC, Mall ID (2014) Comparative study on thermodynamic analysis of CO2 utilization reactions. Chem Eng Technol 37:1765–1777

Tang CF, Tan BW (2015) The impact of energy consumption, income and foreign direct investment on carbon dioxide emissions in Vietnam. Energy 79:447–454

The Republic of Turkey Ministry of Energy and Natural Resources (2014) National Renewable Energy Action Plan for Turkey http://www.ebrd.com/news/2015/ebrd-supports-turkeys-shift-to-renewable-energy.html. Accessed 17 February 2017

Turkish Statistical Institute (2016) http://www.tuik.gov.tr/Start.do. Accessed 24 November 2016.

United States Environmental Protection Agency (EPA) (2017) Global greenhouse gas emissions data https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data. Accessed February 1 2017

World Bank (2016) http://www.worldbank.org/. Accessed 1 September 2016.

Wuebbles DJ, Jain AK, Watts RG (2002) Concerns about climate change and global warming. In: Watts RG (ed) Innovative energy strategies for CO_2 stabilization. Cambridge University Press, Cambridge, pp 1–26

Yavuz NC (2014) CO_2 emission, energy consumption, and economic growth for turkey: evidence from a cointegration test with a structural break. Energy Sources Part B Econ Plan Policy 9:229–235