Environ Sci Pollut Res (2018) 25:790–804
https://doi.org/10.1007/s11356-017-0468-2

RESEARCH ARTICLE

# The impact of foreign direct investment on $CO_2$ emissions in Turkey: new evidence from cointegration and bootstrap causality analysis

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Received: 26 February 2017 / Accepted: 10 October 2017 / Published online: 23 October 2017


**Abstract** Pollution haven hypothesis (PHH), which is defined as foreign direct investment inducing a raising impact on the pollution level in the hosting country, is lately a subject of discussion in the field of economics. This study, within the scope of related discussion, aims to look into the potential impact of foreign direct investments on $CO_2$ emission in Turkey in 1974–2013 period using environmental Kuznets curve (EKC) model. For this purpose, Maki (Econ Model 29(5):2011–2015, 2012) structural break cointegration test, Stock and Watson (Econometrica 61:783–820, 1993) dynamic ordinary least square estimator (DOLS), and Hacker and Hatemi-J (J Econ Stud 39(2):144–160, 2012) bootstrap test for causality method are used. Research results indicate the existence of a long-term balance relationship between FDI, economic growth, energy usage, and $CO_2$ emission. As per this relationship, in Turkey, (1) the potential impact of FDI on $CO_2$ emission is positive. This result shows that PHH is valid in Turkey. (2) Moreover, this is not a one-way relationship; the changes in $CO_2$ emission also affect FDI entries. (3) The results also provide evidence for the existence of the EKC hypothesis in Turkey. Within the frame of related findings, the study concludes several polities and presents various suggestions.

Responsible editor: Philippe Garrigues

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**Keywords** Turkey · Environmental Kuznets curve hypothesis · Pollution haven hypothesis · $CO_2$ emissions · Cointegration · Bootstrap causality

## Introduction

It is clear from several indicators that there have been significant changes in climate over the last century. For instance, the global temperature averages recorded in 1998–2007 period are 0.41° above the 1961–1990 period average (Bilgili et al. 2016a). Furthermore, 0.65–0.15 °C deviation has occurred in the average surface and seawater temperatures; warming in the glaciers of Alps increased in 0.6–1.0 °C range. The snow cover area of the North Hemisphere in 1972–1992 period has decreased approximately 10%, annually. Sea ice levels decreased significantly in the South Hemisphere between 1950 and 1970, and in the North Hemisphere since 1950. The length of seasons in the North Hemisphere in 1981–1991 period increased between 4 and 12 days. In the last century, rainfall in the tropical regions increased rapidly and decreased in the Sahara Desert. Average global sea water level has increased to 1.8 mm per year (Wuebbles and Jain 2002). The effect of this process known as global warming and climate change is not only limited to the environment; it has affected directly the economy, social life, geopolitical factors, politics, and life style (Maslin 2004; Hao and Liu 2015). It has been pointed out that the increase in global temperatures leaves millions of people face to face with hunger, flood, and water shortage. The increasing risk of diseases like malaria causes nearly 150,000 additional deaths each year (Escobar et al. 2009). That is why global warming draws attention as one of the most important problems of today's world.

Why have the global temperatures increased over the last century? Or in other words, what is the reason for global warming? Majority in the science world, though not at a consensus, points to the raise in natural greenhouse effect as the reason for global warming. Especially, in the last 50 years, exhaust released as a result of human activity elevated the greenhouse gas density to above normal (IPCC 1990). This raise in exhaust caused the world to retain more heat by sharpening the greenhouse effect. Among this exhaust, especially, carbon dioxide stands out as the pollutant with the highest global warming potential and whose release increases most rapidly (Lau et al. 2012; Swapnesh et al. 2014). Energy usage that has increased since the industrial revolution with economic, commercial, and social developments has caused a constant raise in $CO_2$ emission. For example, the average density of $CO_2$ before the industrial revolution was 278 ppm (parts per million), whereas it raised to 316 ppm in 1959, 365 ppm in 1998, and 396 ppm in 2013 (Bilgili et al. 2016a). Historically, it is estimated that $CO_2$ alone is responsible for 53% of human-induced greenhouse gas (Griffin 2003). For that reason, the main target of international attempts to reduce the effects of climate change and global warming should be decreasing $CO_2$ emission (IPCC 1990). The success of these attempts depends on the condition that the countries, which produce high levels of $CO_2$ gas, reach their emission decreasing target (Tamazian and Rao 2010). In this context, the developed countries which were responsible for a significant portion of $CO_2$ emission till recent past have achieved their target to a certain extent by reducing their $CO_2$ density over the last 10 years. For example, in 2000–2012 period, North American (Annex II) and European (Annex II) countries reduced their $CO_2$ emissions by, in this order, 9.9 and 9.8%. However, in the same period, developing countries like China, India, Brazil, Turkey, and Mexico increased their emission level quite rapidly by, in this order, 155, 64, 37, 51, and 25% (IEA 2014). That is why it is of great importance that the grounds of $CO_2$ emission in the developing countries are put forth, the factors affecting emission are defined, and the countries are examined individually.

As is known, economic globalization increased in 1990; international trade and free movement of capital intensified foreign direct investment (FDI) entries in developing countries (Hao and Liu 2015). Increasing FDI provided utilities like capital, skill, technology transfer, market accessibility, and export incentive (Mert and Bölük 2016), and in addition, satisfied the saving needs for investments (Shahbaz et al. 2015). Consequently, FDI movements contributed to a rapid economic growth in developing countries. However, despite FDI's contribution to economic growth, its potential impact on environmental quality in the last 10 years is now being discussed (Baek 2016). These discussions are handled in the literature within two opposite approaches. As per the first approach, known as pollution haven hypothesis (PHH), FDI is moving towards the countries with relatively less strict environmental regulations, less environment taxes, and lower standards (Seker et al. 2015). By this means multinational countries are shifting their high-pollution-level industries to developing countries to avoid high environmental costs in their countries. For this reason, developing countries become pollution havens and the environmental pollution levels raise (Zhang and Zhou 2016). PHH, finally, points to the fact that FDI movements will increase pollution/gas emissions by enhancing economic activities in high-pollution-level industries in developing countries (Acharyya 2009). On the other hand, according to the second approach, pollution halo hypothesis in developing countries, thanks to FDI, can transfer directly to cleaner technologies or find the opportunity to develop environment-friendly technologies by attracting high-level research-development investments (Jalil and Feridun 2011). Moreover, the multinational companies that have better environmental management systems may have an impact on the hosting countries, which increases environment standard and raises environmental consciousness (Hoffmann et al. 2005). For this reason, pollution halo hypothesis emphasizes that FDI movements will enhance environmental quality and reduce exhaust emission in developing countries (Shahbaz et al. 2015).

