Environmental Science and Pollution Research (2018) 25:36589–36603
https://doi.org/10.1007/s11356-018-3526-5

RESEARCH ARTICLE

The impact of economic growth, energy consumption, trade openness, and financial development on carbon emissions: empirical evidence from Turkey

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Received: 15 July 2018 / Accepted: 17 October 2018 / Published online: 30 October 2018

Abstract

This study examines the impact of economic growth, energy consumption, trade openness, financial development on carbon emissions for the case of Turkey by using annual time series data for the period of 1960–2013. The Lee and Strazicich test suggests that the variables are suitable for applying the bounds testing approach to cointegration. The cointegration analysis reveals that there exists a long-run relationship between the per capita real income, per capita energy consumption, trade openness, financial development, and per capita carbon emissions in the presence of structural breaks. The results show that in the long run, carbon emissions are mainly determined by economic growth, energy consumption, trade openness, and financial development. The VECM Granger causality analysis indicates a long-run unidirectional causality running from economic growth, energy consumption, trade openness, and financial development to carbon emissions. The findings also show that the EKC hypothesis is valid for Turkey both in the long run and short run. The study provides some implications for policy makers to decrease carbon emissions in Turkey.

Keywords Carbon emissions · EKC hypothesis · Structural breaks · ARDL bounds test · VECM granger causality

Introduction

There exists a broad consensus among scientists and researchers that environmental pollution has significantly caused global warming and climate change over the past two decades. These changes have vital effects on the ecosystems and the well-being of humans in the World (Easterbrook 2006; Shahbaz et al. 2014; IPCC 2014; Gokmenoglu and Taspinar 2016).

Responsible editor: Muhammad Shahbaz

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Global greenhouse gas (GHG) emissions from fossil fuels have significantly increased since the 1900s. Between 1990 and 2012, global emissions of all major GHGs such as carbon dioxide (CO_2), methane, nitrous oxide, and others rose (WRI 2014). Intergovernmental Panel on Climate Change (2014) reveals that the key GHG is CO_2 and 76% of GHG emissions consist of carbon emissions, mostly coming from fossil fuel and industrial processes. IPCC (2014) also reveals that mostly developing countries such as China, India, Russia, Brazil, Indonesia, Mexico, South Africa, and Turkey contribute to the GHG emissions, especially to carbon emissions. Therefore, environmental pollution is one of the vital issues for policy makers in developing countries. For this reason, there has been a great deal of research on the environmental quality and determinants of carbon emissions recently (Ulucak and Lin 2017; Solarin et al. 2017a; Cetin et al. 2018; Solarin and Al-mulali 2018).

Turkey, being one of the fastest-growing emerging economies, is a suitable case to investigate the empirical determinants of environmental degradation for several reasons. Firstly, Turkey had the greatest increase rate in carbon emissions among 42 countries under the Kyoto Protocol (UNFCCC 2012). The total amount of GHG emissions in

Turkey was 187 million tons in 1990 and reached 467.6 million tons in 2014, while the amounts for carbon emissions were 146.7 million tons and 382.2 million tons for the same years, respectively. Carbon emissions per capita were 6.08 tons in 2014, while it was 3.77 tons for the year 1990 in Turkey (TSIa 2016).

Secondly, the report presented by US Energy Information Administration (2013) reveals that Turkey has witnessed the fastest growth in energy demand over the last 2 years in the OECD. Besides, Turkey is an energy-dependent country, importing more than 74% of its total energy consumption, and it is expected to increase energy demand over the next decade. As Solarin et al. (2017b) point out, energy consumption is one of the primary reasons of environmental pollution.

Thirdly, Turkish government has also applied a macroeconomic strategy related to structural and fiscal reforms starting from the first half of 2002. One of the main goals of the structural and fiscal reforms was to improve the efficiency and resiliency of the financial sector. The improvements in financial structure led Turkey to have a more powerful and consistent macroeconomic structure (WTO 2012). As a result, Turkish economy witnessed a rapid economic growth between 2002 and 2014 with an average annual real GDP growth of 4.9%. Per capita GDP rose from 4.565 USD in 2003 to 9.261 USD in 2015 (IMF 2016). Turkey, an upper middle-income country, has become the 18th largest economy in the world, with a GDP of $800 billion in 2014. Turkish government has set a target to become the 10th largest economy in the world by 2023.

Fourthly, Turkey has adopted export-led growth policies since 1980. Turkish economy continues to integrate with the global economy and markets. In this context, Turkey became the 31st largest exporter and the 21st largest importer of the world in 2015. The volume of trade reached 351 billion USD in 2015. Turkey's exports reached 144 billion USD by the end of 2015, up from 36 billion USD in 2002. Turkey's imports reached 207 billion USD by the end of 2015, up from 52 billion USD in 2002 (TSIb 2016). Thus, economic growth, energy, financial development, foreign trade, and environmental pollution have been the main policy dynamics of Turkish economy. It would be very suitable to examine the long run and causality links among these dynamics for Turkey.

Due to the mentioned developments in environmental degradation and Turkey's dependence on energy, it is of importance to investigate this relationship. Therefore, the objective of this study, therefore, is to analyze the effects of economic growth, energy consumption, trade openness, and financial development on carbon emissions in the case of Turkey from 1960 to 2013. The present study contributes to the literature by analyzing the factors underlying environmental pollution. Firstly, we use Lee and Strazicich (2013) unit root test with endogenously designated structural breaks as well as standard unit root tests to provide efficient and consistent empirical evidence for the unit root properties of the variables. Secondly, we also use the ARDL bounds testing approach presented by Pesaran et al. (2001) with structural breaks to test the long-run relationship among the variables. Thirdly, we investigate the causal linkages among the variables by applying Granger causality test based on vector error correction model (VECM). Finally, as seen from Table 1, there exists very limited empirical evidence on the relationship between economic growth, energy consumption, trade openness, financial development, and carbon emissions for Turkey. Therefore, the study is expected provide some evidence for Environmental Kuznets Curve (EKC) literature and present important policy implications for Turkish economy.

The rest of the study is organized as follows: "Literature review" presents the literature, "Model and data" reveals model and data, "Methodology" describes econometric methodology, "Empirical findings and discussion" reports empirical findings, and "Concluding remarks and policy implications" provides concluding remarks with policy implications.

Literature review

There exists a great deal of study on the determinants of carbon emissions. Basically, we can categorize existing literature into four strands. The first strand of the literature investigates the validity of the EKC hypothesis which suggests that there exists an inverted U-shaped relationship between per capita income and environmental pollution. According to the EKC hypothesis, economic growth leads to environmental degradation in its initial stages and then, after a certain level of growth, it causes an improvement in the environmental quality. The EKC hypothesis was first tested by Grossman and Krueger (1995). Selden and Song (1994), Shafik (1994), Al-Mulali et al. (2016), and Solarin et al. (2017c) provided evidences supporting the validity of hypothesis.[1] In recent years, some studies have also examined the panel data dynamics between income and carbon emissions to determine the long run and causal links, for example, for developed countries (Coondoo and Dinda 2002), for 109 countries (Lee and Lee 2009), for 43 countries (Narayan and Narayan 2010), for 36 high-income countries (Jaunky 2011), for 98 countries (Wang 2012), and for 15 countries (Apergis 2016). However, economic growth alone may not explain carbon emissions in these studies. Other panel data studies conducted by Ozcan (2013) for 12 Middle East countries, Dogan and Seker (2016) for top renewable energy countries, Kang et al. (2016) for China, and Li

[1] However, Stern et al. (1996), Ekins (1997), Stern (1997), and Stern and Common (2001) present a critical and comprehensive literature regarding the EKC hypothesis.

