

# Export product diversification and the environmental Kuznets curve: evidence from Turkey

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Received: 12 April 2016 / Accepted: 4 August 2016 / Published online: 12 August 2016  
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**Abstract** Countries try to stabilize the demand for energy on one hand and sustain economic growth on the other, but the worsening global warming and climate change problems have put pressure on them. This paper estimates the environmental Kuznets curve over the period 1971–2010 in Turkey both in the short and the long run. For this purpose, the unit root test with structural breaks and the cointegration analysis with multiple endogenous structural breaks are used. The effects of energy consumption and export product diversification on CO<sub>2</sub> emissions are also controlled in the dynamic empirical models. It is observed that the environmental Kuznets curve hypothesis is valid in Turkey in both the short run and the long run. The positive effect on energy consumption on CO<sub>2</sub> emissions is also obtained in the long run. In addition, it is found that a greater product diversification of exports yields higher CO<sub>2</sub> emissions in the long run. Inferences and policy implications are also discussed.

**Keywords** Environmental Kuznets curve · Energy consumption · Export product diversification · Time series modeling · Structural breaks

**JEL classification** Q56 · O13 · C32

Responsible editor: Philippe Garrigues

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## Introduction

Countries try to stabilize the demand for energy on one hand and sustain economic growth on the other, but the worsening global warming and climate change problems have put pressure on them. In recent years, countries have put serious efforts to take measures to tackle environmental degradation through agreements. Since evidence shows a serious global warming problem, scholars have also intensified their interest in empirical studies related to the environment, and the main interest of these studies is the economic growth–environmental quality nexus.

The environmental Kuznets curve hypothesis is used to investigate the relationship between environmental degradation (measured by CO<sub>2</sub> emissions per capita in general) and economic growth. According to the environmental Kuznets curve hypothesis, environmental degradation increases as a country grows economically. This situation continues until the country reaches a high level of income. When the country reaches a certain level of income (approximately upper-middle income level), CO<sub>2</sub> emissions decline. The main goal of countries at the first stage of economic development is to increase their development level, that is, to increase their output level and to create new job opportunities. In this process, environmental quality has a “secondary importance” (Onafowora and Owoye, 2014). In addition, achieving a certain (high income) level does not necessarily mean that CO<sub>2</sub> emissions in a country will decrease. In other words, policy makers should take the necessary implications into account in reducing environmental degradation.

The environmental Kuznets curve hypothesis was first introduced and empirically tested by Grossman and Krueger (1995). Empirical studies conducted after Grossman and Krueger (1995) emphasize that three different mechanisms affect the environmental Kuznets curve: scale effect, structural

effect, and technique effect. First, observing the emergence of the detrition in environmental parameters (scale effect) is possible. Afterward, through structural and technique effects, there should be a decline in factors causing environmental degradation. The most important cause of structural and technique effects is the use of cleaner technology in production (Kanjilal and Ghosh, 2013).

Research studies on environmental degradation can be grouped into three main categories.<sup>1</sup> The first group focuses on the direct relationship between environmental degradation and economic growth (e.g., Dinda and Coondoo, 2006; Fodha and Zaghoud, 2010; Friedl and Getzner, 2003; Heil and Selden, 1999; Narayan and Narayan, 2010; Romero-Avila, 2008; Song et al., 2008; Yang et al., 2015). The second group analyzes the relationships between environmental degradation, economic growth, and energy consumption (e.g., Ang, 2008; Apergis and Payne, 2009; Bilgili et al., 2016; Lean and Smyth, 2010; Ozcan, 2013; Pao and Tsai, 2010; Saboori and Sulaiman, 2013; Soytas et al., 2007). The third group studies the relationships between environmental degradation, economic growth, and energy consumption while controlling other explanatory variables. In these studies, employment, financial development, fixed capital formation, foreign direct investments, population density, tourism, trade openness, and urbanization are used as explanatory variables in analyzing their effects on environmental degradation (e.g., Akbostanci et al., 2009; Ang, 2009; Bento and Moutinho, 2016; Can and Gozgor, 2016; De Vita et al., 2015; Dogan and Turkekul, 2016; Farhani and Ozturk, 2015; Gozgor and Can, 2016a; Halicioglu, 2009; Javid and Sharif, 2016; Jayanthakumaran et al., 2012; Jebli et al., 2016; Kanjilal and Ghosh, 2013; Katircioglu, 2014; Ling et al., 2015; Managi and Jena, 2008; Nasir and Rehman, 2011; Onafowora and Owoye, 2014; Ozturk et al. 2016; Soytas and Sari, 2009; Tang and Tan, 2015; Wang et al., 2015; Zhang and Cheng, 2009).<sup>2</sup>