Within the frame of related studies, this study aims to analyze the impact of direct foreign investments on $CO_2$ emission in 1974–2013 period in Turkey with annual data. The importance of a study as such and its contribution to the literature is in three ways.

(1) Turkey is a country which liberalizes in foreign trade and finance, urbanizes rapidly, and portrays a significant growth performance in employment and income. According to the World Bank 2015 reports, Turkey has a population of 78.6 million, a GDP of 718 billion dollars, and 93,878 dollar income per capita. Moreover, there has been a significant raise in FDI entries in Turkey in recent years. According to UNCTAD (2014), Turkey was rated as the 14th most promising country for FDI in 2014–2016 period. On the other hand, $CO_2$ gas emission in Turkey increased dramatically in the same period. According to IEA (2014) reports in 2012, emission reached 302.4 million tons increasing 138% whereas in 1990, $CO_2$ gas emission in Turkey was 126.9 million tons. As a member of Kyoto protocol Annex I country, Turkey, with this emission level, is far away from the protocol's target which reads that in 2008–2012 period, Annex I countries reduce their greenhouse gas emission by 5% from the 1990 level. Nonetheless, it is also important for Turkey to fulfill its greenhouse gas emission responsibilities with regard to its European Union membership process (Seker et al. 2015). That is why descriptive factors that affect $CO_2$ emission in Turkey will provide important implications for authorities in terms of designing emission reduction policies. The data gained

by this study is expected to contribute to these authorities.

(2) In the literature, it is assumed that the cointegration vector remains stable through the analyzed period in most of the methods that look into the long-term relationship between the variables. However, there are lots of structural elements such as crisis, technological shocks, institutional developments, politics, and regime change. Thus, cointegration tests that ignore structural breaks (regime change) have less capacity of estimation. As to this shortcoming, Gregory and Hansen (1996) developed a cointegration method that takes a break into account in their pioneering study; Hatemi-J (2008), expanding this method, developed a cointegration test that takes two breaks into account. Maki (2012), on the other hand, developed the cointegration method that has the capacity of estimating up to five breaks. This study will examine the impact of direct foreign capital investment on $CO_2$ emission using Maki (2012) cointegration test. Thus, hypothesis as to FDI-$CO_2$ emission relationship will differ from the literature that uses traditional cointegration methods and will be tested by a more advanced testing method.

(3) In this study, after the cointegration test, in order to determine the direction of FDI-$CO_2$ emission relationship, Hacker and Hatemi-J (2012) bootstrap causality test method will be used. In the literature, causality relationships are often examined by Granger causality test or MWALD test suggested by Toda and Yamamoto (1995). However, for these tests to be statistically significant, error terms of the variables should have a normal distribution. Bootstrap method rules out this constraint. This study aims to provide a methodological contribution to the literature using the abovementioned methods.

The rest of the study is arranged as follows. In the second part, related literature is presented. Third part explains methodology. Fifth part includes data, model, and empirical findings. In the last part, conclusion and policy suggestions are given.

## Literature review

The literature for the relationship between economic developments/indicators and environment seems to focus on especially the estimation of environmental Kuznets curve hypothesis. According to this hypothesis, level of environmental pollution will increase in first stages of economic growth process due to more energy and source usage (scale effect). In later stages, however, with the ongoing growth, structural change process in economy will start (structural effect); demand for a cleaner environment will raise and cleaner technologies that reduce the energy intensity will develop (technological effect) (Koçak 2014; Bilgili et al. 2016b). In other words, EKC hypothesis claims that the effect of economic growth on environment quality is in a positive direction in the long run. In the literature, while the EKC relationship is heavily supported (Grossman and Krueger 1991,1995; Shafik and Bandyopadhyay 1992; Panayotou 1993; Selden and Song 1994; Torras and Boyce 1998; Stern and Common 2001; Jalil and Mahmud 2009; Nasir and Rehman 2011; Esteve and Tamarit 2012; Sulaiman et al. 2013; Apergis and Ozturk 2015, Bilgili et al. 2016b), some studies (Agras and Chapman 1999; Roca and Alcántara 2001; Gangadharan and Valenzuela 2001; He and Richard 2010; Fodha and Zaghdoud 2010; Koçak 2014) reached results that do not support EKC.

On the other hand, it is possible to come across with studies that state the relationship between economic development/indicators and environment has not been completely clarified by the studies within the scope of EKC hypothesis (Tamazian and Rao 2010). Therefore, in order to test the validity of ECC, it is necessary to identify additional indicators other than the economic growth indicator and to develop new perspectives (Shahbaz et al. 2013). The relevant literature has also been developed in this area to include additional and new variables that are thought to have an impact on environmental pollution in EKC model. In this context, energy consumption, (Apergis and Payne 2010; Ozturk and Acaravci 2010; Wang et al. 2011; Arouri et al. 2012; Omri 2013, 2014; Baek 2016; Jebli et al. 2016; Bilgili et al. 2016b), financial development (Tamazian et al. 2009; Farhani and Ozturk 2015; Dogan and Turkekul 2016; Javid and Sharif 2016), urbanization (Salim and Shafiei 2014; Zhang et al. 2014; Kasman and Duman 2015; Al-Mulali and Ozturk 2015; Saidi and Mbarek 2016; Solarin and Lean 2016), trade (Saboori et al. 2012; Shahbaz et al. 2012; Tiwari et al. 2013; Kohler 2013; Onafowora and Owoye 2014; Lau et al. 2014), institutional factors (Leitao 2010; Tamazian and Rao 2010; Buitenzorgy and Mol 2011), tourism (Lee and Brahmasrene 2013; Arbulú et al. 2015; De vita et al. 2015; Zaman et al. 2016; Ozturk 2016), and finally FDI (see Table 1) have drawn attention as significant indicators.

This study focuses on FDI among the abovementioned indicators. For this reason, avoiding a multi-directional evaluation of the literature in terms of economic growth and environment relationship; studies specifically on FDI-$CO_2$ emission are examined. Table 1 shows the studies on FDI-$CO_2$ relationship.