Table 1 Summary of the empirical studies on Turkish economy

Study	Periods	Variables	Methodologies	EKC hypothesis	Cointegration	Long-run causality
Katircioğlu and Taspinar (2017)	1960–2010	GDP, EC, FD, CO_2	GLS unit root, Maki cointegration, DOLS, VECM	Yes	Yes	GDP ↔ CO_2 EC ↔ CO_2 FD → CO_2
Shahbaz et al. (2016)	1972–2013	GDP, EC, CO_2	ADF, PP, NP, LS unit root, ARDL, Time-varying Granger causality	Yes	Yes	GDP → CO_2 GDP → EC
Seker et al. (2015)	1974–2010	GDP, EC, FDI, CO_2	ADF, NP unit root, ARDL, VECM	Yes	Yes	GDP → CO_2 EC ↔ CO_2
Ozturk and Acaravci (2013)	1960–2007	GDP, EC, TR, FD, CO_2	ADF-GLS, ADF-WS unit root, ARDL, VECM	Yes	Yes	GDP → CO_2 EC → CO_2 TR → CO_2 FD → CO_2
Shahbaz et al. (2013c)	1970–2010	GDP, EC, GI, CO_2	ZA unit root, Johansen cointegration, ARDL, Grogery-Hansen test, VECM	Yes	Yes	GDP ↔ CO_2 EC ↔ CO_2
Ozturk and Acaravci (2010)	1968–2005	GNP, EC, EMP, CO_2	ARDL, VECM	No	Yes	–
Soytas and Sari (2009)	1960–2000	GNP, EC, CO_2	ADF, DF-GLS, PP, KPSS, NP unit root, VAR, Toda-Yamamoto causality	–	Yes	CO_2 → EC
Halicioglu (2009)	1960–2005	GDP, EC, TR, CO_2	ADF, PP unit root, ARDL, Johansen cointegration, VECM	Yes	Yes	GDP ↔ CO_2 EC → CO_2 TR → CO_2
Akbostanci et al. (2009)	1968–2003	GDP, CO_2	ADF unit root, Johansen cointegration	Yes	Yes	–
Jobert and Karanfil (2007)	1971–2008	GDP, EC, CO_2	Decomposition analysis	Yes	–	–
Lise (2006)	1980–2003	GNP, CO_2	Decomposition analysis	–	–	–

→ and ↔ denote unidirectional causality and bidirectional causality, respectively

GDP GDP per capita, *CO_2* carbon emissions, *EC* energy consumption, *TR* trade openness, *FD* financial development, *GI* globalization index, *EI* energy intensity, *GNP* GNP per capita, *EMP* employment, *FDI* foreign direct investment

et al. (2016) for China provide more complex and mixed findings related to the EKC hypothesis.

The second strand examines the role of energy consumption in the EKC literature. Since all economic processes require energy, it is always an essential factor of production (Stern 1997). Apergis and Payne (2009) emphasize that examining the relation between energy consumption and economic growth provides a basis for energy consumption-environment nexus.[2] In empirical literature, it was found that there is a positive long-run relationship between energy consumption and carbon emissions by Soytas et al. (2007) for USA, Cetin et al. (2018) for Turkey, Jalil and Mahmud (2009) for China, Acaravci and Ozturk (2010) for Denmark, Germany, Greece, Italy, and Portugal, Pao et al. (2011) for Russia, Pao and Tsai (2011) for BRIC countries, Hamit-Haggar (2012) for Canada, Arouri et al. (2012) for 12 MENA countries, Saboori and Sulaiman (2013) for five ASEAN countries, Baek and Kim (2013) for Korea, Shahbaz et al. (2015) for 13 African countries, Kais and Sami (2016) for 58 countries, Anwar et al. (2016) for Vietnam, and Li et al. (2016) for China. In the context of causality analysis, Acaravci and Ozturk (2010) for 19 EU countries, Ozcan (2013) for Middle East countries, Boutabba (2014) for India, and Shahbaz et al. (2015) for 13 African countries provide an evidence of unidirectional causality running from energy consumption to carbon emissions in the long run. Wang et al. (2011) for China, and Saboori and Sulaiman (2013) for five ASEAN countries reveal that there exists long-run bidirectional causality between energy consumption and carbon emissions.

The third strand investigates the relationship among economic growth, energy consumption, trade openness, and carbon emissions. Trade openness is also another important determinant of environmental pollution. Baumol and Oates (1988), and Tsai (1999) deal with the relation between trade and environment by using partial equilibrium models; on the other hand, Siebert (1992) and Perroni and Wigle (1994) investigate this relationship through the general equilibrium models. Halicioglu (2009) for Turkey, Tiwari et al. (2013) for India, Shahbaz et al. (2014) for Tunisia, Le (2016) for SSA countries, Anwar et al. (2016) for Vietnam, and Ertugrul et al. (2016) for Turkey, India, China, and Indonesia reveal that trade openness contributes to carbon

[2] See Stern (2000), Soytas et al. (2007), Narayan and Smith (2008), Halicioglu (2009), and Ozturk (2010) for comprehensive reviews.

emissions in the long run. On the other hand, Kanjilal and Ghosh (2013) for India, Dogan and Seker (2016) for top renewable energy countries, Kais and Sami (2016) for European and North Asian countries, and Kang et al. (2016) for China show that trade openness has a negative and statistically significant effect on carbon emissions in the long run. Jalil and Mahmud (2009) for China, Jayanthakumaran et al. (2012) for India and China, and Farhani et al. (2014) for Tunisia indicate that there exists no evidence of a significant long-run relation between trade openness and carbon emissions. Halicioglu (2009) for Turkey, Farhani et al. (2014) for Tunisia, Tiwari et al. (2013) for India, Shahbaz et al. (2014) for Tunisia, Boutabba (2014) for India, and Ertugrul et al. (2016) for Thailand, Turkey, India, Indonesia, and Korea show a long-run unidirectional causality running from trade openness to carbon emissions. Ertugrul et al. (2016) for Brazil and China reveal that there exists bidirectional causality between the variables in the long run.