Our study belongs to the third group. Indeed, the control variables of the environmental Kuznets curve hypothesis in the third group remarkably have identical features. For instance, some of these studies use exports, imports, and trade openness as a proxy for international trade in both developed and developing countries (e.g., Bento and Moutinho, 2016, for Italy; Halicioglu, 2009, for Turkey; Jayanthakumaran et al., 2012, for China and India). However, not only the volume of trade but also the diversity of export products can significantly affect CO<sub>2</sub> emissions since efforts to add new products into the export basket can lead to a hike in CO<sub>2</sub> emissions. In this context, the aim of our study is to investigate

the dynamic relationships between CO<sub>2</sub> emissions, export product diversification, energy consumption, and per capita gross domestic product (GDP) in Turkey, where the export-led (oriented) growth strategy has been adopted.<sup>3</sup> To the best of our knowledge, this is the first study that investigates the dynamic relationships between income, energy consumption, and CO<sub>2</sub> emissions while controlling the effects of export product diversification within the context of the environmental Kuznets curve hypothesis.

Indeed, export product diversification is one of the most important issues in the international trade literature. This topic has been evaluated in the context of developing countries in particular, and one of the most important problems in developing countries is that they have a narrow export basket (Hesse, 2008). In general, the export baskets of developing economies consist of traditional products, and these countries are making an effort to widen their diversification by adding nontraditional products into their export baskets.

Studies on export product diversification mainly investigate the relationship between diversification and economic growth, and most of them have concluded that export product diversification has a significant contribution to economic growth (e.g., Aditya and Acharyya, 2013; Agosin et al., 2012; Al-Marhubi, 2000; De Pineres and Ferrantino, 1997; Gozgor and Can, 2016b; Herzer and Nowak-Lehmann, 2006; Hesse, 2008). It is important to note that the diversification of export products emerges at the first stage of the development effort, and the process continues until the country reaches a particular income level (Cadot et al., 2011). Following this process, that is, at the second stage, the country focuses on export concentration rather than diversification after a turning point. In other words, there is an inverted U relationship between export product diversification and income (Imbs and Wacziarg, 2003). This turning point is calculated to be \$22,500 by Klinger and Lederman (2006) and \$25,000 by Cadot et al. (2011).

During the process of diversifying the export basket, observing more CO<sub>2</sub> emissions in developing countries is highly possible. Diversifying the export basket may also result in an increase in energy consumption since energy plays a significant role in reaching sustainable economic growth, which means a rise in macroeconomic activity. Increasing the macroeconomic activity will bring about higher energy consumption, and energy consumption can lead to environmental degradation. At this point, this paper empirically shows that not only economic growth and energy consumption but also export product diversification matter for CO<sub>2</sub> emissions in Turkey over the period 1971–2010.

The remainder of the paper is organized as follows: “Data, empirical model, and econometric methodology” section

<sup>1</sup> Besides, some studies focus on the energy consumption–economic growth nexus. For a detailed review of the literature, see, for example, Omri (2014), Ozturk (2010), and Payne (2010).

<sup>2</sup> Note that another branch of literature claims that data measurements in controls can be leading to biased support for the EKC hypothesis (see, e.g., Ikonen, 2012; Kaika and Zervas, 2013a, b).

<sup>3</sup> We refer to the recent papers of Ageliki and Ioannis (2016), Bölük and Mert (2015), and Tutulmaz (2015) for a brief overview of Turkey’s CO<sub>2</sub> emissions, economy, and energy sector, and international trade.

explains the data and empirical model and discusses the econometric methodology. “Empirical results” section reports the empirical results. “Discussion and policy implications” section discusses the findings and policy implications. “Conclusion” section concludes.

## Data, empirical model, and econometric methodology

### Data

This paper uses CO<sub>2</sub> emissions (metric tons per capita) over the period 1971–2010 in Turkey as the dependent variable. The real (constant \$ price in 2005) GDP per capita and the squared real GDP per capita (constant \$ price in 2005) are used to capture the linear and nonlinear effects of income, respectively. Energy consumption (kilogram of oil equivalent) per capita is also considered in the empirical model. All of these variables are used in logarithmic form in the empirical analyses. The frequency of the data is annual. The source of the related data is the World Development Indicators (WDI) of the World Bank.

The data on the diversification of exports are obtained from the database of the International Monetary Fund (IMF). The related data set has recently been compiled by the IMF staff, and it considers indexes of diversification across products and trading partners (market or destination). Here, the product diversification index (Theil index) is the benchmark measure of the diversification of a country’s exports. In addition, a higher value of the Theil index means a lower export product diversification.<sup>4</sup> Since the benchmark model is defined in logarithmic form, the export product diversification index is also considered in logarithmic form. Finally, a summary of the descriptive statistics is reported in Appendix 1.