When the literature is reviewed,

(1) One can see that there is not a consensus on FDI-$CO_2$ relationship. In accordance with the country at hand, period, and methods used in this context, some of the studies support PHH (Acharyya 2009; Ajide and Adeniyi 2010; Lan et al. 2012; Lee 2013; Lau et al. 2014; Kivyiro and Arminen 2014; Tang and Tan 2015;

**Table 1** Empirical studies on FDI-$CO_2$ emission nexus

| Author(s) | Country | Period | Methodology | Conclusion |
|---|---|---|---|---|
| Aliyu (2005) | Non-OECD countries | 1990–2000 | Panel OLS | Neutrality |
| Merican (2007) | 5 ASEAN countries | 1976–2002 | ARDL, UECM | Pollution haven (Malaysia, Thailand, the Philippines) Pollution halo (Indonesia) Neutrality (Singapore) |
| Acharyya (2009) | India | 1980–2003 | OLS | Pollution haven |
| Tamazian et al. (2009) | BRIC countries, the USA, Japan | 1992–2004 | Panel random effect | Pollution halo |
| Ajide and Adeniyi (2010) | Nigeria | 1970–2006 | OLS, ARDL | Pollution haven |
| Lan et al. (2012) | 29 provinces in China | 1996–2006 | Panel random effect, panel fixed effect | Pollution haven |
| Lee (2013) | G20 countries | 1971–2009 | Panel fixed effect | Pollution haven |
| Al-mulali and Tang (2013) | Gulf Cooperation Council (GCC) countries | 1980–2009 | Pedroni cointegration, panel FMOLS, panel VEC causality | Pollution halo |
| Asghari (2013) | MENA region | 1980–2011 | Panel random effect, panel fixed effect | Pollution halo |
| Chandran and Tang (2013) | ASEAN-5 economies | 1971–2008 | Johansen cointegration, VECM Granger causality | Neutrality (Indonesia, Malaysia, Singapore, Thailand) Pollution haven (the Philippines) |
| Lau et al. 2014 | Malaysia | 1970–2008 | ARDL, VECm Granger causality | Pollution haven |
| Yıldırım (2014) | 76 countries | 1980–2009 | Kónya bootstrap causality | Pollution haven (Mozambique, United Arab Emirates, Oman) Pollution halo (India, Iceland, Panama, and Zambia) Neutrality (other countries) |
| Kivyiro and Arminen (2014) | Sub-Saharan Africa | 1971–2009 | ARDL, VEC Granger causality | Pollution haven |
| Shaari et al. (2014) | 15 developing countries | 1992–2012 | Pedroni cointegration, panel FMOLS, panel VEC causality | Neutrality |
| Tang and Tan (2015) | Vietnam | 1976–2009 | Johansen cointegration, VECM Granger causality | Pollution haven |
| Gökmenoğlu and Taspinar (2016) | Turkey | 1974–2010 | ARDL, Toda-Yamamoto causality | Pollution haven |
| Shahbaz et al. | | 1975–2012 | Pedroni and Johansen-Fisher cointegration, panel | Pollution halo |

Table 1 (continued)

| Author(s) | Country | Period | Methodology | Conclusion |
|---|---|---|---|---|
| (2015) | High-, middle-, and low-income countries | | FMOLS, Dumitrescu-Hurlin causality | (high-income countries)<br>Pollution haven<br>(middle- and low-income countries) |
| Seker et al. (2015) | Turkey | 1974–2010 | ARDL, Hatemi-J cointegration, VECM Granger causality | Pollution haven |
| Keho (2015) | Economic Community of West African States (ECOWAS) countries | 1970–2010 | ARDL | Pollution halo<br>(Côte d'Ivoire, Ghana, Mali, Nigeria)<br>Pollution haven<br>(Gambia, Liberia, Niger)<br>Neutrality<br>(Benin, Burkina Faso, Senegal, Sierra Leone, Togo) |
| Hao and Liu (2015) | 29 provinces in China | 1995–2011 | GMM | Pollution halo |
| Zhang and Zhou (2016) | 29 provinces in China | 1995–2010 | Panel fixed effect, N-W, FGLS, PCSE, DK | Pollution halo |
| Mert and Bölük (2016) | Kyoto Annex countries | 2002–2010 | Pedroni cointegration, panel ARDL, panel VEC causality | Pollution halo |
| Baek (2016) | 5 ASEAN countries | 1981–2010 | Pedroni cointegration, panel ARDL | Pollution haven |

Gökmenoğlu and Taspinar 2016; Seker et al. 2015; Baek 2016), others support pollution halo hypothesis (Tamazian et al. 2009; Al-mulali and Tang 2013; Asghari 2013; Hao and Liu 2015; Zhang and Zhou 2016; Mert and Bölük 2016), some of them support neutrality/no relationship hypothesis (Aliyu 2005; Shaari et al. 2014), and some support mixed results (Merican 2007; Chandran and Tang 2013; Yıldırım 2014; Shahbaz et al. 2015; Keho 2015)

Another prominent study is Shahbaz et al. (2015). The study concluded that FDI reduces $CO_2$ emission in high-income countries (pollution halo), while increasing in middle- and low-income countries (pollution haven). These findings support the idea that there are differences between developed and under-developed countries in terms of environmental understanding and regulations.

(2) Methods of analyses are in two ways; panel data and time series analyses. In panel data analysis, ordinary least squares (OLS), random effect, fixed effect, Pedroni cointegration, full modified least squares (FMOLS), generalized method of moments (GMM), Newey–West standard errors (N-W), feasible generalized least square (FGLS), corrected standard errors (PCSE), Driscoll–Kraay standard errors (DK), autoregressive-distributed lag (ARDL), and causality methods are often used.

(3) In time series analysis, traditional cointegration analysis like Johansen and ARDL is often used. Apart from that, vector error correction (VECM), unrestricted error correction (UECM), and Granger and Toda-Yamamoto causality methods are also used. However, in the literature, it can be observed that there is a gap in terms of cointegration methods that take structural breaks into account. In addition to that, there is no other study that examines FDI-$CO_2$ emission relationship using Hacker and Hatemi-J (2012) bootstrap causality analysis.

(4) In the studies conducted on Turkey, Gökmenoğlu and Taspinar (2016) using ARDL and Toda-Yamamoto causality analysis and Seker et al. (2015) using ARDL, Hatemi-J cointegration, and VECM causality

analysis reached results that support PHH. In addition to the existing findings, our study examines FDI-$CO_2$ relationship for Turkey using Maki (2012) cointegration and Hacker and Hatemi-J (2012) bootstrap causality methods which have not been used in the related literature yet.

## Methodology

Estimating the parameters for long-run relationship between economic variables has been an important field of interest in the literature. The Gauss-Markov statistical properties or the best linear unbiased estimators need to fulfill the following two conditions. First, regression variables should be stable in their level values or their cointegration degrees should be zero [I(0)]. Regression results for parameter estimation are significant in this circumstance. Second, if both variables are stable in their first difference [I(1)], in order for the estimation parameters to be significant, there should be at least one cointegration relationship between the series. Otherwise, regression estimation is misleading and traditional *t*, Wald, and *F* statistics may produce biased and inefficient results (Bilgili 2012). For this reason, at the first step of the econometric analysis, it should be analyzed if the series are stable or if they include a unit root or not. In this study, Dickey and Fuller (hereafter ADF, 1981) and Phillips and Perron (hereafter PP, 1988) unit root tests that are commonly used in the econometrics literature are used for testing stability.