The last strand deals with the relationship among economic growth, energy consumption, trade openness, financial development, and carbon emissions. The effect of financial development on carbon emissions has been discussed by many authors (e.g., Birdsall and Wheeler 1993; Jensen 1996; Frankel and Rose 2002; Tamazian et al. 2009; Yuxiang and Chen 2010). Birdsall and Wheeler (1993), Frankel and Rose (2002), and Tamazian et al. (2009) suggest that financial development in developing countries provides different opportunities to apply new technology, clean and environmentally friendly production, enhance energy efficiency, and consequently improve environmental quality. Yuxiang and Chen (2010) suggest that improvements in financial sector enable firms to use advanced technology and may support capitalization and financial regulations. Hence, these may lessen carbon emissions and develop environmental quality. On the other hand, Jensen (1996) reveals that the presence of well-developed financial sector facilitates to attract foreign direct investment and may encourage economic growth, and therefore, increase industrial pollution and reduce environmental quality. From the empirical perspective, Pao and Tsai (2011) for BRIC countries, Shahbaz et al. (2013a) for Indonesia, Boutabba (2014) for India, and Le (2016) for SSA countries reveal that the impact of financial development on carbon emissions is positive and statistically significant in the long run. Jalil and Feridun (2011) for China, Shahbaz et al. (2013b) for Malaysia, Salahuddin et al. (2015) for GCC countries, and Dogan and Seker (2016) for top renewable energy countries show that in the long run, financial development decreases carbon emissions. Abid (2016) for SSA countries shows that there exists no significant relationship between financial development and carbon emission. Pao and Tsai (2011) for BRIC countries and Shahbaz et al. (2013b) for Malaysia provide an evidence for the existence of long-run bidirectional causality between financial development and carbon emissions. Boutabba (2014) for India, Salahuddin et al. (2015) for GCC countries, and Katircioğlu and Taspinar (2017) for Turkey indicate that there exists a long-run unidirectional causality running from financial development to carbon emissions.

As seen from Table 1, there exists a limited number of studies on the relationship between economic growth, energy consumption, financial development, trade openness, and carbon emissions for Turkey. Using Johansen-Juselius and ARDL bounds testing approaches and VECM Granger causality test, Halicioglu (2009) investigated the cointegration and causal relationships between energy consumption, economic growth, trade openness, and carbon emissions in Turkey over the period 1960–2005. Empirical results show that carbon emissions are determined by economic growth, energy consumption, and trade openness, respectively. Empirical results also show that there exists unidirectional causality running from all explanatory variables to carbon emissions in the long run.

Shahbaz et al. (2013c) employ ARDL bounds testing, Johansen-Juselius, Grgory-Hansen approaches to cointegration and VECM Granger causality method to test the links among economic growth, energy intensity, globalization, and carbon emission from 1970 to 2010 for Turkey. Zivot-Andrews structural break unit root test suggests that all the variables are $I(1)$. Cointegration tests show that there exists a long-run relationship between the variables. In the long run, it was found that carbon emissions are positively correlated with economic growth and energy intensity. It was also found that there exists a negative and statistically significant relation between globalization and carbon emissions in the long run. VECM Granger causality analysis reveals that there exists a long-run bidirectional causal linkage between economic growth and carbon emissions. In addition, a bidirectional causality between energy intensity and carbon emissions was found in the long run.

Katircioğlu and Taspinar (2017) examined the impact of financial development on carbon emissions by employing GLS unit root test with multiple structural breaks, Maki cointegration method, DOLS, and VECM approaches over the period 1960–2010. The results of model with main effects indicate that financial development is negatively correlated with carbon emissions in the long run. Conversely, the results of the model with interaction effects indicate that in the long run, financial development is positively linked with carbon emissions. The VECM Granger causality analysis reveals that there exists a unidirectional causality running from financial development to carbon emissions and bidirectional causality between economic growth and carbon emissions. It was found that there exists a long-run bidirectional causality between energy consumption and carbon emissions.

The most important study related to Turkish economy was conducted by Ozturk and Acaravci (2013). The study analyzed the relationship among economic growth, energy consumption, trade openness, financial development, and carbon emissions by using ARDL bounds test and VECM Granger causality method over the period 1960–2007. The study indicates that economic growth, energy consumption, and trade openness positively affect carbon emissions in the long run. The study also indicates that there exists no significant relationship between financial development and carbon emissions in the long run. Besides, it was found that in the long run, there exists bidirectional causality running from economic growth, energy consumption, trade openness, and financial development to carbon emissions. The present study differs from this work by employing Lee and Strazicich unit root test and bounds *F*-test with structural breaks to examine the unit root and the long-run properties of the variables. In addition, the present study provides a broader literature review.

Model and data

Following the empirical literature, we use the standard log-linear specification to examine the impact of economic growth, energy consumption, trade openness, and financial development on carbon emissions along with the presence of EKC hypothesis. With this specification, it is possible to provide efficient and consistent findings. Following Jalil and Feridun (2011), Ozturk and Acaravci (2013), Shahbaz et al. (2013a), and Boutabba (2014), the relationship among the variables is expressed as follows:

$$LCO_{2t} = \alpha_0 + \alpha_1 LGDP_t + \alpha_2 LGDP_t^2 + \alpha_3 LEN_t + \alpha_4 LTR_t + \alpha_5 LFD_t + \mu_t \quad (1)$$

where CO_{2t} is per capita carbon dioxide emissions (tons),[3] EN_t is per capita energy consumption (kg of oil equivalent),[4] GDP_t is per capita real GDP (constant 2010 US$),[5] GDP^2 is the square of per capita real GDP,[6] TR_t is the openness ratio (foreign trade, % of GDP),[7] FD_t is the measure of financial development (domestic credit to private sector, % of GDP),[8] and μ_t is the i.i.d. error term. Annual time series data covering the period 1960–2013 were derived from the World Development Indicators (WDI 2016) online database for Turkey. All the variables are used in their logarithmic forms. The parameters, α_i, $i = 1, 2, 3, 4, 5$, represent the long-run elasticities of per capita carbon emissions with respect to per capita real income, the square of per capita real income, per capita energy consumption, trade openness, and financial development, respectively. Under the EKC hypothesis, the sign of α_1 is expected to be positive, while a negative sign is expected for α_2. If the signs on the LGDP and $LGDP^2$ are found to be statistically significant, this implies an inverted U-shaped relationship between the variables (Pao and Tsai 2011). The sign of α_3 is expected to be positive because more energy consumption would result in greater economic activity and hence increases carbon emissions (Saboori and Sulaiman 2013). According to the pollution haven hypothesis, developing countries which have lax or no environmental regulations would specialize in pollution-intensive industries, while others focus on light manufacturing and services. Under this hypothesis, the developed country imports pollution-intensive goods from the developing nation by bypassing local regulations (He 2006; Kearsley and Riddel 2010). In addition, trade openness can affect environment through three mechanisms, namely scale, technique, and composition effects.[9] Therefore, the sign of α_4 can be either positive or negative (Antweiler et al. 2001). A developed financial sector leads firms to apply new and environmentally friendly technologies. This positively affects environmental quality. Also, financial sector can boost industrial sectors. The investors or firms which aim to maximize profit at any cost may contribute to environmental pollution. Therefore, the sign of α_5 can be either positive or negative (Shahbaz et al. 2013d).

Table 2 reports the descriptive statistics and correlation matrix of the variables for Turkish economy. The correlation matrix reported in Table 2 indicates a positive relation between the underlying variables. For instance, per capita energy use is positively correlated with per capita carbon emissions and the same is true between per capita real income and per capita carbon emissions. In addition, trade openness and financial development are positively correlated with per capita carbon emissions. Figure 1 presents the plots of the series used in the study.