### Empirical model

In this paper, a standard environmental Kuznets curve model in the literature is used; and income, squared income, and energy consumption are considered the main determinants of CO<sub>2</sub> emissions (e.g., Ang, 2008; Bilgili et al., 2016; Ozcan, 2013; Pao and Tsai, 2010; Saboori and Sulaiman, 2013; Soytas and Sari, 2009; Soytas et al., 2007; Zhang and Cheng, 2009). The income effect is measured by the level real GDP per capita and the squared real GDP per capita, and energy effect is captured by the energy

consumption per capita. We also suggest that export product diversification can also be a significant determinant of CO<sub>2</sub> emissions. Therefore, the following empirical model for the environmental Kuznets curve can be written as such:

$$\text{CO}_{2t} = f(\text{RGDP}_t^{\alpha_1}, \text{SRGDP}_t^{\alpha_2}, \text{ENC}_t^{\alpha_3}, \text{EXPDIV}_t^{\alpha_4}) \quad (1)$$

The empirical model in Eq. (1) can be expressed in logarithmic form as such:

$$\begin{aligned} \log\text{CO}_{2t} = & \alpha_0 + \alpha_1 \log\text{RGDP}_t + \alpha_2 \log\text{SRGDP}_t \\ & + \alpha_3 \log\text{ENC}_t + \alpha_4 \log\text{EXPDIV}_t + \varepsilon_t \end{aligned} \quad (2)$$

In Eqs. (1) and (2), logCO<sub>2t</sub> is CO<sub>2</sub> emissions in logarithmic form at time *t*; logRGDP<sub>*t*</sub> and logSRGDP<sub>*t*</sub> are the level and the squared real GDP per capita in logarithmic form at time *t*; logENC<sub>*t*</sub> is the energy consumption per capita in logarithmic form at time *t*; and logEXPDIV<sub>*t*</sub> is the export diversification index in logarithmic form at time *t*. The error term is also denoted by ε<sub>*t*</sub>.

It should be expected that α<sub>1</sub> > 0, α<sub>2</sub> < 0, and α<sub>3</sub> > 0. Actually, this is the main hypothesis of the paper: The environmental Kuznets curve hypothesis suggests that α<sub>1</sub> > 0 and it is elastic, as well as α<sub>2</sub> < 0, and both coefficients should be obtained as statistically significant. Otherwise, it can be said that there is no valid CO<sub>2</sub> emission function in the country; that is, there is a no significant inference for environmental pollution (Halicioglu, 2009). In addition, a greater energy consumption should yield a higher economic activity and should hike CO<sub>2</sub> emissions in a developing economy. As we have discussed in the introduction, the effect of export diversification α<sub>4</sub> on CO<sub>2</sub> emissions can be either positive or negative since it depends on the economic development stage of a country: it should be expected that in a developing country, export basket provides pollution-intensive goods, and diversifying its export basket leads to greater CO<sub>2</sub> emissions. However, as a country develops, it starts to exclude these goods from the export basket (probably it will import these goods from other countries with “less-restrictive environmental protection laws”). So as a country’s export basket sophisticates, lower CO<sub>2</sub> emissions are produced in the case of a developed country. It is important to note that the key point here is to obtain a statistically significant (long-run) coefficient.

On the other hand, reaching a long-run equilibrium can take time for CO<sub>2</sub> emissions in Turkey. In such case, the speed of adjustment between short-run and long-run CO<sub>2</sub> emissions can also be modeled by the following error correction model (ECM):

$$\begin{aligned} \Delta \log\text{CO}_{2t} = & \alpha_0 + \sum_{i=1}^n \alpha_1 \Delta \log\text{CO}_{2t-k} + \sum_{i=0}^n \alpha_2 \Delta \log\text{RGDP}_{t-k} \\ & + \sum_{i=0}^n \alpha_3 \Delta \log\text{SRGDP}_{t-k} + \sum_{i=0}^n \alpha_4 \Delta \log\text{ENC}_{t-k} \\ & + \sum_{i=0}^n \alpha_5 \Delta \log\text{EXPDIV}_{t-k} + \alpha_6 \varepsilon_{t-1} + \mu_t \end{aligned} \quad (3)$$

<sup>4</sup> In other words, finding the diversification of exports to positively contribute to CO<sub>2</sub> emissions implies that the relationship between two variables is negative. The positive sign implies that the concentration of exports positively contributes to CO<sub>2</sub> emissions. We refer to Papageorgiou and Spatafora (2012) for the technical details and calculation method of the export product diversification (Theil) index.

In Eq. (3),  $\Delta$  indicates the change in both dependent and independent variables, and  $\mu_t$  is the error term. In addition,  $\varepsilon_{t-1}$  is the lagged error correction term (ECT) obtained from the estimation of Eq. (2), and it represents the speed of adjustment of the disequilibrium between short-run and long-run levels of CO<sub>2</sub> emissions. It is expected that  $\alpha_6 < 0$ .