Unit root studies often show the related series that are not stable at their level value, but at their first difference [I(1)]. Therefore, in this case, linear cointegration relationship between the series should be analyzed. In the literature, cointegration methods developed by Engle and Granger (1987), Johansen (1988, 1991), and Johansen and Juselius (1990) are intensively used. However, these test methods assume that long-run cointegration parameters do not change in time; in other words, they do not take structural breaks into consideration. As to this shortcoming, Gregory and Hansen (1996) developed a cointegration test that takes a regime change/structural break in to consideration. Hatemi-J (2008), expanding this method, introduced the cointegration test that defines two breaks. The latest test related to this issue is the cointegration test that has been developed by Maki (2012) and can estimate up to five breaks.

In Maki's (2012) cointegration test, in the sampling process, a possible break point for each period and *t* statistics are calculated. The following methods are developed to test cointegration under the assumption of multiple break points.

Model 0:

$$y_t = \mu + \sum_{i=1}^{k} \mu_i D_{i,t} + \beta' x_t + \mu_t \quad (1)$$

Model 1:

$$y_t = \mu + \sum_{i=1}^{k} \mu_i D_{i,t} + \beta' X_t + \sum_{i=1}^{k} \beta_i' x_t D_{i,t} + \mu_t \quad (2)$$

Model 2:

$$y_t = \mu + \sum_{i=1}^{k} \mu_i D_{i,t} + \gamma t + \beta' x_t + \sum_{i=1}^{k} \beta_i' x_t D_{i,t} + \mu_t \quad (3)$$

Model 3:

$$y_t = \mu + \sum_{i=1}^{k} \mu_i D_{i,t} + \gamma t + \sum_{i=1}^{k} \gamma_i t D_{i,t} + \beta_i' x_t + \sum_{i=1}^{k} \beta_i' x_t D_{i,t} + u_t, \quad (4)$$

where $t = 1,2,\ldots,T$. $y_t$ represents observable I(1) variables, $u_t$ is the error term, and $y_t$ is a numeral and an (mx1) vector. As an assumption in Maki (2012), an (nx1) vector $z_t$ is constitute by, where $\varepsilon_t$ are i.i.d. with mean zero, positive definite variance-covariance matrix Σ, and ∞ for some s > 4. $\mu$, $\mu i$, $\gamma$, $\gamma i$, $\beta' = (\beta_1, \ldots, \beta_m)$, and $\beta_i' = (\beta_{i1}, \ldots, \beta_{im})$ are true parameters. $D_{i,t}$ denotes dummy variables equal to 1 if $t >$ TBi ($i = 1,\ldots,k$) and equal to 0 otherwise, where $k$ is the maximum number of breaks and $TB_i$ represent the time period of break. Equation (1) has the model with level shifts. Equation (2) includes structural breaks of level and regressors (level shift with trend). Equation (3) is extended form of Eq. (2) with a trend (regime shifts). Equation (4) allows for structural breaks of levels, trends, and regressors employed (regime shifts with trend).

In the case when the test statistics calculated in cointegration analysis are greater than the critical value, empty hypothesis suggesting no cointegration relationship between the series is rejected. In that case, a long-run balance relationship between the variables is accepted to be valid. Critical values are identified by Monte Carlo simulation (Maki 2012) and are presented in Table 1.

Next step in econometric analysis for defining the cointegration analysis is to estimate the flexibility coefficients that reveal the relationship between variables. In this study, dynamic ordinary least squares (DOLS) method developed by Stock and Watson (1993) is used for coefficient estimation.

To correct the possible endogeneity and serial correlation problems in the OLS estimation, Stock and Watson (1993) use a long-run dynamic equation with leads and lags of explanatory variables (Esteve and Requena 2006). The DOLS model, then, can be written as Eq. (5).

$$y_t = \alpha_0 + \alpha_1 t + \alpha_2 x_t + \sum_{i=-q}^{q} \delta_i \Delta x_{t-i} + \varepsilon_t \quad (5)$$

where $y$, $t$, $x$, $q$, $\Delta$, and $e$ denote dependent variable, time trend, independent variable, optimum leads and lags, difference operator, and error term, respectively.

Causality analyses are often used to investigate the direction of relations between variables. In this study, we use the causality test that is recently developed by Hacker and Hatemi-J (2012) to investigate the relationship between variables.

Hacker and Hatemi-J (2006) investigate the size properties of the modified Wald (MWALD) test, which is developed by Toda and Yamamoto (1995), and find that this test performs poorly in small samples. They suggest the use of a leveraged bootstrap distribution to lower the size distortions, and remark that Monte Carlo simulation results indicate that an MWALD test based on a bootstrap distribution has much smaller size distortions, with and without autoregressive conditional heteroscedasticity effect present. Then, Hacker and Hatemi-J (2012) modify their bootstrap approach in Hacker and Hatemi-J (2006) by endogenizing the lag length selection.

Hacker and Hatemi-J (2012) use a vector autoregressive model (VAR ($k$)) with $k$ orders as in Eq. (6):

$$y_t = B_0 + B_1 y_{t-1} + \ldots + B_k y_{t-k} + u_t. \tag{6}$$

In Eq. (6), $y_t$, $B_0$, and $u_t$ are nx1 dimensional vectors, and if $i \geq 1$, $B_i$ is a nxn dimensional parameter matrix. Hatemi-J (2003, 2008) has developed an alternative criterion such as Schwarz Bayesian criterion (SBC) and criterion Akaike information criterion (AIC) for the lag length determined internally in the model. Hatemi-J (HJC) information criterion is calculated as follows:

$$\text{HJC} = \ln\left(det\hat{\Omega}_j\right) + j\frac{(n^2 lnT + 2n^2 ln(lnT))}{2T} \qquad j = 0, \ldots .k \tag{7}$$

Here, $\det\hat{\Omega}_j$ is the determinant of the estimated maximum likelihood variance-covariance matrix of the residuals in the VAR ($j$) model. Here, $n$ is the numbers of the variables, $T$ is the sample size, and ln is used to show the natural logarithmic transformation.

For causality analysis, the null hypothesis is defined as "there is no causality relationship between the first variable and the second variable." The Wald statistic is calculated to test the null hypothesis. If the calculated test statistic is greater than the bootstrap critical values obtained by the Monte Carlo simulation, the null hypothesis is rejected.

