Environ Sci Pollut Res
DOI 10.1007/s11356-015-5323-8

RESEARCH ARTICLE

CO_2 emissions, real output, energy consumption, trade, urbanization and financial development: testing the EKC hypothesis for the USA

Eyup Dogan[1] · **Berna Turkekul**[2]

Received: 4 August 2015 / Accepted: 25 August 2015

Abstract This study aims to investigate the relationship between carbon dioxide (CO_2) emissions, energy consumption, real output (GDP), the square of real output (GDP^2), trade openness, urbanization, and financial development in the USA for the period 1960–2010. The bounds testing for cointegration indicates that the analyzed variables are cointegrated. In the long run, energy consumption and urbanization increase environmental degradation while financial development has no effect on it, and trade leads to environmental improvements. In addition, this study does not support the validity of the environmental Kuznets curve (EKC) hypothesis for the USA because real output leads to environmental improvements while GDP^2 increases the levels of gas emissions. The results from the Granger causality test show that there is bidirectional causality between CO_2 and GDP, CO_2 and energy consumption, CO_2 and urbanization, GDP and urbanization, and GDP and trade openness while no causality is determined between CO_2 and trade openness, and gas emissions and financial development. In addition, we have enough evidence to support one-way causality running from GDP to energy consumption, from financial development to output, and from urbanization to financial development. In light of the long-run estimates and the Granger causality analysis, the US government should take into account the importance of trade openness, urbanization, and financial development in controlling for the levels of GDP and pollution. Moreover, it should be noted that the development of efficient energy policies likely contributes to lower CO_2 emissions without harming real output.

Keywords CO_2 emissions · Financial development · Urbanization · Trade · Energy · Output

Responsible editor: Marcus Schulz

We hereby declare that the manuscript has not been published before nor submitted to another journal for the consideration of publication.
We would like to thank the editor and two anonymous referees for their comments and suggestions. Any remaining errors are solely ours.

✉ Eyup Dogan
eyup.dogan@agu.edu.tr

Berna Turkekul
berna.turkekul@ege.edu.tr

1 Department of Economics, Abdullah Gul University, Sumer Campus, Office #B206, Kayseri, Turkey

2 Department of Agricultural Economics, Ege University, Bornova, Turkey

Introduction

The environmental Kuznets curve (EKC) hypothesizes that the relationship between environmental quality and real output has an inverted U-shaped feature as environmental degradation first increases until a certain level of GDP and then decreases with increases in GDP. Akbostancı et al. (2009), Lee and Lee (2009), Fodha and Zaghdoud (2010), and Saboori et al. (2012) among others analyze the possible presence of the EKC hypothesis in Turkey, panel of 109 countries, Tunisia, and Malaysia, respectively. In addition, a group of study focus on the relationship between GDP per capita (or economic growth) and energy consumption for a variety of countries and regions (Soytas and Sari 2003; Wolde-Rufael 2005; Ozturk 2010; Shahbaz and Lean 2012; Smyth and Narayan 2014; Dogan 2014, 2015a, 2015b; Aslan 2014; Komal and Abbas 2015; Shahbaz et al. 2015). As one of the leading works in the literature, Ang (2007) combines the energy–output nexus and environment–output nexus under a modified EKC framework in which carbon dioxide (CO_2) emissions as a proxy for environmental degradation are regressed on energy consumption, GDP per capita, and the

Published online: 09 September 2015

square of GDP per capita. Ang (2007) supports the validity of an inverted U-shaped relationship between carbon dioxide emissions and output in France as CO_2 is positively impacted by GDP per capita and negatively impacted by the square of GDP per capita. The EKC hypothesis begins to be widely analyzed in the energy literature after energy consumption is inserted as an additional explanatory variable into the conventional EKC model (Soytas et al. 2007; Zhang and Cheng 2009; Soytas and Sari 2009; Ozturk and Acaravci 2010; Wang et al. 2011; Nasir and Rehman 2011; Kanjilal and Ghosh 2013; Salahuddin and Gow 2014; Kasman and Duman 2015; Bastola and Sapkota 2015; Baek 2015).