**Econometric methodology**

First, following Strazicich et al. (2004), the unit root tests of Lee and Strazicich (2003, 2013), which accounts for two endogenous structural breaks and one endogenous structural break in the series, are implemented, respectively. To successfully implement the cointegration analysis, finding a statistically significant unit root in all (five) variables is necessary.

Second, the cointegration test of Maki (2012), which considers the structural breaks in the level and regime shifts, is run. The null hypothesis of the test is “there is no cointegration among the series,” and the alternative hypothesis is “cointegration with  $i$  breaks.” The critical values are generated by the Monte Carlo simulations in Maki (2012). In addition, the maximum number of structural breaks is selected as two events. The most important feature of the cointegration test of Maki (2012) is considering each period as a potential structural break point. In other words, the test statistics of the cointegration test of Maki (2012) is defined to determine the endogenous structural break(s).

At this stage, Maki (2012) offers four different models to analyze the cointegrating relationships between the variables. These models can be written as follows:

*Model 1* considers the structural break(s) in the level (intercept) without the time trend:

$$y_t = \mu + \sum_{i=1}^k \mu_i K_{i,t} + \beta x_t + v_t \tag{4}$$

*Model 2* considers the structural break(s) in the level (intercept) and the coefficients without the time trend:

$$y_t = \mu + \sum_{i=1}^k \mu_i K_{i,t} + \beta x_t + \sum_{i=1}^k \beta_i x_i K_{i,t} + v_t \tag{5}$$

*Model 3* considers the structural break(s) in the level (intercept) and the coefficients with the time trend:

$$y_t = \mu + \sum_{i=1}^k \mu_i K_{i,t} + \gamma x + \beta x_t + \sum_{i=1}^k \beta_i x_i K_{i,t} + v_t \tag{6}$$

*Model 4* considers the structural break(s) in the level (intercept), the coefficients, and the time trend:

$$y_t = \mu + \sum_{i=1}^k \mu_i K_{i,t} + \gamma t + \sum_{i=1}^k \gamma_i t K_{i,t} + \beta x_t + \sum_{i=1}^k \beta_i x_i K_{i,t} + v_t \tag{7}$$

In Eqs. (4) to (7),  $K_{i,t}$  is the dummy variable, and if the test statistics is greater than the critical value,  $K_{i,t} = 1$ ; otherwise, it will be equal to zero ( $K_{i,t} = 0$ ).  $\mu_i$  is the constant (intercept),  $\gamma$  is the coefficient,  $\beta$  is the time trend, and  $v_t$  is the error terms.

Since the results of the unit root test consider the break in the level and they indicate significant I(1) for all variables, the cointegration test of Maki (2012) that models the break in the level is used. In other words, model 1 (structural break(s) in the level (intercept) without the time trend) is used within the cointegration test methodology of Maki (2012).

Third, the long-run coefficients of the model that is represented in Eq. (2) are estimated with the dynamic ordinary least squares (DOLS) by Stock and Watson (1993) with the heteroskedasticity and autocorrelation consistent (HAC) standard errors (Bartlett kernel, Newey-West fixed bandwidth = 4.0000). Following Apergis and Lau (2015), two structural break dates are also included, and the selection of structural break dates is based on the results of unit root tests of Lee and Strazicich (2003, 2013).

Fourth, the ECM for the short-run coefficients is estimated for the empirical model expressed in Eq. (3).

Fifth, the Granger causality/block exogeneity Wald tests are run, and the test procedure can be identified as follows:

$$\begin{bmatrix} \Delta \log CO_{2t} \\ \Delta \log RGDP_t \\ \Delta \log SRGDP_t \\ \Delta \log ENC_t \\ \Delta \log EXPDIV_t \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \\ \mu_5 \end{bmatrix} + \begin{bmatrix} \lambda_{11,1} & \lambda_{12,1} & \lambda_{13,1} & \lambda_{14,1} & \lambda_{15,1} \\ \lambda_{21,1} & \lambda_{22,1} & \lambda_{23,1} & \lambda_{24,1} & \lambda_{25,1} \\ \lambda_{31,1} & \lambda_{32,1} & \lambda_{33,1} & \lambda_{34,1} & \lambda_{35,1} \\ \lambda_{41,1} & \lambda_{42,1} & \lambda_{43,1} & \lambda_{44,1} & \lambda_{45,1} \\ \lambda_{51,1} & \lambda_{52,1} & \lambda_{53,1} & \lambda_{54,1} & \lambda_{55,1} \end{bmatrix} \begin{bmatrix} \Delta \log CO_{2t-1} \\ \Delta \log RGDP_{t-1} \\ \Delta \log SRGDP_{t-1} \\ \Delta \log ENC_{t-1} \\ \Delta \log EXPDIV_{t-1} \end{bmatrix} + \dots + \begin{bmatrix} \lambda_{11,k} & \lambda_{12,k} & \lambda_{13,k} & \lambda_{14,k} & \lambda_{15,k} \\ \lambda_{21,k} & \lambda_{22,k} & \lambda_{23,k} & \lambda_{24,k} & \lambda_{25,k} \\ \lambda_{31,k} & \lambda_{32,k} & \lambda_{33,k} & \lambda_{34,k} & \lambda_{35,k} \\ \lambda_{41,k} & \lambda_{42,k} & \lambda_{43,k} & \lambda_{44,k} & \lambda_{45,k} \\ \lambda_{51,k} & \lambda_{52,k} & \lambda_{53,k} & \lambda_{54,k} & \lambda_{55,k} \end{bmatrix} \begin{bmatrix} \Delta \log CO_{2t-k} \\ \Delta \log RGDP_{t-k} \\ \Delta \log SRGDP_{t-k} \\ \Delta \log ENC_{t-k} \\ \Delta \log EXPDIV_{t-k} \end{bmatrix} + \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ \varepsilon_{3,t} \\ \varepsilon_{4,t} \\ \varepsilon_{5,t} \end{bmatrix} \tag{8}$$