## Model, data, and results

### Model and data

This study examines FDI-$CO_2$ emission relationship in Turkey with 1974–2013 period annual data using environmental Kuznets curve (EKC) model. For this purpose, quadratic model below is estimated:

$$lnCO_{2t} = \beta_0 + \beta_1 \ln Y_t + \beta_2 \ln {Y^2}_t + \beta_3 lnFDI_t + \beta_4 lnEC_t + \varepsilon_t. \tag{8}$$

In model number (8), $\ln CO_2$ refers to $CO_2$ emission per capita, lnY to income per person, $\ln Y^2$ to square of per capita income, lnFDI to foreign direct capital investments, and lnEC to energy consumption per capita. $\beta_0$ indicates constant term and $\beta_1$, $\beta_2$, $\beta_3$, and $\beta_4$ are long-run parameters that demonstrate the impact of income, square of income, FDI, and energy use on $CO_2$ emission. In the model, $t$ and $\varepsilon$ represent period and error terms. All the data are transformed into natural logarithms. This transformation prevents problems related to the dynamic characteristics of the data set and log-linear specification of the model produces more consistent and productive empirical results (Koçak and Şarkgüneşi 2017). Table 2 provides explanations for the data.

The environmental Kuznets curve is a fundamental model used to explore the relationship between income and the environment. The EKC model reveals a non-monotonic long-run relationship between income and the environment. Also, additional variables may be added to the EKC model, which are thought to be affecting environmental pollution. Thus, the environmental impact of other economic factors besides income is also investigated (Dinda 2004; Carson 2009). Many studies in the literature use the EKC model to reveal the environmental impact of factors such as financial development, foreign direct investment, trade, and industrialization (Cole 2004; Tamazian and Rao 2010). Therefore, the EKC model is preferred in this study to investigate the environmental impact of foreign direct investment or demonstrate the validity of the pollution haven hypothesis (PHH).

Variables in the EKC model (model 8) used to test the pollution haven hypothesis are selected for the following reasons: (1) $CO_2$ emission (dependent variable/$\ln CO_2$) is preferred as environmental pollution/quality indicator. Because $CO_2$ gas is considered the most important and harmful greenhouse gas. The world of science shows $CO_2$ emissions as the most important cause of global warming (Bilgili et al. 2017a). In many studies, $CO_2$ emissions are shown as indicators of environmental pollution. (2) GDP per capita (independent variable/lnY) represents the income in the EKC model. Today, all

**Table 2** Definitions of variables and data sources

| Variable | Definition | Unit | Source |
|---|---|---|---|
| $lnCO_2$ | $CO_2$ emissions per capita | Metric tons | World Bank Development Indicators |
| lnY | GDP per capita (constant 2010) | Dollar (US$) | World Bank Development Indicators |
| $lnY^2$ | Square of GDP per capita | Dollar (US$) | World Bank Development Indicators |
| lnFDI | Share of foreign direct investments in GDP | Percent (%) | World Bank Development Indicators |
| lnEC | Energy consumption per capita | Kilograms of oil equivalent | World Bank Development Indicators |

economies and international organizations (such as the World Bank) use the per capita GDP indicator as a measure of basic income and wealth. (3) In order to test the hypothesis of the pollution haven, it is necessary to investigate the environmental impact of foreign investment in the host country. For this reason, the most favorable indicator of foreign capital investments in the host country is the share of foreign direct investment in GDP (see Table 1). (4) Finally, the energy consumption indicator is added to the model as a control variable. Because energy consumption is considered as the most important cause of $CO_2$ emissions (Acharyya 2009; Chandran and Tang 2013; Kivyiro and Arminen 2014; Seker et al. 2015).

According to EKC hypothesis, $CO_2$ emission will increase in the first stages of economic growth process due to more production, energy, and source usage (scale effect). In later stages, however, when the income per capita reaches a certain level with the ongoing growth, structural change process in economy will start (structural effect); demand for a cleaner environment will raise and clean technologies will develop in economy-wide (technological effect), and $CO_2$ emission will decrease. Namely, the eventual outcome of EKC hypothesis is decrease in $CO_2$ emission. For this reason in case the estimation result of model number one is $\beta_1 > 0$ and $\beta_2 < 0$, another important issue is at which income level of the turning point (tp), that is decrease in pollution, will occur. In this context, turning point is calculated with $tp = \exp(-\beta_1 / 2\beta_2)$ formula (Stern 2004).

The effect of FDI on $CO_2$ emission depends on $\beta_3$. If $\beta_3 > 0$, pollution haven; if $\beta_3 < 0$, pollution halo; and if $\beta_3$ is statistically insignificant, neutrality hypothesis will apply.

Finally, the expected value of the parameters that belong to energy usage included in the model as controlling variable is positive ($\beta_4 > 0$) as in the literature energy consumption is shown as the substantial reason for the rapid increase in $CO_2$ emission (Koçak 2014).

**Fig. 1** The trends of $lnCO_2$, lnY, lnFDI, and lnEC, 1974–2013 ▶

## Results

Table 3 shows the correlation matrix and the descriptive statistics of data used in the preliminary analysis. In all the statistics, values of lnY and $lnY^2$ are greater than the values of other variables. All the series used in the analysis have a normal distribution. In addition, a high correlation is observed between the independent variables. For this reason, estimation methods such as DOLS which corrects correlation between series will be preferred for regression analysis.

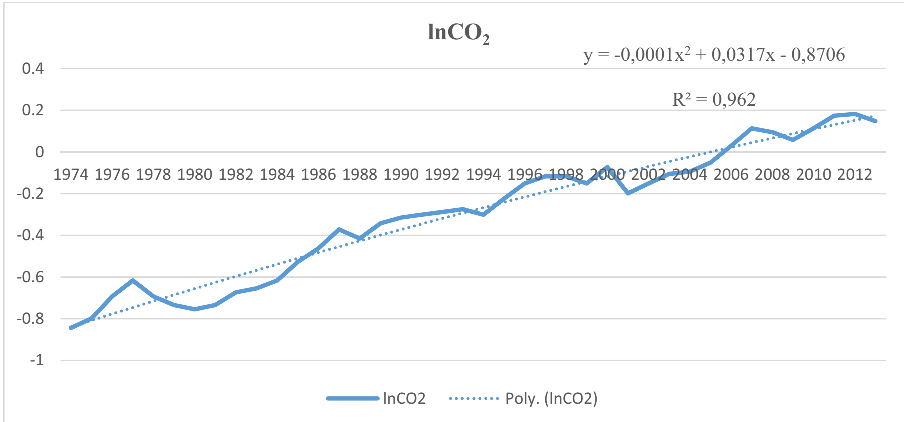
Variations of the variables with respect to time are shown in Fig. 1. Accordingly, (1) we can see that in all series there is a tendency to increase related to time and a tendency of co-movements (2) Structural breaks that reveal as peak and bottom in time-related tendencies of series are observed. (3) Coefficient of determination ($R^2$) values calculated to measure the goodness of fit for tendency line of variables is, in turn, 0.96, 0.97, 0.76, and 0.96.