The existing literature about the energy–environment–output nexus is abundant (Al-Mulali et al. 2015a). Therefore, the linkage between GDP, energy consumption, and environmental degradation should be tested by taking into account particular segments of the economy rather than by testing the validity of the EKC hypothesis using the simple econometric model in which CO_2 emissions are regressed on real output, the square of real output, and energy consumption. By means of including additional variables into the simple model, the state-of-the-art attempt to eliminate the omitted-variable bias problem. Trade openness can be considered as a commonly used variable in the literature (Ang. 2009; Halicioglu 2009; Jalil and Mahmud 2009; Nasir and Rehman 2011; Jayanthakumaran et al. 2012). Farhani et al. (2014) decompose the effect of trade on pollution, energy consumption, and output into three components, namely scale, composition, and technique. The scale effect basically implies that the increases in the amount of trade influence output, energy consumption, and thus, CO_2 emissions. The composition effect refers to the re-allocation in a country's traded goods basket. In other words, free trade enables the country to specialize on the production of goods for which it has comparative advantage. Hence, the use of energy and environmental quality may increase or decrease depending on whether or not the sectors that the country specializes need more energy. The technique effect means that trade liberalization leads to environmental improvements since the technology gets better in producing goods and using energy more efficiently.

Another variable that recently begins to be introduced into the simple model is urbanization. Martínez-Zarzoso and Maruotti (2011) argue the possible impact of urbanization on environmental degradation through several channels. At the most basic interpretation, the increase in urban population results in higher industrial output, transportation, and energy consumption and gas emissions. Hossain (2011), Sharma (2011), and Kasman and Duman (2015) add trade and urbanization into the simple EKC model.

Financial development is the recent additional variable used by the recent works in the literature. Financial development may lead to lower financing costs and better and larger financing networks through which enterprises can have higher opportunity to make more investment and buy new machines and equipment, resulting in more energy consumption and CO_2 emissions. Because financial development likely links to cheaper personal loan rates, it may trigger consumers to purchase houses, cars, and durable goods (i.e., refrigerator and dish washer), which increases output, energy consumption, and gas emissions. On the other hand, financial development may detracts energy consumption and gas emissions as it can potentially stimulate the efficiency of business performance as well as energy efficiency (Tamazian et al. 2009). Sadorsky (2010) and Aslan et al. (2014) find significantly positive relationship between energy consumption and financial development. Zhang (2011) claims that financial development negatively impacts environmental degradation. Islam et al. (2013) find financial development and economic growth to have impact on energy consumption. Tang and Tan (2014) reveal that financial development affects economic growth and energy consumption influences financial development. Al-Mulali and Lee (2013) indicate that GDP, financial development, urbanization, and trade positively impact energy consumption. In addition, Tamazian et al. (2009), Tamazian and Rao (2010), Jalil and Feridun (2011), Ozturk and Acaravci (2013), Shahbaz et al. (2013a, b), and Omri et al. (2015) include trade and financial development into the simple EKC model.

Al-Mulali et al. (2015b) and Farhani and Ozturk (2015) include trade, urbanization, and financial development as separate sectors of the economy into the simple EKC model so as to attempt to obtain unbiased effect of energy consumption on carbon dioxide emissions and to test the validity of EKC hypothesis. Only these two studies, to the best of our knowledge, simultaneously take into account the possible effects of trade, urbanization, and financial development, and only a few studies consider the impacts of one or two variables among financial development, trade, and urbanization while the influence of energy consumption and GDP on environmental quality is investigated. Furthermore, these studies reach different conclusions in terms of whether trade, urbanization, and financial development negatively or positively impact carbon dioxide emissions and whether or not the EKC hypothesis is present.