Methodology

Unit root tests

We use several unit root tests developed by Dickey and Fuller (1979) (ADF), Phillips and Perron (1988) (PP), and Ng and

[3] Since carbon emissions as the primary GHG emission is responsible for global warming and climate change, several studies (e.g., Jalil and Feridun 2011; Sharma 2011; Omri 2013) employ this variable as a main indicator of environmental pollution.

[4] Per capita energy use is generally employed as an explanatory variable in the equation of carbon emissions (Acaravci and Ozturk 2010; Omri 2013).

[5] Following Shahbaz et al. (2014) and Saboori et al. (2014), we use per capita real GDP as a determinant of carbon emissions and it also represents economic growth.

[6] The square of per capita real GDP is a main variable used in several empirical studies related to EKC hypothesis (Akbostanci et al. 2009; Shahbaz et al. 2014).

[7] Jayanthakumaran et al. (2012) and Shahbaz et al. (2013a) use trade openness as an explanatory variable in the carbon emissions function.

[8] It is generally known that the most common proxies for financial development are the ratio of money and quasi-money to GDP, the ratio of liquid liabilities to GDP, the ratio of domestic credit on private sector to GDP, and the ratio of domestic credit provided by the banking sector to GDP (Ang 2009; Sadorsky 2011). However, several studies (e.g., Shahbaz and Lean 2012; Mudakkar et al. 2013) use the ratio of domestic credit on private sector to GDP as the main indicator of financial development.

[9] Free trade brings about environmental pollution owing to economic expansion. This is called the scale effect. According to technique effect, the import of efficient technologies can reduce environmental pollution. The composition effect implies that free trade can decrease or increase environmental pollution depending on whether there exists a comparative advantage in cleaner or dirty industries of a country (Antweiler et al. 2001).

Perron (2001) to examine the stationarity properties of the variables.[10] However, as Perron (1989) points out, structural change and unit roots are closely related, and conventional unit root tests are biased toward a false unit root null when the data are trend stationary with a structural break. Therefore, we also use Lee and Strazicich (2004, 2013) unit root test with one structural break. This methodology is based on the assumption of unknown breakpoint in the deterministic trend function.

To briefly mention the essentials of the test, let us consider the below data generating process:

$$y_t = \delta' Z_t + \beta X_{t-1} + \varepsilon_t \tag{2}$$

where Z_t contains exogenous variables. The null hypothesis of unit root $(H_0 : \beta = 1)$is tested against the alternative of stationary$(H_1 : \beta < 1)$. Lee and Strazicich consider two models of structural change: the level shift model if $Z_t = [1, t, D_t]'$ allows for a one-time change in intercept under the alternative hypothesis and the trend shift model if $Z_t = [1, t, D_t]'$ allows for a shift in intercept and change in trend slope under the alternative hypothesis where $D_t = 1$ and $DT_t = t - T_B$ for $t \geq T_B + 1$, and $D_t = DT_t = 0$; otherwise, T_B is the date of structural break.

Based on the LM principle, unit root test statistics are obtained from the following regression:

$$\Delta y_t = \delta' \Delta Z_t + \phi \tilde{S}_{t-1} + \sum_{j=1}^{p} c_j \Delta \tilde{S}_{t-j} + u_t \tag{3}$$

where $\tilde{S} = y_t - \tilde{\psi}_x - Z_t \tilde{\delta}$ for $t = 2, \ldots, T$ and $\tilde{\delta}$ are the coefficients in the regression of Δy_t on ΔZ_t; and $\tilde{\psi}_x = y_1 - Z_1 \tilde{u}$. In Eq. (3), the unit root null hypothesis is described by $\varphi = 0$ of unit root is tested against the alternative of stationary and the test statistic is the standard t-ratio ($\tilde{\tau}$). The location of the break ($I_B = T_B/T$) is determined by searching all possible break points to find the minimum $\tilde{\tau}$ statistic as follows:

$$Inf\,\tilde{\tau}\left(\tilde{\lambda}\right) = Inf\,\tilde{\tau}(\lambda), \text{where } \lambda = T_B/T \text{ and } \lambda \in [0, 1]. \tag{4}$$

It is also worth noting that the lag length is added to both equations to correct for any serial correlation in the error term.

Bounds testing approach

We prefer ARDL bounds testing approach to cointegration presented by Pesaran et al. (2001) since it has several advantages over other cointegration methods. Firstly, the bounds testing procedure is a more appropriate method compared with standard cointegration techniques developed by Engle and Granger (1987) and Johansen and Juselies (1990). Secondly, in this approach, the regressors may be $I(0)$ or $I(1)$. Thirdly, the short and long-run parameters can be simultaneously estimated through an unrestricted error correction model (UECM) derived from the ARDL model. Fourthly, it is possible to provide better results for finite and small sample sizes. Finally, all the variables are assumed to be endogenous in this model (Pesaran and Shin 1999). The equation of UECM for the ARDL bounds approach can be expressed as:

$$\begin{aligned}\Delta LCO_{2t} = \beta_0 + \sum_{i=1}^{m} \beta_{1i} \Delta LCO_{2t-i} + \sum_{i=0}^{m} \beta_{2i} \Delta LGDP_{t-i} \\ + \sum_{i=0}^{m} \beta_{3i} \Delta LGDP^2_{t-i} + \sum_{i=0}^{m} \beta_{4i} \Delta LEN_{t-i} \\ + \sum_{i=0}^{m} \beta_{5i} \Delta LTR_{t-i} + \sum_{i=0}^{m} \beta_{6i} LFD_{t-i} + \delta DUM + \gamma_1 LCO_{2t-1} \\ + \gamma_2 LGDP_{t-1} + \gamma_3 LGDP^2_{t-1} \\ + \gamma_4 LEN_{t-1} + \gamma_5 LTR_{t-1} + \gamma_6 LFD_{t-1} + \varepsilon_t\end{aligned} \tag{5}$$

where $\beta_0$is a constant parameter, Δ is the first difference operator, and ε_t is the error term. DUM represents dummy variable for structural breakpoint. Following Jayanthakumaran et al. (2012), Shahbaz et al. (2013a), and Shahbaz et al. (2014), we employ dummy variable in this specification to capture the effects of any structural change.

The appropriate lag length can be selected by the Akaike Information Criterion (AIC) or Schwarz Bayesian Criterion (SBC). The first step of the bounds testing approach is to compare the computed F-statistic with the critical bounds generated by Pesaran et al. (2001) or Narayan (2005)—the upper critical bound (UCB) and lower critical bound (LCB).[11] Here, the null hypothesis $H_0 : \gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 = \gamma_6 = 0$ of no cointegration is tested against the alternative hypothesis $H_a : \gamma_1 \neq \gamma_2 \neq \gamma_3 \neq \gamma_4 \neq \gamma_5 \neq \gamma_6 \neq 0$ of cointegration. If the computed F-statistic exceeds the UCB, we reject the null hypothesis meaning that there exists a cointegration relationship between the variables. If the computed F-statistic is below the LCB, we cannot reject the null hypothesis meaning that there is no cointegration relationship between the variables. If computed F-statistic falls between the UCB and LCB, the inference would be inconclusive.