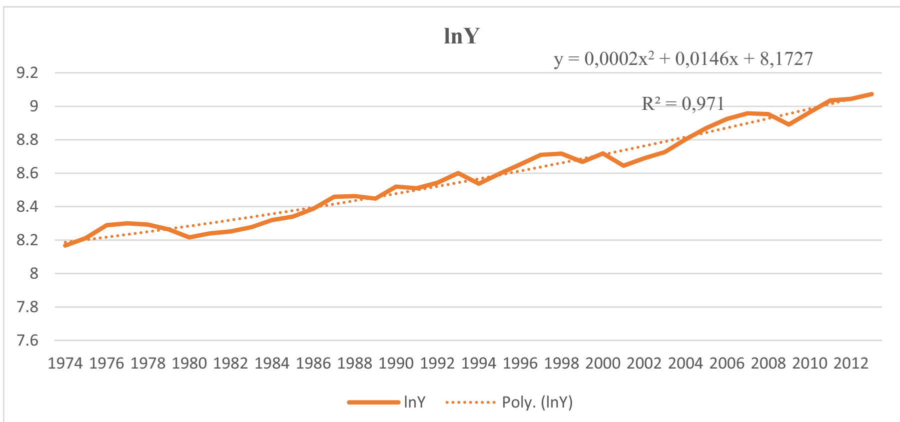
Without a doubt, time-related tendencies of series for variables, descriptive statistics, and correlation matrix present quite significant elementary or foreknowledge as to the relationship between $lnCO_2$, lnY/lnY2, lnFDI, and lnEC variables. However, aside from the related evaluations, methods like unit root, cointegration, and causality analysis are used to investigate the relationship between the variables in order to reach more efficient and unbiased results. Therefore, unit root, cointegration, and causality tests will be reported after preliminary analyses.

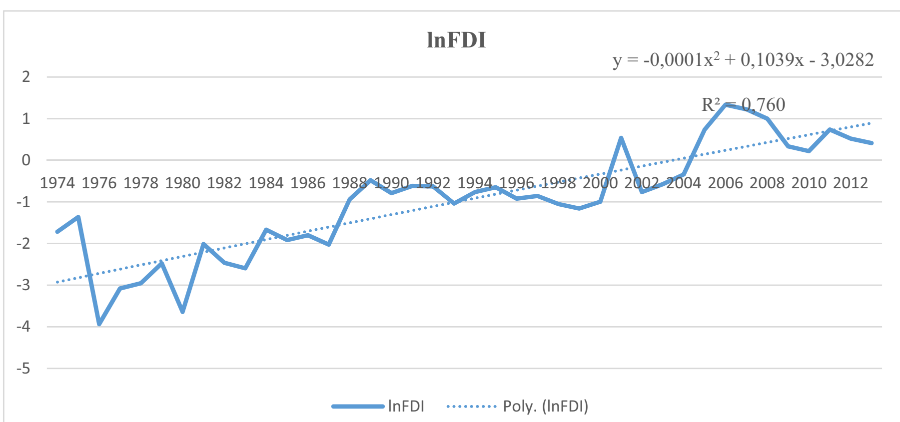
The unit root test results are presented in Table 4. Test results shows that the level values of the variables used in the analysis include unit root, and for that reason, they are

**Table 3** Descriptive statistics and correlation matrix for variables

| Descriptive statistics | $lnCO_2$ | lnY | $lnY^2$ | lnFDI | lnEC |
|---|---|---|---|---|---|
| Mean | − 0.298 | 8.582 | 73.725 | − 0.979 | 6.915 |
| Median | − 0.281 | 8.570 | 73.448 | − 0.889 | 6.894 |
| Maximum | 0.182 | 9.073 | 82.325 | 1.335 | 7.363 |
| Minimum | − 0.843 | 8.164 | 66.707 | − 3.937 | 6.484 |
| Std. dev. | 0.309 | 0.271 | 4.669 | 1.311 | 0.261 |
| Jarque-Bera | 2.474 | 2.480 | 2.508 | 0.764 | 2.333 |
| (Probability) | (0.290) | (0.2480) | (0.285) | (0.682) | (0.311) |
| Observations | 40 | 40 | 40 | 40 | 40 |
| Correlation matrix | | | | | |
| $lnCO_2$ | 1 | | | | |
| lnY | 0.984 | 1 | | | |
| $lnY^2$ | 0.982 | 0.999 | 1 | | |
| lnFDI | 0.862 | 0.865 | 0.864 | 1 | |
| lnEC | 0.994 | 0.993 | 0.992 | 0.856 | 1 |


lnCO2
y = -0,0001x² + 0,0317x - 0,8706
R² = 0,962
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
lnCO2
Poly. (lnCO2)


lnY
y = 0,0002x² + 0,0146x + 8,1727
R² = 0,971
9.2
9
8.8
8.6
8.4
8.2
8
7.8
7.6
1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
lnY
Poly. (lnY)


lnFDI
y = -0,0001x² + 0,1039x - 3,0282
R² = 0,760
2
1
0
-1
-2
-3
-4
-5
1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
lnFDI
Poly. (lnFDI)

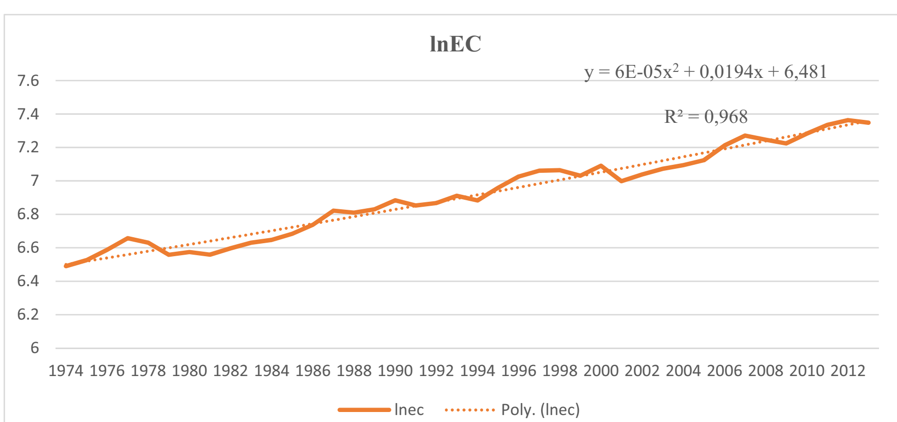

lnEC
y = 6E-05x² + 0,0194x + 6,481
R² = 0,968
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
6
1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
lnec
Poly. (lnec)

