

The impacts of non-renewable and renewable energy on CO₂ emissions in Turkey

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Received: 28 February 2017 / Accepted: 1 May 2017 / Published online: 16 May 2017
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Abstract As a result of great increases in CO₂ emissions in the last few decades, many papers have examined the relationship between renewable energy and CO₂ emissions in the energy economics literature, because as a clean energy source, renewable energy can reduce CO₂ emissions and solve environmental problems stemming from increases in CO₂ 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 CO₂ emissions in Turkey over the period 1970–2013 by employing fixed parameter and time-varying parameter estimation methods. Estimation methods reveal that CO₂ emissions are positively related to non-renewable energy and renewable energy in Turkey. Since policy makers expect renewable energy to decrease CO₂ emissions, this paper argues that renewable energy is not able to satisfy the expectations of policy makers though fewer CO₂ 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

Responsible editor: Philippe Garrigues

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parameter and time-varying parameter estimation methods · 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 (CO₂), methane (CH₄), nitrous oxide (N₂O) 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 CO₂ had the greatest share in global GHGs with 76% in 2014. Therefore, CO₂ 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.

2015; Bilgili et al. 2017). CO₂ 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 CO₂ 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 CO₂ emissions in the world. With regard to the World Bank (2016) data, in 2013, the shares of China and the USA in global CO₂ emissions were 28.59 and 14.46%, respectively. During 1960–2013, China's CO₂ emissions annually grew by 5.98%, while the USA's CO₂ emissions annually grew by 1.36%. On the other hand, as an emerging market economy, the growth in CO₂ emissions of Turkey was higher than those of China and the USA during the same period. Turkey's CO₂ emissions annually grew by 6.87% during 1960–2013. Figure 1 presents CO₂ 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 CO₂ 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 CO₂ 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 CO₂ emissions has the potential to increase.

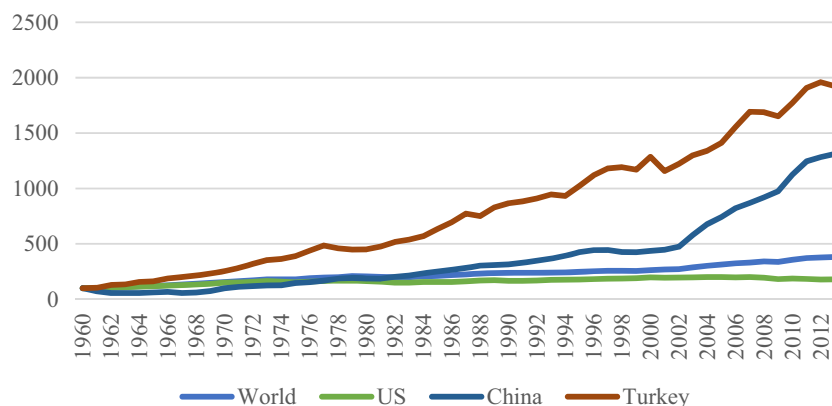
Based on these figures, this paper focuses on the second expectation about renewable energy for Turkey. Put differently, this paper examines the effects of non-renewable and renewable energy on CO₂ emissions by using annual data from 1970 to 2013. The contribution of the paper to the empirical research is twofold. The first contribution arises from the sample. As a result of the rapid increases in Turkey's CO₂ 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 CO₂ 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 CO₂ 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 CO₂ emissions, he/she will observe that many papers have been performed so far (see e.g. Soytaş 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 Turkecul 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 CO₂ emissions.

Fig. 1 CO₂ 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 CO₂ 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 CO₂ emissions while renewable energy consumption reduces CO₂ 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 CO₂ emissions, while renewable energy consumption has no effects on CO₂ emissions in Vietnam.

Besides these papers, some papers examine the relationships between total, non-renewable, and/or renewable energy and CO₂ emissions for Turkey. For instance, Say and Yucel (2006) yield that total energy consumption affects CO₂ 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 CO₂ emissions. He yields that energy consumption has statistically significant impacts on CO₂ emissions and that there is bidirectional causality between variables. Soytaş and Sari (2009) analyse the causal relationships between total energy consumption and CO₂ emissions using data from 1960 to 2000. They explore that there is unidirectional causality running from CO₂ 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 CO₂ emissions. They yield that there is no causality between energy consumption and CO₂ emissions. Yavuz (2014) utilizes data covering the period 1960–2007 and finds that CO₂ emissions are positively related to total energy consumption. Boluk and Mert (2015) examine the impact of electricity production from renewable sources on CO₂ emissions using data from 1961 to 2010. They yield that electricity

production from renewable sources has statistically significant and negative effects on CO₂ emissions. Seker et al. (2015), using data from 1974 to 2010, find that CO₂ emissions are positively related to total energy consumption and that there is unidirectional causality from CO₂ emissions to energy consumption.