In Eq. (8),  $ECT_{t-1}$  is the lagged error correction term obtained from the long-run equilibrium model.  $\varepsilon_{1,t}$ ,  $\varepsilon_{2,t}$ ,  $\varepsilon_{3,t}$ ,  $\varepsilon_{4,t}$ , and  $\varepsilon_{5,t}$  indicate the independent and identically distributed random errors, and they are defined within a finite covariance matrix with mean zero.

**Empirical results**

First, the results of the unit root test of Lee and Strazicich (2003) are reported in Table 1 (see panel A). The results of the unit root test of Lee and Strazicich (2013) are also reported in Table 1 (see panel B) for each of the five variables. The results here are considered for the structural break in the level.

The results in Table 1 indicate that all variables contain a unit root at a statistical significance level of 5 % and the first difference ( $\Delta$ ) among them is stationary. In other words, all variables can be defined as I(1) process. Therefore, it is observed that all variables in the empirical model are suitable for the cointegration technique.

Second, the results of the cointegration test of Maki (2012) are reported in Table 2.

The results of the four models of the cointegration test of Maki (2012) in Table 2 indicate that the cointegration of log CO<sub>2</sub> emissions, log GDP per capita, log squared GDP per capita, log energy consumption, and log export diversification

is statistically significant at the 1 % level. Therefore, the short-run and long-run coefficients can be obtained.

The results of the DOLS estimations for long-run coefficients are reported in Table 3. As expected, the long-run coefficients of the log real GDP per capita are positive and elastic (7.53), and the long-run coefficients of the log squared log real GDP per capita are negative and inelastic (−0.94). In addition, the long-run coefficients of the log energy consumption per capita are also positive and inelastic (0.61), as expected. The effects of income variables are statistically significant at the 1 % level. In addition, the coefficients of the energy consumption and the structural break dates are statistically significant at the 5 % level.

The effect of the log export product diversification (Theil index) on the log CO<sub>2</sub> emissions is also found to be negative and inelastic (−0.046), and that means export diversification yields higher CO<sub>2</sub> emissions. The long-run coefficient of the log export product diversification is obtained as statistically significant at the 1 % level. In other words, the results in Table 3 indicate that 1 % decrease in the Theil index (1 % increase in export product diversification) to increase CO<sub>2</sub> emissions by 0.046 % in Turkey over the long run.

The results of the ECM are reported in Table 4. Now, the effects of the lagged log real GDP per capita and the lagged log squared real GDP per capita on CO<sub>2</sub> emissions are positive and elastic (14.46) and negative and elastic (−2.007),

**Table 1** Results of the minimum Lagrange multiplier (LM) unit root tests of Lee and Strazicich (2003, 2013)

Variables	LM	CV (1 %)	CV (5 %)	CV (10 %)	Lag	Break dates	Variables	LM	Lag
Panel A: two structural breaks									
Log real GDP per capita	−3.606*	−4.916	−3.808	−3.132	0	1979, 2002	$\Delta$ Log real GDP per capita	−6.792***	0
Log squared real GDP per capita	−3.696*	−4.916	−3.808	−3.132	0	1979, 2003	$\Delta$ Log squared real GDP per capita	−6.903***	0
Log CO <sub>2</sub> emissions per capita	−3.580*	−4.916	−3.808	−3.132	0	1982, 2000	$\Delta$ Log CO <sub>2</sub> emissions per capita	−6.297***	0
Log energy consumption per capita	−3.573*	−4.916	−3.808	−3.132	0	1976, 2008	$\Delta$ Log energy consumption per capita	−6.827***	0
Log export product diversification	−2.683	−4.916	−3.808	−3.132	1	1976, 1987	$\Delta$ Log export product diversification	−5.876***	1
Panel B: one structural break									
Log real GDP per capita	−3.347	−5.121	−4.011	−3.468	0	1979	$\Delta$ Log real GDP per capita	−6.280***	0
Log squared real GDP per capita	−3.323	−5.121	−4.011	−3.468	0	1979	$\Delta$ Log squared real GDP per capita	−6.264***	0
Log CO <sub>2</sub> emissions per capita	−3.402	−5.121	−4.011	−3.468	0	2000	$\Delta$ Log CO <sub>2</sub> emissions per capita	−6.218***	0
Log energy consumption per capita	−3.335	−5.121	−4.011	−3.468	0	1976	$\Delta$ Log energy consumption per capita	−6.624***	0
Log export product diversification	−2.077	−5.121	−4.011	−3.468	1	1976	$\Delta$ Log export product diversification	−5.168***	0