**Table 4** ADF and PP unit root tests

| Variable[a] | | ADF test statistic | | PP test statistic | |
|---|---|---|---|---|---|
| | | Intercept | Intercept and trend | Intercept | Intercept and trend |
| $lnCO_2$ | | − 1.043 | − 2.674 | − 1.055 | − 2.802 |
| lnY | | 0.018 | − 2.617 | 0.083 | − 2.716 |
| $lnY^2$ | | 0.118 | − 2.531 | 0.199 | − 2.622 |
| lnFDI | | − 1.680 | − 2.666 | − 1.342 | − 2.662 |
| lnEC | | − 0.446 | − 2.997 | − 0.364 | − 3.041 |
| $\Delta lnCO_2$ | | − 5.906[b] | − 5.852[b] | − 6.260[b] | − 6.187[b] |
| ΔlnY | | − 6.187[b] | − 6.176[b] | − 6.200[b] | − 6.312[b] |
| $\Delta lnY^2$ | | − 6.183[b] | − 6.194[b] | − 6.195[b] | − 6.634[b] |
| ΔlnFDI | | − 8.775[b] | − 8.699[b] | − 9.574[b] | − 9.373[b] |
| ΔlnEC | | − 6.101[b] | − 6.088[b] | − 6.265[b] | − 6.168[b] |
| Critical values | 1% | − 3.611 | − 4.211 | − 3.610 | − 4.211 |
| | 5% | − 2.938 | − 3.529 | − 2.938 | − 3.529 |
| | 10% | − 2.607 | − 3.196 | − 2.607 | − 3.196 |

[a] Δ is the first difference operator

[b] Illustrates 1% statistical significance

not stable. When the first differences of the series are taken, however, they stabilize. That is, all the variables are I(1) according to unit root test.

After determining the integration degree of the series used in analysis -I(1)- Maki (2012), existence of a relationship between the structural break cointegration test and the variables is analyzed. Table 5 reports the cointegration test results. According to these results, Model 0, Model 1, and Model 2 test statistics indicate that the null hypothesis of no cointegration is rejected. These results indicate that there is a long-run balance relationship between $CO_2$ emission, economic growth, FDI, and energy usage in 1974–2013 Turkey.

The break dates in Table 5 refer to the periods when structural changes that are important for economy of Turkey occurred. For instance, years 1976 and 1978 correspond to Cyprus Peace Operation and World Petrol Crisis. Years 1984 and 1985 correspond to the periods that governance constituted after the coup was handed over to the civil government. Besides, this period is when transition to liberal economic policies accelerated and transition from import substitution industrialization to export oriented economic policies began. 1992, 1995, 1998, and 1999 periods refer to the economic crisis of Turkish economy that began in 1993 and grew in 1994 and its aftermath. 2000 and 2001 periods show the November, 2000 and February, 2001 economic crisis and their aftermath. 2004 period corresponds to the period when the impact of the crisis disappeared to a large extend and when the country entered a rapid economic recovery by global conjuncture. Finally, 2010 and 2011 periods refer to initially the period when the recession in USA property market and the period of global financial crisis that affected the whole world in the ensuing years.

The step that follows the cointegration relationship is estimating the long-run parameters. For this, break dates acquired

**Table 5** Maki (2012) cointegration test results

| Model | Test statistic | Critical values[a] | | | Break dates |
|---|---|---|---|---|---|
| | | 1% | 5% | 10% | |
| Model 0 (level shift) | − 7.40[b] | − 6.85 | − 6.30 | − 6.03 | 1992; 1995; 1998; 2000; 2004 |
| Model 1 (level shift with trend) | − 7.73[b] | − 7.05 | − 6.49 | − 6.22 | 1976; 1984; 1999; 2004; 2011 |
| Model 2 (regime shifts) | − 19.80[b] | − 9.44 | − 8.86 | − 8.54 | 1978; 1985; 2000; 2004; 2010 |
| Model 3 (regime shifts and trend) | − 6.96 | − 10.08 | − 9.48 | − 9.15 | 1976; 1995; 2001; 2004; 2010 |

[a] Critical values are obtained from Table 1 in Maki (2012)

[b] Illustrates 1% statistical significance

by Maki (2012) test results and that belong to Model 0 are added to the model as dummy variables. By this means the effect of structural changes in the related periods on $CO_2$ emission is estimated. Table 6 shows DOLS estimate results.

DOLS estimation results are as follows:

(1) The parameter for InY standing for economic growth is positive and statistically significant at a 1% significance level. The parameter for $InY_2$ standing for square of economic growth is negative and statistically significant at a 1% significance level. That is, $lnY > 0$ and $lnY_2 < 0$ status is valid; findings supporting EKC hypothesis between economic growth and $CO_2$ emission in 1974–2013 period Turkey are reached. In the frame of this hypothesis, turning point is calculated US$5356. According to this, while the economic growth process increases $CO_2$ emission until the Turkish economy reaches US$5356 income level, after this, income level growth process has a reducing impact on $CO_2$ emission. (2) It can be seen that the parameter for InFDI standing for foreign direct investment is positive and statistically significant at a 10% significance level. This result asserts that increase in foreign capital investment entering Turkey in 1974–2013 period has an impact that increases $CO_2$ emission. According to this, findings supporting PHH between FDI and $CO_2$ emission in Turkey. (3) Parameter for InEC standing for energy usage is positive and statistically significant at a 1% significance level. According to this, increase in energy usage in Turkey in the related period has an effect that increases $CO_2$ emission. (4) Parameters for break dates added into the model as dummy variables are statistically insignificant. This status indicates that structural changes occurred in related periods in Turkey does not have an impact on $CO_2$ emission.

Cointegration test and long-term coefficient estimation do not give information about whether the relationship between variables is a bidirectional relationship or about the direction of the relationship. For this reason, Table 7 reports the results for Hacker and Hatemi-J (2012) bootstrap causality test conducted to define the direction of the relationship between $CO_2$ emission, economic growth, FDI, and energy usage.

Bootstrap causality test results are as follows:

(1) It can be seen that while there is not a causality relationship from $CO_2$ emission to economic growth (lnY) in 1974–2013 period Turkey, there is a one-way causality relationship from economic growth (lnY) to $CO_2$ emission. This result indicates that economic growth is a determinant of $CO_2$ emission and a very important variable in the estimations for. (2) There is a two-way relationship between FDI and $CO_2$ emission. In other words, a change in FDI level causes a change in $CO_2$ emission. However, this relationship is one-way, and changes in $CO_2$ emission affect FDI level. These findings support PHH and assert a feedback relationship between FDI and $CO_2$ emission. (3) Finally, a two-way/co-feeding causality relationship is found between energy usage and $CO_2$ emission. These results support the general opinion that a prominent reason for the increase in $CO_2$ emission is energy usage.