In light of the abovementioned arguments, the fundamental contribution of this study is that for the first time in the literature ,this study aims to analyze the relationship between carbon dioxide emissions, energy consumption, real output, trade, urbanization, and financial development for the USA in an econometric model based on the EKC hypothesis. Given that the analyzed variables are connected to each other, this study also tries to eliminate the omitted-variable bias problem. Because this type of investigation is a significant gap in the literature and, thus, the outcome has a high value in terms of policy implications, we focus on a single-country study rather than a panel study. According to the World Development Indicators, the USA is famous for large amount of energy consumption, output, and gas emissions. The USA is also one of the top countries in the world in terms of trade openness, urbanization, and financial development. In addition, the USA is an important country in terms of its impressive regional and world affairs and its role in the energy market since it is among the NAFTA countries, one of the G7 countries, and one of the five permanent members of the United Nations. The rest of the study is as follows: the "Literature review" section provides a literature review, the "Methods and data" section explains the methods and data, the "Empirical results" section reveals the empirical results, and the "Conclusions" section concludes the aims and findings.

Literature review

A number of existing studies including Ang (2007), Iwata et al. (2010), Hamit-Haggar (2012), Saboori et al. (2012), Tiwari et al. (2013), Lau et al. (2014), Yavuz (2014), and Osabuohien et al. (2014) among others investigate the relationship between income and carbon dioxide emissions and validate the existence of the EKC hypothesis in a variety of countries and regions. In addition, various studies validate the EKC hypothesis using the following panel data: for instance, Skaza and Blais (2013) for 190 developing and developed countries; Al-Mulali and Sheau-Ting (2014) for 189 countries from six different regions, namely Asia Pacific, Eastern Europe, the Americas, Middle East and North Africa (MENA), Sub-Saharan Africa, and Western Europe; Omri et al. (2015) for MENA countries; Ziaei (2015) for European, East Asian, and Oceania countries; and Al-Mulali et al. (2015c) for 93 countries. Moreover, Ang (2007), Jalil and Mahmud (2009), Alam et al. (2012), Ozturk and Acaravci (2013), Shahbaz et al. (2013a), Alkhathlan and Javid (2013), and Boutabba (2014), using time series data, also support the empirical presence of the EKC hypothesis for France, China, Turkey, Bangladesh, South Africa, Saudi Arabia, and India. On the other hand, Al-Mulali et al. (2015a) and Farhani and Ozturk (2015) find controversial results not supporting the validity of EKC for Vietnam and Tunisia.

As seen above, different studies reach conflicting results as to the effect of income on the environment. These differences may occur from omitted-variable bias problem, the choice of specific functional forms (econometric techniques), and sample selection bias. To overcome the omitted-variable bias problem, several studies include different variables ranging from financial development, trade, foreign direct investment, and energy consumption to energy prices, labor, gross fixed capital formation, and urbanization (Farhani and Ozturk 2015; Shahbaz et al. 2015; Al-Mulali et al. 2015a; Komal and Abbas 2015). In the literature, there are some efforts attempting to examine environmental pollution including the impact of trade. Ang (2009) explores the estimation of the Chinese pollution function using CO_2 emissions (as an endogenous variable) and GDP, energy use, and trade openness (as exogenous variables) over the annual period of 1953–2006. The findings indicate that more energy use, GDP, and trade openness lead to more CO_2 emissions. In the same way, Halicioglu (2009) suggests the dynamic causal relationships between CO_2 emissions, GDP, energy consumption, and foreign trade in Turkey over the period of 1960–2005. Jalil and Mahmud (2009) extend the methodology of Halicioglu (2009) for China over the period of 1975–2005. The findings also indicate that CO_2 emissions can be determined by GDP and energy consumption, while trade has insignificant impact on CO_2 emissions in the long run. Jayanthakumaran et al. (2012) test the long-run and short-run relationships between CO_2 emissions, growth, energy use, trade, and endogenously determined structural breaks for both China and India over the period of 1971–2007. Using the autoregressive distributed lag (ARDL) approach to cointegration, the findings indicate that CO_2 emissions in China are determined by real GDP, energy consumption, and structural changes while no causal relationship is detected for India.