The table shows the results of the unit root test of Lee and Strazicich (2003), and the results include break on the level. Null hypothesis: the series have unit root. The optimal number of lag is selected by the Akaike Information Criteria (AIC). The maximum number of lag is 3. Trimmer rate is defined as 0.10 CV critical values

\*\*\* and \* indicate the rejection of the null hypothesis at the 1 and 10 % significance levels

**Table 2** Results of the cointegration test of Maki (2012): CO<sub>2</sub> emissions, GDP per capita, squared GDP per capita, energy consumption, export diversification

Cointegration among variables	Test statistics	CV (1 %)	CV (5 %)	CV (10 %)	Break dates
Model 1	-7.465***	-6.303	-5.839	-5.575	1984, 2000
Model 2	-8.764***	-6.556	-6.055	-5.805	1984, 1989
Model 3	-8.862***	-7.756	-7.244	-6.964	1984, 1990
Model 4	-8.629***	-8.167	-7.638	-7.381	1987, 1993

The table shows the results of the four models of the cointegration test of Maki (2012). The null hypothesis: there is no cointegration among the series, and the alternative hypothesis is cointegration with *i* breaks. The maximum number of breaks is 3. Trimmer rate is defined as 0.10

Critical values are based on the bootstrapped values of Table 1 in Maki (2012)

CV critical values

\*\*\* indicates the rejection of the null hypothesis at the 1 % significance level

respectively. In addition, their short-run coefficients are found to be statistically significant at the 5 % level. The positive and inelastic coefficients for the lagged CO<sub>2</sub> emissions (0.25) and the lagged log energy consumption per capita (0.11) are also obtained; however, their short-run coefficients are found to be statistically insignificant.

The ECT term of the ECM regression is -0.263, and it is found to be statistically significant at the 5 % level. Here, the negative sign implies that CO<sub>2</sub> emissions in Turkey converge to its long-run equilibrium path by a speed of adjustment of 26.3 % through the channels of the real GDP per capita, squared real GDP per capita, energy consumption per capita, and export product diversification (Theil) index.

**Table 3** Results of the dynamic ordinary least square (DOLS) estimations for the long-run coefficients

Dependent variable	Log CO <sub>2</sub> emissions per capita
Log real GDP per capita	7.530 (2.101)***
Log squared real GDP per capita	-0.942 (0.257)***
Log energy consumption per capita	0.611 (0.234)**
Log export product diversification	-0.046 (0.014)***
D1982	0.018 (0.006)***
D2000	-0.009 (0.004)**
Constant term	-16.41 (3.686)***
Observations	37
Adjusted R <sup>2</sup>	0.996
Leads and lags	(1, 1)
Standard error of regression	0.007
Durbin–Watson statistics	2.106
Long-run variance	0.409
Sum squared residuals (SSRs)	0.001

Selection of break dates is based on the results of the unit root tests of Lee and Strazicich (2003, 2013). The heteroskedasticity and autocorrelation consistent (HAC) standard errors (Bartlett kernel, Newey–West fixed bandwidth = 4.0000) are in parentheses

\*\*\* and \*\* indicate statistical significance at the 1 and 5 % levels, respectively

The short-run impact of the log export diversification (Theil) index on the log CO<sub>2</sub> emissions is found to be -0.033, but the coefficient is not statistically significant in the short run. Diversification process of the export basket takes time in any developing economy, and it should be expected to obtain the statistically insignificant effects for the short run. Note that the long-run effect of product diversification of the export basket on CO<sub>2</sub> emissions is found as statistically significant. Finally, the results of the Granger causality/block exogeneity Wald tests are reported in Table 5.

The results in Table 5 indicate that a statistically significant causal relationship runs from the log real GDP per capita and the log squared real GDP per capita to the log CO<sub>2</sub> emissions in the short run. These results are in line with the results of ECM estimations for the short-run coefficients. In addition, the overall chi-square test statistics of the causality relationship for the log CO<sub>2</sub> emissions is also statistically significant. These results are in line with the results of the DOLS estimations for long-run coefficients. Therefore, the results of the Granger causality/block exogeneity Wald tests show that previously obtained empirical results for both the short run and the long run are statistically robust in modeling CO<sub>2</sub> emissions in Turkey.