Table 1 summarizes the empirical literature about the relationship between energy consumption and CO₂ 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 CO₂ emissions one by one, and (ii) all papers examining the relationships between energy and CO₂ emissions employ fixed parameter estimation methods. This paper investigates the effects of both non-renewable and renewable energy on CO₂ 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 CO₂ 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 CO₂ 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 CO₂ 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-CO₂ 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	CO ₂ → 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, CO₂, EPRS, →, ↔ and ≠→ refer to the total energy consumption, CO₂ 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:

$$\ln\text{CO}_{2t} = \beta_0 + \beta_1 \ln\text{GDP}_t + \beta_2 \ln\text{EPNRS}_t + \beta_3 \ln\text{EPRS}_t + \varepsilon_t \tag{1}$$

where lnCO₂, lnGDP, lnEPNRS and lnEPRS stand for natural logarithmic forms of CO₂ 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 CO₂ 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 lnCO₂, lnGDP, lnEPNRS and lnEPRS follow the trends of [y = 7E - 06 × 3 - 0.0008 × 2 + 0.0698x + 10.667], [y = 4E - 06 × 3 - 0.0003 × 2 + 0.0465x + 25.656], [y = -5E - 05 × 3 + 0.0031 × 2 + 0.0303x + 8.8221] and

[y = 6E - 05 × 3 - 0.0054 × 2 + 0.2057x + 7.5828], respectively. The trend lines of the variables yield the goodness of fit measure R² 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 lnCO₂, 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) lnCO₂ 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 lnCO₂ 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 CO₂ emissions of Turkey

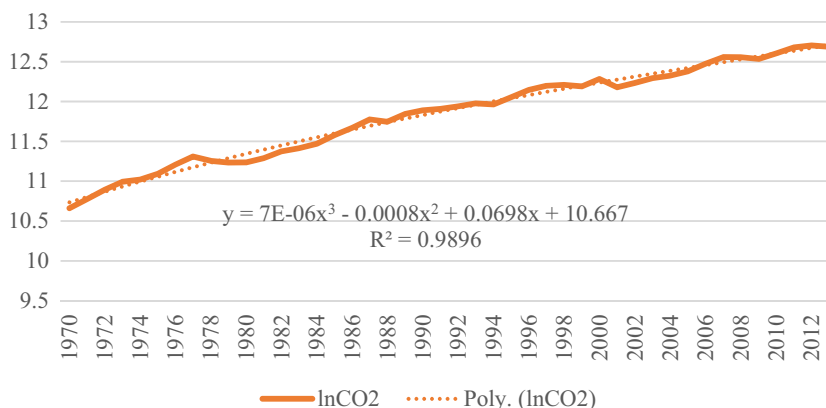
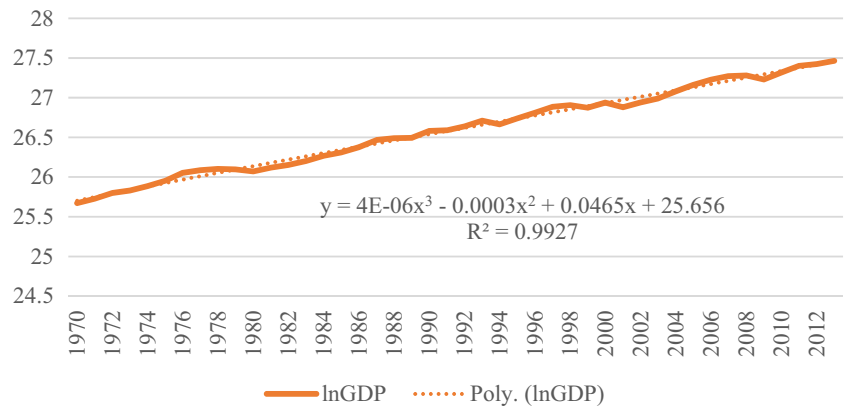


Fig. 3 GDP of Turkey

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.

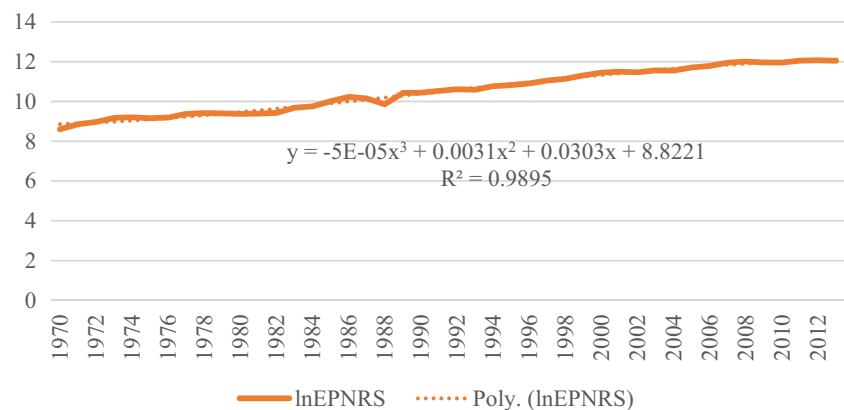
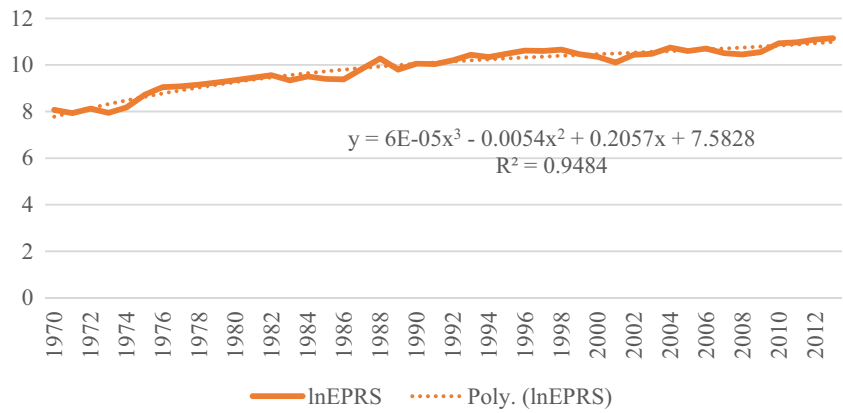
Fig. 4 Electricity production from non-renewable sources in Turkey