The financial development factor is recently included in the environmental function through the works of Jalil and Feridun (2011), Ozturk and Acaravci (2013), and Shahbaz (2013). The study of Jalil and Feridun (2011) discusses the impact of economic growth energy consumption, trade openness, and financial development on carbon emissions in China from 1953 to 2006. The findings show that financial development has no significant impact on carbon emissions in the long run, while economic growth, energy consumption, and trade openness present significant impacts on carbon emissions. In addition, Ozturk and Acaravci (2013) investigate the causal relationship between carbon emissions, GDP, energy consumption, trade openness, and financial development in Turkey over the period of 1960–2007. The findings show that an increase in trade openness leads to an increase in carbon emissions, while financial development has no significant effect on carbon emissions in the long run. Finally, Shahbaz (2013) examines the relationship between financial instability and the environmental degradation within the presence of GDP, energy consumption, and trade openness in Pakistan over the period of 1971–2009. The empirical findings indicate that the long-run relationship between variables can be detected and financial instability may increase the environmental degradation.

The inclusion of urbanization in the environmental function presents an intense debate for discussion, especially in terms of environmental and regional development. There are, however, limited works (Hossain 2011; Sharma 2011; Kasman and Duman 2015) that have documented the importance of the inclusion of urbanization in the relationship between CO_2 emissions, economic growth, energy consumption, and trade. Hossain (2011) investigates the relationship between gas emissions, energy consumption, real output, energy consumption, trade, and urbanization for newly industrialized countries over the period 1971–2007. The empirical findings show that unidirectional causality runs from real output and trade openness to CO_2, from real output to energy consumption, from trade openness to real output, from urbanization to GDP, and from trade openness to urbanization in the short run, although there is no long-run causal relationship between the analyzed variables. Sharma (2011) examines the relationship between environmental quality, energy consumption, GDP, energy consumption, openness, and urbanization for a panel of 69 countries for the years 1985–2005. The results indicate that trade openness, output per capita, and energy consumption lead to environmental degradation while CO_2 is negatively impacted by urbanization. Kasman and Duman (2015) analyze the causal linkage between gas emissions, energy consumption, real output, energy consumption, trade, and urbanization for new European Union members and candidate countries over the period 1992–2010. The study supports the evidence of the EKC hypothesis in the analyzed countries; in addition, the fully modified ordinary least squares (FMOLS) regression presents that openness and urbanization have a positive effect on the level of gas emissions. Moreover, one-way causality is detected from energy consumption, trade openness, and urbanization to CO_2; from GDP to energy consumption; from GDP, energy consumption, and urbanization to trade openness; from urbanization to GDP; and from urbanization to trade openness.

Al-Mulali et al. (2015b) and Farhani and Ozturk (2015) are the only published studies considering the effects on environmental quality of urbanization, trade, and financial development in conjunction with energy consumption and GDP. Al-Mulali et al. (2015b) analyze the long-run relationship between CO_2, energy consumption, real output, urbanization, trade openness, and financial development for a panel of 129 countries from four groups: namely low-income countries, lower middle-income countries, upper middle-income countries, and high-income countries. The results from dynamic ordinary least squares (DOLS) show that energy consumption leads to environmental degradation in all groups while financial development improves the environmental quality in the four groups. In addition, urbanization and GDP have negative and positive effects on CO_2 in the three groups, respectively. Finally, trade openness has no significant effect in one group, negative effect in two groups, and positive effect in one group. Farhani and Ozturk (2015) investigate the linkage between gas emissions, GDP, the square of GDP, energy consumption, urbanization, trade, and financial development for Tunisia over the period 1971–2012. According to the results obtained from ARDL approach, all of the analyzed variables lead to environmental degradation. In addition, the EKC hypothesis is not valid in Tunisia since the coefficients on GDP and the square of GDP are positive and statistically significant. The empirical findings of the Granger causality test indicate that long-run causality runs from output, energy consumption, financial development, openness, and urbanization to gas emissions as well as from CO_2, output, energy consumption, openness, and urbanization to financial development.

According to the above survey of the literature, the empirical studies fail to achieve unanimous conclusion regarding the effects of urbanization, financial development, and trade openness as well as the validity of the EKC hypothesis. The main reason for the discrepancy in results in the previous research comes from data characteristics, estimation techniques (cointegration methods and causality tests), and development level of the country on which a study is conducted.