**Table 6** Estimation of the long-run coefficients

Dependent variable: $lnCO_2$

| Regressor | Coefficient | *t* statistic | *p* value |
|---|---|---|---|
| lnY | 6.353[a] | 4.244 | 0.000 |
| $lnY^2$ | − 0.370[a] | − 4646 | 0.000 |
| lnFDI | 0.007[b] | 1.768 | 0.087 |
| lnEC | 1.184[a] | 6.221 | 0.000 |
| d1(1992) | 0.038 | 1.399 | 0.171 |
| d2(1995) | − 0.027 | − 0.651 | 0.573 |
| d3(1998) | − 0.004 | − 0.226 | 0.822 |
| d4(2000) | 0.013 | 0.012 | 0.990 |
| d5(2004) | − 0.021 | − 0.215 | 0.819 |
| Intercept | − 34.617[a] | − 5.809 | 0.000 |
| Turning point | US$5356 | | |
| Diagnostics | | | |
| Adj. $R^2$ = 0.978 | | | |
| S.E. of regr. = 0.020 | | | |
| Durbin-Watson stat. = 1.793 | | | |

Break dates selected based on model 0 in Maki [62]

[a] Illustrates 1% statistical significance

[b] Illustrates 10% statistical significance

## Conclusion and policy suggestions

The impact of FDI movements that have an important role on the development process of the developing countries on the environment has been the subject of discussion lately. The literature focuses on two main hypotheses as to FDI-$CO_2$ emission. The first is the PHH that emphasizes that FDI movements have a reducing effect on $CO_2$ emission in developing countries. The second one is, on the contrary, the pollution halo hypothesis advocating that FDI movements improve environmental quality in developing countries and thus, reduce $CO_2$ emission. This study analyses the relationship between FDI and $CO_2$ emission in 1974–2013 period Turkey within the frame of EKC model. For the analysis, Maki (2012) structural break cointegration test, Stock and Watson (1993) DOLS estimator, and Hacker and Hatemi-J (2012) bootstrap causality test methods were used.

The results indicate that there is a long-run balance relationship between $CO_2$ emission, economic growth, FDI, and energy usage. According to this relationship, (a) EKC relationship is true between economic growth and $CO_2$ emission, and this relationship is one-way from economic growth to $CO_2$ emission. The turning point within the frame

**Table 7** Hacker and Hatemi-j (2012) bootstrap causality test results

| Null hypotheses | MWALD statistic | Bootstrap critical values[a] | | | Decision |
|---|---|---|---|---|---|
| | | 1% | 5% | 10% | |
| lnY does not cause $lnCO_2$ | 6.142[c] | 7.294 | 4.167 | 2.927 | Reject |
| $lnCO_2$ does not cause lnY | 1.868 | 7.734 | 4.223 | 3.006 | Fail to reject |
| lnFDI does not cause $lnCO_2$ | 4.880[c] | 7.348 | 4.112 | 2.859 | Reject |
| $lnCO_2$ does not cause lnFDI | 4.618[c] | 7.363 | 4.024 | 2.826 | Reject |
| lnEC does not cause $lnCO_2$ | 9.301[b] | 7.222 | 4.167 | 2.941 | Reject |
| $lnCO_2$ does not cause lnEC | 4.282[c] | 9.374 | 4.855 | 3.426 | Reject |

[a] Critical values are calculated through bootstrap approach

[b] Illustrates 1% statistical significance

[c] Illustrates 5% statistical significance

of EKC calculated for Turkey is US$5356. In other words, economic growth process reduces $CO_2$ emission as of this income level. According to World Bank data, Turkey reached a US$5356 income in 2004, and income level per person is US$9130 since 2015. According to these results, that the growing process continues in the future periods is expected to have a positive impact on environmental quality. (b) Impact of FDI on $CO_2$ is positive, this relationship is positive, and this relationship is two-way. That is, while FDI movements are a reason for $CO_2$ emission, $CO_2$ emission is also a reason for FDI movements in Turkey. For this reason, both cointegration and causality test findings indicate that PHH is valid for Turkey, supporting Gökmenoğlu and Taspinar (2016) and Seker et al. (2015). (c) Finally, it is seen that increase in energy usage has an impact that increases $CO_2$ emission in Turkey and this relationship is two-way. This result, considering Turkey meets 89% of its total energy demand with fossil resources (Koçak 2014), is as expected.

Empirical findings provide some policy suggestions. Firstly, Turkey should encourage foreign direct investment into technology-intensive and environmentally friendly areas and develop various environmental regulations in this direction (Gökmenoğlu and Taspinar 2016; Shahbaz et al. 2015). Investments in these areas will play an important role in reducing long-term $CO_2$ emissions. The impact of FDI is not limited only to the activities of foreign firms. They create knowledge spillovers of environmentally friendly technologies in the invested sector, region, and even throughout the country. Turkey needs to make arrangements to strengthen the absorptive capacity mechanisms in order to be able to make this process more efficiently.

Some studies in the literature emphasize that increases in renewable energy consumption will make an important contribution to reducing $CO_2$ emissions (Bilgili et al. 2017a, b; Bulut 2017). Turkey is a country with a high potential for biomass, solar, and wind energy. For example, the total agricultural area of Turkey is 23,063,000 ha. Of these, 38% are cultivated areas, 45% are forests, 10% fallow lands, and 7% are cultivated fruit and vegetable fields (Renewable Energy Working Group 2007). The potential for plant, animal, and forestry production, which forms the raw material for modern biomass energy, is very high. Similarly, Turkey has a surface area of about 800,000 $km^2$. The three sides of the country are surrounded by the sea. Turkey has a very long coastline of 8500 km long. Theoretically, Turkey has 160 TW of wind energy per year (Oğulata 2003). It is also a country with a potential of solar energy, due to its location (with latitudes 36–42 N and longitudes 26–45 E) in the Northern Hemisphere (Saylan et al. 2002). After all, Turkey should channel direct foreign investment into the field of renewable energy technologies. Thus, the dependence on fossil resources such as coal, natural gas, and oil is reduced. These results provide a significant reduction in $CO_2$ emissions and increase environmental quality.

Finally, the literature refers to the increasing importance of various environmental taxes in the fight against $CO_2$ emissions (Lin and Li 2011; Fang et al. 2013). For example, regulations such as carbon taxation and carbon trading, which will reduce the negative impacts of foreign direct investment on the environment, have critical importance. As a result, these tools for fighting emissions are applicable policy instruments for Turkey. At present, it is necessary for Turkey to adopt alternative practices such as carbon limitation, trade, and carbon taxation for the full harmonization of the European Union Emissions Trading System. In this context, companies that will invest in Turkey may become obliged to calculate and report their carbon emissions accurately and reliably. Thus, negative environmental impacts of foreign direct investment can be minimized.

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