The robustness of the ARDL model can be investigated by using several diagnostic tests such as autocorrelation, functional form, normality of error term, and heteroskedasticity. The stability of the ARDL parameters can be checked by

[10] ADF, PP, and Ng-Perron (MZ_a and MZ_t) unit root tests use the null hypothesis of a unit root. In these methods, the null hypothesis is tested against the alternative of stationarity. However, Ng-Perron test results are more reliable and consistent compared to the traditional unit root tests. In addition, the problem of over-rejection of null hypothesis can be solved by Ng-Perron test, and it can be performed for small sample size (DeJong et al. 1992).

[11] Narayan (2005) provides the critical bounds which are suitable for small sample (30–80). These are significantly greater than the critical bounds presented by Pesaran et al. (2001) (Narayan and Narayan 2005).

Table 2 Descriptive statistics and correlation matrix (time series data: 1960–2013)

Statistics/variables	LCO_2	LEN	LGDP	$LGDP^2$	LTR	LFD
Mean	0.741	6.721	8.675	75.389	3.219	2.992
Median	0.865	6.774	8.675	75.270	3.444	2.881
Std. dev.	0.543	0.405	0.369	6.405	0.670	0.366
Min.	− 0.493	5.951	8.005	64.083	1.745	2.539
Max.	1.482	7.353	9.314	86.767	4.057	4.249
Skewness	− 0.627	− 0.291	− 0.022	0.041	− 0.430	1.904
Kurtosis	2.442	2.026	2.026	2.019	1.766	6.141
Observations	54	54	54	54	54	54
LCO_2	1.000					
LEN	0.992	1.000				
LGDP	0.977	0.992	1.000			
$LGDP^2$	0.973	0.990	0.999	1.000		
LTR	0.921	0.928	0.911	0.909	1.000	
LFD	0.578	0.617	0.663	0.672	0.492	1.000

means of the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of recursive residuals (CUSUMsq) tests presented by Brown et al. (1975).

After the selection of the ARDL model by SBC or AIC, the long-run relationship between the variables can be estimated by ordinary least square (OLS) method. Finally, the short run dynamics are investigated by the error correction model (ECM) based on ARDL model. The equation of ECM is specified as follows:

$$\begin{aligned}\Delta LCO_{2t} = \beta_0 + \sum_{i=1}^{m}\beta_{1i}\Delta LCO_{2t-i} + \sum_{i=0}^{n}\beta_{2i}\Delta LGDP_{t-i} \\ + \sum_{i=0}^{p}\beta_{3i}\Delta LGDP^2_{t-i} + \sum_{i=0}^{r}\beta_{4i}\Delta LEN_{t-i} \\ + \sum_{i=0}^{s}\beta_{5i}\Delta LTR_{t-i} + \sum_{i=0}^{t}\beta_{6i}\Delta LFD_{t-i} + \delta ECT_{t-1} + \mu_t\end{aligned} \quad (6)$$

The error correction term (ECT_{t-1}) shows the speed of the adjustment which indicates how quickly the variables return to the long-run equilibrium. It should be a statistically significant coefficient with a negative sign. This means that there exists an empirical evidence of a long-run relationship between the variables.

VECM granger causality test

In this study, ARDL bounds testing approach is employed to investigate the presence of a long-run relationship between the variables. But, we cannot indicate the direction of causality between the variables by using this approach. The presence of cointegration reveals that there is a long-run relationship between the variables and a Granger causality between them in at least one direction (Engle and Granger 1987). We can examine the direction of causal relationships between the variables through the Granger causality test based on VECM. In this model, error correction term (ECT_{t-1}) is derived from the long-run relationship and added to the standard VAR model as an additional variable. The empirical equation of the VECM Granger causality approach is modeled as follows:

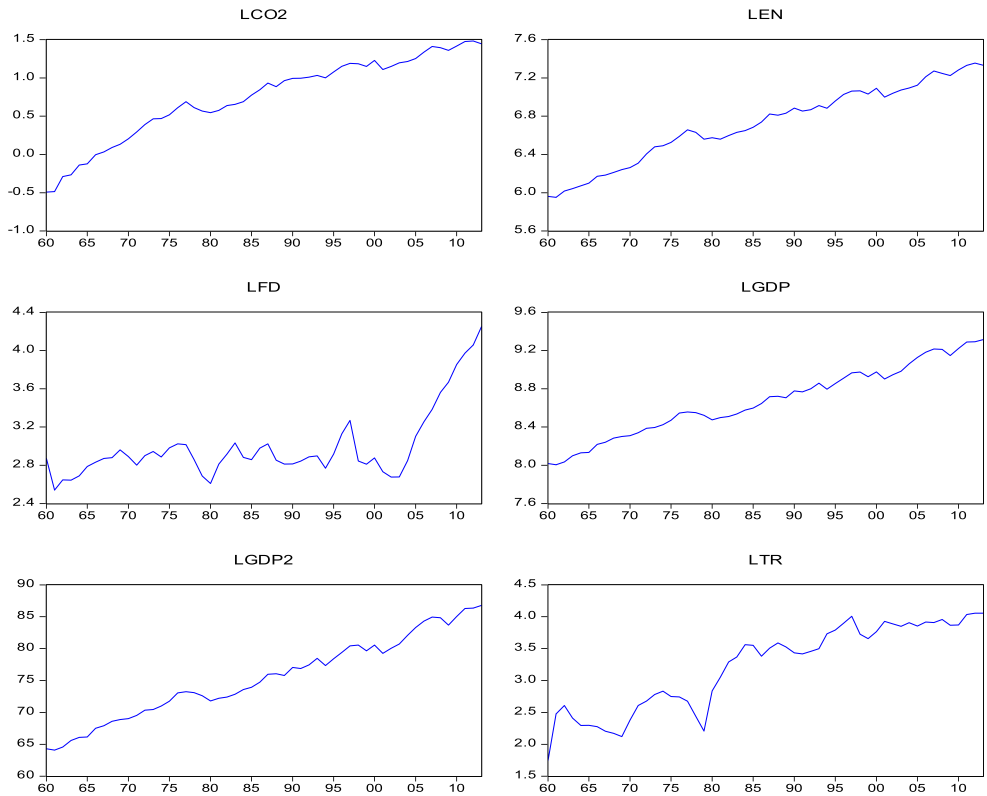
$$(1-L)\begin{bmatrix} LCO_{2t} \\ LGDP \\ LGDP^2_t \\ LEN_t \\ LTR_t \\ LFD_t \end{bmatrix} = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \\ a_6 \end{bmatrix} + \sum_{i=1}^{p}(1-L)\begin{bmatrix} b_{11i}b_{12i}b_{13i}b_{14i}b_{15i}b_{16i} \\ b_{21i}b_{22i}b_{23i}b_{24i}b_{25i}b_{26i} \\ b_{31i}b_{32i}b_{33i}b_{34i}b_{35i}b_{36i} \\ b_{41i}b_{42i}b_{43i}b_{44i}b_{45i}b_{46i} \\ b_{51i}b_{52i}b_{53i}b_{54i}b_{55i}b_{56i} \\ b_{61i}b_{62i}b_{63i}b_{64i}b_{65i}b_{66i} \end{bmatrix} x\begin{bmatrix} LCO_{2t-1} \\ LGDP_{t-1} \\ LGDP^2_{t-1} \\ LEN_{t-1} \\ LTR_{t-1} \\ LFD_{t-1} \end{bmatrix} + \begin{bmatrix} \alpha \\ \beta \\ \gamma \\ \delta \\ \theta \\ \vartheta \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \mu_{1t} \\ \mu_{2t} \\ \mu_{3t} \\ \mu_{4t} \\ \mu_{5t} \\ \mu_{6t} \end{bmatrix} \quad (7)$$