Methods and data

Following the works of Al-Mulali et al. (2015b) and Farhani and Ozturk (2015), the model that we are going to use is

$$(CO_2)_t = \beta_0 + \beta_1 GDP_t + \beta_2 GDP_t^2 + \beta_3 EC_t + \beta_4 URB_t + \beta_5 TR_t + \beta_6 FD_t + e_t \qquad (1)$$

where CO_2 is the carbon dioxide emissions per capita, GDP is the real gross domestic product per capita, GDP^2 is the square of real gross domestic product per capita, EC is the energy consumption measured in kilograms of oil equivalent per capita, URB is the urbanization measured by urban population to total population, TR is the trade openness measured by total trade as a share of GDP, and FD is the financial development measured by domestic credit to private sector. The time series data are from 1960 to 2010 and obtained from the World Development Indicators (http://data.worldbank.org). We use the longest available time series data. All variables are transformed into their natural logarithmic forms.

The relationship between per capita carbon emissions, per capita real income, and the square of per capita real income, per capita energy consumption, trade openness, urbanization, and financial development in the USA is performed in four steps. First, we test the integration properties of CO_2, GDP, GDP^2, EC, TR, URB, and FD. Second, in case that they are non-stationary, the long-run relationship among the analyzed variables is investigated using the ARDL bounds testing approach of cointegration. Third, assuming that the variables are cointegrated, the short-run and long-run coefficients on real output, the square of real output, energy consumption, openness, urbanization, and financial development are estimated. Last, we test the causal relationship between the analyzed variables using the error correction-based causality models.

Unit root tests

This study uses the following unit root tests: the augmented Dickey–Fuller test due to Dickey and Fuller (1979) and the Zivot–Andrews test with one structural break due to Zivot and Andrews (2002). The augmented Dickey–Fuller (ADF) unit root test is employed to test the integration level of the variables. A well-known weakness of the ADF unit root test is its potential confusion of structural breaks in the series as evidence of non-stationarity. In other words, it may fail to reject the unit root hypothesis if the series has a structural break. For the series that is found to be I, there may be a possibility that they are, in fact, stationary around the structural break(s), I(0), but are erroneously classified as I(1). To overcome this, the Zivot–Andrews (ZA) unit root test is employed. The ZA unit root test allows for one structural break. In this test, the null hypothesis is that the series has a unit root with structural break against the alternative hypothesis that they are stationary with break. We apply the ZA test with one-time changes in the level and slope of the trend function of the series.

ARDL approach to cointegration

In case where the analyzed variables are found to be either integrated to one order or mixed order, the ARDL bounds testing procedure introduced by Pesaran et al. (2001) should be used to expose whether or not gas emissions, GDP, GDP^2, energy consumption, URB, TR, and FD are cointegrated. Therefore, this study uses the ARDL approach to cointegration which estimates the conditional ARDL model for CO_2 emission, GDP, GDP^2, energy consumption, urbanization, trade, and financial development given in Eq. 1. The ARDL method can perform well in small samples and irrespective of whether the variables are I(0), I(1), or mutually cointegrated, and it is unbiased and efficient. The ARDL approach for the model given in Eq. 1 takes the following as in Eq. 2:

$$\begin{aligned}\Delta CO_{2_t} = {} & \delta_0 + \sum_{k=1}^{n1} \delta_{1k} \Delta CO_{2_{t-k}} + \sum_{k=0}^{n2} \delta_{2k} \Delta GDP_{t-k} \\ & + \sum_{k=0}^{n3} \delta_{3k} \Delta GDP^2_{t-k} + \sum_{k=0}^{n4} \delta_{4k} \Delta EC_{t-k} \\ & + \sum_{k=0}^{n5} \delta_{5k} \Delta URB_{t-k} + \sum_{k=0}^{n6} \delta_{6k} \Delta UTR_{t-k} \\ & + \sum_{k=0}^{n7} \delta_{7k} \Delta FD_{t-k} + \gamma_1 CO_{2_{t-1}} + \gamma_2 GDP_{t-1} \\ & + \gamma_3 GDP^2_{t-1} + \gamma_4 EC_{t-1} + \gamma_5 URB_{t-1} \\ & + \gamma_6 TR_{t-1} + \gamma_7 FD_{t-1} + \mu_t \end{aligned} \quad (2)$$