In addition, it is observed that a statistically significant causal relationship runs from the log CO<sub>2</sub> emissions, log real GDP per capita, and log squared real GDP per capita to the log energy consumption per capita in the short run. Plus the overall chi-square test statistics of the causal relationship for the log energy consumption per capita is also statistically significant. Therefore, it is found that income per capita causes energy consumption in a direct way, and income causes energy consumption indirectly through CO<sub>2</sub> emissions in Turkey. Plus the causal effect of income per capita is found to be nonlinear.

## Discussion and policy implications

### Discussion

The empirical results show that the environmental Kuznets curve hypothesis is valid in Turkey over the period under

**Table 4** Results of the error correction model (ECM) estimations for short-run coefficients

Dependent variable	$\Delta\text{Log CO}_2$ emissions per capita
Error correction term (ECT)	-0.263 (0.129)**
$\Delta\text{Lagged log CO}_2$ emissions per capita	0.252 (0.372)
$\Delta\text{Lagged log real GDP}$ per capita	14.46 (7.065)**
$\Delta\text{Lagged log squared real GDP}$ per capita	-2.001 (0.951)**
$\Delta\text{Lagged log energy consumption}$	0.113 (0.482)
$\Delta\text{Lagged log export product diversification}$	-0.033 (0.066)
Constant term	0.009 (0.004)**
Observations	38
Adjusted $R^2$	0.036

The optimal number of lag length is selected by the Schwarz Information Criteria (SIC). The standard errors are in parentheses

\*\* indicates statistical significance at the 5 % level

concern. It is observed that income is the most important variable in explaining  $\text{CO}_2$  emissions in Turkey since its effect is statistically significant in both the short run and the long run. Besides, there is an inverted U relationship between income and  $\text{CO}_2$  emissions in Turkey; that is, empirical evidence for the validity of the environmental Kuznets curve hypothesis illustrates that the level of  $\text{CO}_2$  emissions increases with income at first until they reach stabilization. Then, they reduce in the long run. It is also found that energy consumption is positively related to  $\text{CO}_2$  emissions in Turkey in the long run, as expected in the case of a developing country. These empirical results on the effects of income and energy consumption on  $\text{CO}_2$  emissions are in line with the previous empirical results of studies on several developing countries (e.g., Halicioglu, 2009, for Turkey; Javid and Sharif, 2016, for Pakistan; Jayanthakumaran et al., 2012, for China and India; Kanjilal and Ghosh, 2013, for India; Managi and Jena, 2008, for India; Nasir and Rehman, 2011, for Pakistan; Tang and Tan, 2015, for Vietnam). In other words, the  $\text{CO}_2$  emission function with energy consumption is valid in Turkey, and this result is in line with the previous findings of Halicioglu (2009) in particular. These results mean that forecasting future  $\text{CO}_2$

emissions from past levels of income and energy consumption is possible in the long run.

Finally, it is also observed that the wider product diversification in the export basket yields higher  $\text{CO}_2$  emissions in Turkey in the long run. However, the short-run effect is found to be statistically insignificant. To the best of our knowledge, these are the first empirical results on the effect of export basket diversification on  $\text{CO}_2$  emissions in the literature.

### Policy implications

Empirical findings show that there could be some environmental policy implications that would suppress  $\text{CO}_2$  emissions. First, it is observed that rapid economic growth leads to a hike in environmental pollutants. However, sustainable economic growth is crucial for any developing economy not only for catching up with developed economies but also for creating new job opportunities, especially for young people. So in developing economies, as income increases,  $\text{CO}_2$  emissions systematically increase as well. At this point, policy implications should focus on reducing the initial costs of environmentally friendly investments.

**Table 5** Results of the Granger causality/block exogeneity Wald tests

Dependent variable	$\Delta\text{Log CO}_2$ emissions	$\Delta\text{Log GDP}$ per capita	$\Delta\text{Log squared GDP}$ per capita	$\Delta\text{Log energy consumption}$	$\Delta\text{Log export diversification}$	Overall chi-square statistics
$\Delta\text{Log CO}_2$ emissions	–	7.272*** [0.0070]	7.664*** [0.0056]	0.012 [0.9112]	1.370 [0.2418]	11.90** [0.0180]
$\Delta\text{Log GDP}$ per capita	0.561 [0.4537]	–	1.330 [0.2488]	0.001 [0.9683]	0.039 [0.8416]	2.338 [0.6738]
$\Delta\text{Log squared GDP}$ per capita	0.547 [0.4593]	1.173 [0.2787]	–	0.0005 [0.9807]	0.041 [0.8386]	2.270 [0.6861]
$\Delta\text{Log energy consumption}$	7.777*** [0.0053]	8.411*** [0.0037]	9.003*** [0.0027]	–	1.423 [0.2329]	21.04*** [0.0003]
$\Delta\text{Log export diversification}$	0.732 [0.3921]	0.049 [0.8244]	0.032 [0.8580]	0.637 [0.4245]	–	2.859 [0.5816]