where $(1-L)$ is the difference operator and ECT_{t-1} is the lagged error correction term obtained from the long-run relationship. The VECM is an appropriate method which distinguishes causal relations between short run and long run. A significant t-statistic on the coefficient of the lagged error correction term indicates that there exists a causal relation between the variables in the long run. On the other hand, a significant F-statistic on the first differences of the variables reveals an evidence for the presence of a short-run causality between the variables.

Empirical findings and discussion

Table 3 presents the outcome of the ADF, PP, and Ng-Perron unit root tests on the levels and the first differences of the variables. The results reveal that all the variables are non-

Fig. 1 Plots of the logarithmic series in Turkey



stationary at their levels but stationary at first differences. This implies that all the series are integrated at $I(1)$. Since the standard unit root tests do not take into account structural breaks, we also applied the Lee and Strazicich unit root test with structural break. The results of Lee and Strazicich unit root test are presented in Table 4. The structural break stems in the series of per capita carbon emissions, per capita energy consumption, per capita real income, the square of per capita real income, trade openness, and financial development in

Table 3 The unit root tests results

Regressor	ADF	PP	NG-PERRON	
	(t)	(Adj. t)	MZ_a	MZ_t
LCO_2	-2.444^{b}	-2.528^{b}	1.175^{a}	1.845^{a}
LEN	-1.280^{a}	-1.346^{a}	-7.709^{b}	-1.900^{b}
LGDP	-0.492^{a}	-0.471^{a}	-13.108^{b}	-2.557^{b}
$LGDP^2$	-0.283^{a}	-0.242^{a}	-13.593^{b}	-2.591^{b}
LTR	-1.883^{a}	-1.886^{a}	-10.858^{b}	-2.273^{b}
LFD	1.067^{a}	1.040^{a}	-5.030^{b}	-1.196^{b}
ΔLCO_2	-7.941^{b***}	-7.929^{b***}	-25.709^{a***}	-3.552^{a***}
ΔLEN	-6.960^{a***}	-6.954^{a***}	-25.692^{b***}	-3.548^{b***}
$\Delta LGDP$	-7.471^{a***}	-7.488^{a***}	-25.854^{b***}	-3.594^{b***}
$\Delta LGDP^2$	-7.484^{a***}	-7.508^{a***}	-25.880^{b***}	-3.596^{b***}
ΔLTR	-7.197^{a***}	-7.286^{a***}	-16.255^{b**}	-2.839^{b**}
ΔLFD	-6.143^{a***}	-6.138^{a***}	-21.524^{b**}	-3.279^{b**}

The optimal lag length is selected automatically using SBC for ADF test, and the bandwidth is selected using the Newey-West method for PP test

*Significance at 10% level

**Significance at 5% level

***Significance at 1% level

[a] The model with constant

[b] The model with constant and trend

Table 4 Lee-Strazicich unit root test results

Variable	Level		First difference	
	t-statistic	Time break	t-statistic	Time break
LCO_2	-3.532^{b} (2)	1973	-8.928^{b} (1)***	1977
LEN	-3.164^{a} (0)	2001	-7.714^{a} (0)***	1977
LGDP	-4.006^{b} (0)	1978	-7.601^{b} (0)***	1976
$LGDP^2$	-4.002^{b} (0)	1978	-7.602^{b} (0)***	1976
LTR	-3.955^{a} (1)**	1980	–	–
LFD	-1.391^{a} (1)	2004	-3.577^{a} (2)**	1982

Maximum lags are set to 2, and optimal lag was selected by Akaike Information Criterion. The optimal lag lengths are reported in parentheses. The critical values are −4.239 (%1) and −3.566 (5%) for the level shift model; −5.11 (%1) and −4.50 (5%) for the trend shift model (Lee and Strazicich 2013, 2488)

**Significance at 5% level

***Significance at 1% level

[a] Break in level

[b] Break in level and trend

1973, 2001, 1978, 1978, 1980, and 2004, respectively. The first-world energy crisis occurred in 1973. In addition, Turkish economy witnessed military intervention and slower growth during 1971–1973 (Aricanlı and Rodrik 1990). These developments widely affected the level of carbon emissions in Turkey. The break date of 2001 for energy consumption coincides with the severe financial crisis in Turkey which led to a fall of 9.5% in GNP. The break dates of 1978 and 1979 correspond to the Iranian revolution and the second oil crisis. Regarding break date for trade openness, LS approach captures the effects of the 24 January 1980 decisions which paved the way for greater liberalism of the Turkish economy. The break date of 2004 for financial development coincides with the rising trend toward foreign direct investment.

Structural break unit root test results indicate that the variables are integrated at $I(1)$ except for trade openness. This finding provides two implications: (i) Shocks to the carbon dioxide, economic growth, gross domestic product, and financial development are permanent implying that an initial shock never dies out, and (ii) since the macro-variables are integrated at the same order, they might have a long-run cointegration relation.

We use SBC to calculate the bounds F-test for cointegration. Table 5 reports the results of the bounds F-test for cointegration. The results indicate that calculated F-statistic is greater than UCB at 5% in the existence of structural break. This reveals that the series are cointegrated meaning that there exists a long-run relationship between per capita carbon emissions, per capita energy consumption, per capita real income, the square of per capita real income, trade openness, and financial development for Turkey. The results were also confirmed by the findings of the bounds F-test for cointegration without structural breaks. The diagnostic tests of ARDL model were also presented in the lower part of Table 5. The results indicate that the ARDL model passes all the tests successfully. This means that error terms of the ARDL model are normally distributed. This also means that the residuals are free from serial correlation and heteroskedasticity. The functional form of the model is well specified.