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	-1.407	-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:

$$\Delta x_t = \gamma + \beta_t \quad (3)$$

where γ signifies a $k \times 1$ vector of drift parameters, and β is a $k \times 1$ 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):

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

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 CO₂ 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 CO₂ 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 $n \times 1$ vector y_t is depicted by the system of equations as follows:

$$y_t = c_t + Z_t \alpha_t + \varepsilon_t \quad (5)$$

$$\alpha_{t+1} = d_t + T_t \alpha_t + v_t \quad (6)$$

where α_t is the $m \times 1$ vector of unobserved state variables, c_t , Z_t , d_t and T_t are the conformable vectors and matrices and ε_t and v_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 v_t , are assumed to be serially independent and to have contemporaneous variance structure:

$$\Omega_t = \text{var} \begin{bmatrix} \varepsilon_t \\ v_t \end{bmatrix} = \begin{bmatrix} H_t & G_t \\ G_t & Q_t \end{bmatrix} \quad (7)$$

where H_t is an $n \times n$ symmetric variance matrix, Q_t is an $m \times m$ symmetric variance matrix and G_t is an $n \times m$ 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:

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

$$\beta_{i,t+1} = \beta_{i,t} + \nu_{i,t} \tag{9}$$

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 CO₂ 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 CO₂ emissions are positively related to non-renewable energy consumption and are negatively related to renewable energy consumption.

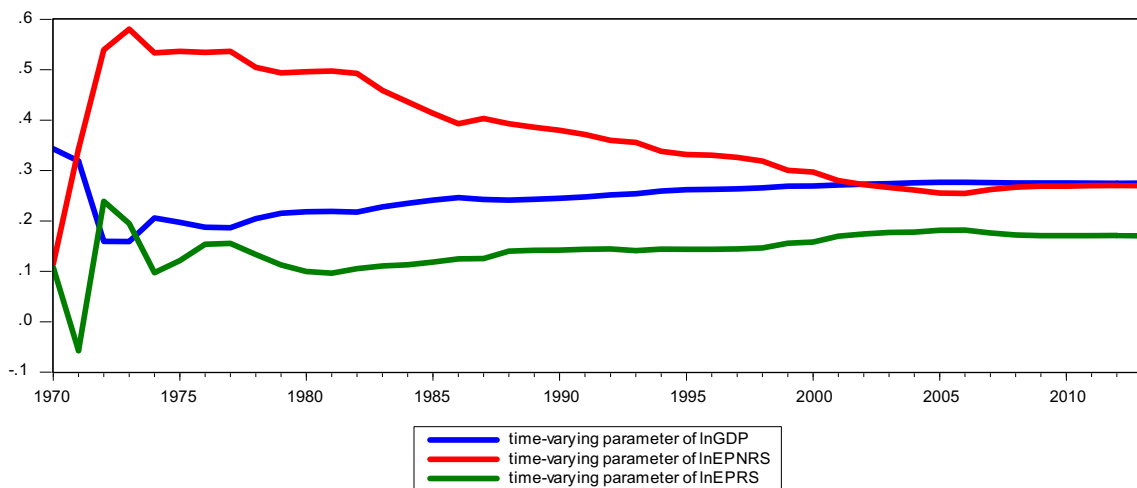


Fig. 6 Time-varying parameters. While Figs. 1–5 are generated through Microsoft Excel, Fig. 6 is produced using Eviews 9

Besides, the findings of this paper are inconsistent with those of Boluk and Mert (2015), which indicates electricity production from renewable sources that reduces CO₂ 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 CO₂, CH₄, N₂O 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 CO₂ 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 CO₂ 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 CO₂ 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 CO₂ 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 CO₂ 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 CO₂ 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 CO₂ 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 CO₂ emissions in Turkey. This paper also remarks that renewable energy may reduce CO₂ 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 CO₂ emissions in Turkey.

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