The optimal number of lag length is selected by the Schwarz Information Criteria (SIC). The probability values are in brackets

\*\*\* and \*\* indicate the rejection of the null hypothesis at the 1 and 5 % significance levels, respectively

Second, given that Turkey is still a net energy importer and energy consumption increases as per capita income increases, reducing the level of energy consumption is also not feasible. Here, policy implications should be based on supporting the more efficient use of renewable energy in the Turkish economy. It should be noted that investment or tax incentives on technologies that consume renewable energy can be noteworthy policy tools.

Third, another issue is the efficient use of nuclear energy in the production process. Indeed, nuclear energy can reduce the consumption of fossil energy sources; therefore, it can suppress the CO<sub>2</sub> emissions in Turkey. It can be suggested that the policy implications for nuclear energy can provide significant results in reducing CO<sub>2</sub> emissions in Turkey.

Fourth, the results from this paper also indicate that export product diversification significantly affects CO<sub>2</sub> emissions in Turkey. Indeed, it is found that the product diversification of exports can be beneficial not only for rapid economic growth but also for environmental pollutant management. For instance, firms should avoid producing goods that cause severe CO<sub>2</sub> emissions. This issue should be assessed in widening the export basket, and products with high CO<sub>2</sub> emissions can be imported. Of course, all of these policy implications require a detailed knowledge of the scale of environmental pollutants for each sector in the Turkish economy (Tunc et al., 2007).

### Conclusion

In recent years, countries have put serious efforts to take measures to tackle environmental degradation through agreements. Since evidence shows a serious global warming problem, scholars have also intensified their interest in empirical studies related to the environment, and the main interest of these studies is the economic growth–environmental quality nexus. In this paper, the validity of the environmental Kuznets curve hypothesis in the Turkish economy is analyzed for the

period 1971–2010. To do so, the unit root test of Lee and Strazicich (2003, 2013) and the cointegration analysis of Maki (2012), which is assumed to have endogenous structural breaks in time series, are used. By using the ECM and the DOLS estimation techniques, the short-run and the long-run coefficients are also obtained. In addition, the effects of energy consumption and export product diversification on CO<sub>2</sub> emissions are also controlled in the dynamic empirical models. In other words, this paper investigates the dynamic relationships between CO<sub>2</sub> emissions, export product diversification, energy consumption, and per capita gross domestic product (GDP) in Turkey, where the export-led (oriented) growth strategy has been adopted. To the best of our knowledge, this is the first study that investigates the dynamic relationships between income, energy consumption, and CO<sub>2</sub> emissions while controlling the effects of export product diversification within the context of the environmental Kuznets curve hypothesis.

The findings of this paper are threefold: First, it is observed that the environmental Kuznets curve hypothesis is valid in Turkey in both the short run and the long run over the period under concern. Second, the positive, but the inelastic impact of energy consumption on CO<sub>2</sub> emissions is also obtained in the long run. Third, it is observed that a higher product diversification of export yields higher CO<sub>2</sub> emissions in Turkey in the long run; and actually, this is the novel contribution of the paper to the existing empirical literature.

Future research on the effects of export diversification (product and trading partner diversification) on CO<sub>2</sub> emissions and energy consumption can be conducted in other developing or developed countries. In addition, the effects of the sub-indexes of the export diversification (Theil) index (e.g., extensive margin and intensive margin) can also be considered within this context with different econometric tools.

**Acknowledgments** We would like to express our gratitude to five anonymous reviewers and the editor (Philippe Garrigues) for their valuable comments and suggestions, which substantially improved the paper. All the remaining errors are our own.

### Appendix 1

**Table 6** Descriptive summary statistics and the description of variables: 1971–2010

Variable	Unit	Data source	Mean	Standard deviation	Skewness	Kurtosis
Real per capita GDP (constant \$ price in 2005)	Logarithmic form	World Bank, WDI	3.696	0.113	0.174	1.877
Squared real per capita GDP (constant \$ price in 2005)	Logarithmic form	World Bank, WDI	13.67	0.844	0.213	1.897
CO <sub>2</sub> emissions (metric tons per capita)	Logarithmic form	World Bank, WDI	0.401	0.138	−0.204	1.852
Energy consumption (kilogram of oil equivalent per capita)	Logarithmic form	World Bank, WDI	2.972	0.115	−0.070	1.936
Export product diversification (Theil index)	Logarithmic form	International Monetary Fund	−1.075	0.214	0.772	2.276



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