After examining the long-run relationship between the variables, the impacts of economic growth, energy consumption, trade openness, and financial development on carbon emissions are investigated. The estimated long-run and short-run results were reported in panels A and B of Table 6, respectively. The long-run results indicate that per capita real income has positive and statistically significant impact on per capita

Table 5 Cointegration test results

Bounds F-test		
Structural break	1973	Calculated F-statistics
Model	$F(lnco/lnen, lny, lny, lntr, lnfd)$	4.29** (with structural break)
ARDL lag order	[2,1,1,0,0,0]	5.85*** (no structural break)
Pesaran et al. (2001) critical value bounds of the F-statistic: unrestricted intercept and no trend		
Significance level	Lower bounds, $I(0)$	Upper bounds, $I(1)$
1%	3.41	4.68
5%	2.62	3.79
10%	2.26	3.35
Narayan (2005) critical value bounds of the F-statistic: unrestricted intercept and no trend ($T = 55$)		
Significance level	Lower bounds, $I(0)$	Upper bounds, $I(1)$
1%	3.92	5.40
5%	2.84	4.16
10%	2.39	3.58
Diagnostic tests	(with structural break)	(no structural break)
R^2	0.919	0.959
Adjusted R^2	0.874	0.901
F-statistic	20.817***	16.418***
Breusch-Godfrey LM test	1.446 (0.250)	2.660 (0.998)
ARCH LM test	0.033 (0.855)	0.305 (0.583)
J-B normality test	2.454 (0.293)	4.407 (0.110)
Ramsey RESET test	0.015 (0.903)	2.969 (0.101)

The model with constant is used for cointegration analysis. The optimal lag length was selected based on AIC. The values in parentheses indicate the probabilities

**Significance at 5% level

***Significance at 1% level

Table 6 Estimated coefficients from ARDL model

Panel A: long-run results		
Regressors	Coefficient	*t*-statistic
Constant	− 48.736	− 8.640***
LFD	0.040	1.832*
LEN	0.608	3.347***
LGDP	9.660	6.950***
$LGDP^2$	− 0.512	− 6.519***
LTR	0.076	2.022**
Panel B: short-run results		
Dependent variable: ΔLCO_2		
Regressors	Coefficient	*t*-statistic
Constant	− 0.003	− 0.774
ΔLFD	0.046	1.922*
ΔLEN	0.965	9.270***
ΔLGDP	4.886	2.947***
$\Delta LGDP^2$	− 0.270	− 2.879***
ΔLTR	0.038	1.963*
ECT(− 1)	− 0.714	− 7.860***
Panel C: long-run diagnostic test statistics		
R^2		0.998
Adjusted R^2		0.998
F-statistic		3230.485***
Breusch-Godfrey LM test		0.358 (0.553)
ARCH LM test		0.009 (0.922)
Jarque-Bera normality test		1.366 (0.504)
Ramsey RESET test		0.748 (0.392)

The long-run and short-run coefficients are obtained on the basis of ARDL (2,1,1,0,0,0) model, decided by the SBC. The values in parentheses indicate the probabilities

*Significance at 10% level

**Significance at 5% level

***Significance at 1% level

carbon emissions at 1% level of significance. This means that a 1% increase in per capita real income raises per capita carbon emissions by 9.66%. The positive impact of real GDP on carbon emissions could be explained on the basis that having higher GDP would in turn drive higher energy consumption. Over the years, both emissions and real GDP have been increasing. According to the world development indicators of the World Bank, real GDP increased by an average of 4.7% in the period of 1990–2016 in Turkey. In the same period, gross GHG emissions have increased from 210 million tons to 496 million tons in the period of 1990–2014, which corresponds to an increase of 135%. This increase was largely driven by the increase in CO_2 emissions. The impact of the square of per capita real income on per capita carbon emissions is negative, and it is statistically significant at 1% level implying that a 1% increase in the square of per capita real income decreases per capita carbon emissions by 0.51%.

Taken together, the findings validate the presence of the EKC hypothesis in Turkish economy. This means that as economic growth increases, pollution will increase, up to a point, where further growth will result in less pollution. This finding is confirmed by Halicioglu (2009) for Turkey, Pao and Tsai (2010) for BRIC countries, Pao and Tsai (2011) for BRIC countries, Jayanthakumaran et al. (2012) for India and China, Hamit-Haggar (2012) for Canadia, Arouri et al. (2012) for Middle East and North African countries, Shahbaz et al. (2013c) for Turkey, Ozcan (2013) for UAE, Egypt, and Lebanon, Farhani et al. (2014) for Tunisia, Seker et al. (2015) for Turkey, Boluk and Mert (2015) for Turkey, and Dogan and Seker (2016) for top renewable energy countries.

It was found that the impact of per capita energy consumption on per capita carbon emissions is positive and statistically significant at 1% level meaning that a 1% rise in per capita energy consumption increases per capita carbon emissions by 0.60%. This empirical evidence is broadly consistent with Pao and Tsai (2010) for BRIC countries, Pao et al. (2011) for Russia, Sharma (2011) for high-income countries, Ozcan (2013) for nine countries, Saboori and Sulaiman (2013) for ASEAN countries, Alkhathlan and Javid (2013) for Saudi Arabia, Shahbaz et al. (2013e) for Romania, Omri (2013) for MENA countries, Shahbaz et al. (2013c) for Turkey, Farhani et al. (2014) for Tunisia, and Dogan and Seker (2016) for top renewable energy countries. The positive impact of energy on carbon emissions is not surprising given that energy sector is the main emitter of carbon dioxide in Turkey with a share of 81% in 2015, according to the Turkish Statistical Institute.

It was also found that trade openness positively affects per capita carbon emissions at 5% level of significance indicating that a 1% increase in trade openness rises per capita carbon emissions by 0.07%. This finding is in line with Halicioglu (2009) for Turkey, Hossain (2011) for newly industrialized countries, Jalil and Feridun (2011) for China, Shahbaz et al. (2013a) for Indonesia, Tiwari et al. (2013) for India, Al-mulali (2012) for Middle East countries, Ozturk and Acaravci (2013) for Turkey, Ren et al. (2014) for China, Lau et al. (2014) for Malaysia, Shahbaz et al. (2014) for Tunisia, and Anwar et al. (2016) for Vietnam. On the other hand, this finding is not supported by Shahbaz et al. (2013d) for South Africa, Shahbaz (2013) for Pakistan, Dogan and Seker (2016) for top renewable energy countries, and Boutabba (2014) for India. An explanation for the positive impact of trade openness on emissions is that companies move their pollution-intensive factories to Turkey. Another explanation for the positive role of trade openness on emissions is the type of goods that constitute the bulk of Turkey's exports.

Finally, in the long run, we find that financial development is positively correlated with per capita carbon emissions at 10% level of significance meaning that a 1% increase in financial development rises per capita carbon emissions by

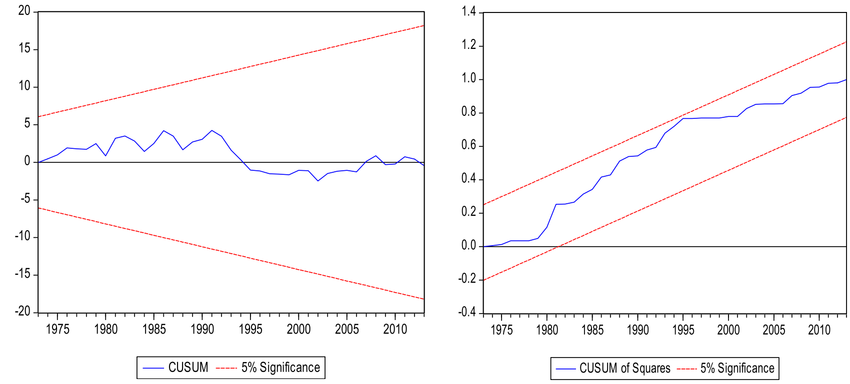


Fig. 2 Plot of CUSUM and CUSUMsq tests for the parameter stability

0.04%. This empirical evidence is supported by Shahbaz et al. (2013a) for Indonesia, Le (2016) for 15 SSA countries, and Boutabba (2014) for India. But, this finding is not consistent with Jalil and Feridun (2011) for China, Ozturk and Acaravci (2013) for Turkey, Shahbaz et al. (2013d) for South Africa, Dogan and Seker (2016) for top renewable energy countries, Abid (2016) for 25 SSA countries, and Salahuddin et al. (2015) for GCC countries.

The short-run results are given in the lower part of Table 6. The results reveal that per capita energy consumption positively affects per capita carbon emissions at 1% level of significance indicating that a 1% increase in per capita energy consumption rises per capita carbon emissions by 0.96%. This empirical evidence is in line with Shahbaz et al. (2014) for Tunisia, Shahbaz (2013) for Pakistan, Pao and Tsai (2010) for Brazil, Russia, and China, and Alkhathlan and Javid (2013) for Saudi Arabia. The impact of trade openness on per capita carbon emissions is positive, and it is statistically significant at 10% level of significance implying that a 1% increase in openness rises per capita carbon emissions by 0.03%. This empirical result is supported by Hossain (2011) for Thailand. But, it is not consistent with Shahbaz (2013) for Pakistan and Hossain (2011) for India. The results also reveal that there exists a positive relation between financial development and per capita carbon emissions at 10% level of significance meaning that a 1% increase in financial development rises per capita carbon emissions by 0.04%. This result is not in line with Shahbaz et al. (2013d) South Africa and Ozturk and Acaravci (2013) for Turkey. It was found that there exists a positive relationship between per capita real income and per capita carbon emissions. It was also found that there exists a negative relationship between the square of per capita real income and per capita carbon emissions. Therefore, the EKC hypothesis is valid for Turkey in the short run. The result is in line with Acaravci and Ozturk (2010) for Italy and Denmark, Boutabba (2014) for India, Farhani et al. (2014) for Tunisia, and Boluk and Mert (2015) for Turkey.

The coefficient of lagged error correction term (ECT_{t-1}) is found to be statistically significant with a negative sign. This means that there exists an evidence supporting the presence of long-run relationship between the variables and deviation of per capita carbon emissions from short run to long run is corrected by 71.40% every year. The results of serial correlation, functional form, normality, and heteroscedasticity related to long-run model are presented in the latter part of Table 6. The results reveal that the underlying model passes all the diagnostic tests. We also use the CUSUM and CUSUMsq tests to further examine the stability of long-run coefficients. Figure 2 provides the plots of CUSUM and CUSUMsq statistics. The results demonstrate that the long-run parameters are stable because the plots of CUSUM and CUSUMsq are within the critical bounds of 5% significance. Therefore, the estimation results can be used for policy implications in the case of Turkey.

Table 7 VECM Granger causality test results

	Short run (*F*-statistic)						Long run (*t*-statistic)
Dependent variable	ΔLCO_2	ΔLEN	ΔLGDP	$\Delta LGDP^2$	ΔLTR	ΔLFD	
ΔLCO_2	–	0.326 (0.745)	0.367 (0.714)	0.365 (0.716)	1.039 (0.304)	0.865 (0.391)	− 3.051 (0.003)
ΔLEN	1.210 (0.232)	–	0.457 (0.649)	0.489 (0.626)	0.760 (0.451)	1.411 (0.165)	− 0.637 (0.527)
ΔLGDP	0.486 (0.628)	0.315 (0.753)	–	0.064 (0.948)	0.043 (0.965)	2.501 (0.016)	− 1.375 (0.176)
$\Delta LGDP^2$	0.411 (0.683)	0.320 (0.749)	0.225 (0.822)	–	0.077 (0.938)	2.509 (0.015)	− 1.291 (0.203)
ΔLTR	0.317 (0.752)	0.995 (0.324)	0.557 (0.579)	0.587 (0.560)	–	0.280 (0.780)	0.985 (0.329)
ΔLFD	0.414 (0.680)	0.321 (0.749)	0.489 (0.626)	0.455 (0.650)	0.686 (0.495)	–	− 0.235 (0.814)

The values in parentheses indicate the probabilities

Finally, we apply Granger causality test within the VECM framework to investigate the causality among the variables. Table 7 presents the findings of the Granger causality test. The results indicate that the estimate of ECT_{t-1} is statistically significant with a negative sign only in carbon emissions equation. This means that there exists unidirectional causality running from per capita real income, per capita energy consumption, trade openness, and financial development to per capita carbon emissions in the long run. These findings are in line with Jalil and Feridun (2011) for China and Ozturk and Acaravci (2013) for Turkey. We find that there exists unidirectional causality running from financial development to per capita real income in the short run. This finding is consistent with Ozturk and Acaravci (2013) for Turkey.

Concluding remarks and policy implications

Turkey is a developing country which has a strong financial structure, high economic growth, and trade volume. In addition, energy demand and carbon emissions in Turkey have been increasing fast recently. For these reasons, applying the ARDL bounds testing approach to cointegration and VECM Granger causality test, this study investigates the cointegration and causal relationships between economic growth, energy consumption, trade openness, financial development, and carbon emissions over the period of 1960–2013 for the case of Turkey.

Empirical results reveal that the variables are cointegrated, meaning that there exists a long-run relationship between the variables in the presence of structural breaks in the series. Furthermore, inverted U-shaped relationship was found between per capita real income and per capita carbon emissions supporting the validity of EKC hypothesis in Turkish economy in the long run. This means that the level of per capita carbon emissions initially increases with per capita real income until it reaches a threshold level, and then an increase in per capita real income reduces per capita carbon emissions in Turkey. The empirical evidence of a positive relationship between the per capita real income, per capita energy consumption, trade openness, financial development, and per capita carbon emissions indicates that in the long run, carbon emissions is determined by economic growth, energy consumption, trade openness, and financial development. The causality analysis reveals that there exists unidirectional causality running from per capita real income, per capita energy consumption, trade openness, and financial development to per capita carbon emissions in the long run meaning that economic growth, energy consumption, trade openness, and financial development Granger cause carbon emissions in the long-term.

This study provides some policy implications for Turkey. A variety of measures can be taken by policy makers without compromising on the targets of trade liberalization, economic growth, and financial development. Firstly, environmentally-sensitive trade subsidies can be applied to the critical industries. Pollution-intensive industries can be taxed by optimal environmental taxes. Secondly, to decrease carbon emissions and energy import in Turkey, the usage of alternative energy sources such as solar, wind, geothermal sources, bio-diesel fuel, and environmentally-sensitive technologies can be effectively supported. Thirdly, financial sector can provide a number of credit facilities to the real sector which wants to adopt cleaner and environmentally friendly technologies and thus can support these types of investments. Finally, it could be said that Turkish government should sustain sensitivity to the environmental objectives as well as economic objectives.

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