where Δ denotes the first difference term and μ_t is the disturbance term assumed to have a mean value of zero and to be uncorrelated with the independent variables. The ARDL approach based on the F-statistics is employed to examine the existence of cointegration between the analyzed variables. The null hypothesis of no cointegration in Eq. 2 (H_0: $\gamma_i = 0$; $\forall$ $i=1,\ldots,7$) is tested against the alternative hypothesis of cointegration (H_1: $\gamma_i \neq 0$; $\forall$ $i=1,\ldots,7$). The critical value bounds are computed by stochastic simulations using 20,000 replications because the actual critical values for relatively small sample sizes can potentially differ from the critical values posted in Pesaran et al. (2001).

Having established the existence of a long-run relationship based on the F- test, the second step of the ARDL analysis is to estimate the long-run and the associated short-run coefficients. The long-run effects of GDP, GDP^2, EC, URB, TR, and FD on CO_2 are the estimates of $-(\gamma_2 \backslash \gamma_1)$, $-(\gamma_3 \backslash \gamma_1)$, $-(\gamma_4 \backslash \gamma_1)$, $-(\gamma_5 \backslash \gamma_1)$, $-(\gamma_6 \backslash \gamma_1)$, and $-(\gamma_7 \backslash \gamma_1)$ in Eq. 2. Furthermore, the short-run effects of each explanatory variable on the response variable are posed by the coefficient estimates of the first-differenced series in Eqs. 3–8. For instance, the short-run effects of EC and TR on gas emissions are posed by the estimates of δ_{4k} and δ_{6k} in Eq. 3. The order of the lags in the ARDL model is selected using the Akaike information criterion (AIC) ensuring that there is no evidence of residual serial correlation, functional form misspecification, non-normality, and heteroscedasticity.

Error correction-based Granger causality analysis

The ARDL method tests the existence or absence of cointegration relationship between variables, but not the direction of causality. If we do not find any evidence for cointegration among the variables, then the specification of the Granger causality test will be a vector autoregression (VAR) in first difference form. However, if we find evidence for cointegration, then we need to augment the Granger-type causality test model with a one-period lagged error correction term (ECT_{t-1}). Having found that there is a long-run relationship between the analyzed variables, the next step is to estimate the vector error correction model (VECM) given in Eqs. 3–8 by following Engle and Granger (1987):

$$\begin{aligned}\Delta CO_{2_t} = {} & \delta_0 + \sum_{k=1}^{n1} \delta_{1k} \Delta CO_{2_{t-k}} + \sum_{k=0}^{n2} \delta_{2k} \Delta GDP_{t-k} \\ & + \sum_{k=0}^{n3} \delta_{3k} \Delta GDP^2_{t-k} + \sum_{k=0}^{n4} \delta_{4k} \Delta EC_{t-k} \\ & + \sum_{k=0}^{n5} \delta_{5k} \Delta URB_{t-k} + \sum_{k=0}^{n6} \delta_{6k} \Delta TR_{t-k} \\ & + \sum_{k=0}^{n7} \delta_{7k} \Delta FD_{t-k} + \tau\, ECT_{t-1} + \mu_t \end{aligned} \quad (3)$$

$$\begin{aligned}\Delta GDP_t = {} & \delta_0 + \sum_{k=0}^{n1} \delta_{1k} \Delta CO_{2_{t-k}} + \sum_{k=1}^{n2} \delta_{2k} \Delta GDP_{t-k} \\ & + \sum_{k=0}^{n3} \delta_{3k} \Delta GDP^2_{t-k} + \sum_{k=0}^{n4} \delta_{4k} \Delta EC_{t-k} \\ & + \sum_{k=0}^{n5} \delta_{5k} \Delta URB_{t-k} + \sum_{k=0}^{n6} \delta_{6k} \Delta TR_{t-k} \\ & + \sum_{k=0}^{n7} \delta_{7k} \Delta FD_{t-k} + \tau\, ECT_{t-1} + \mu_t \end{aligned} \quad (4)$$

$$\begin{aligned}\Delta \mathrm{EC}_t = \delta_0 &+ \sum_{k=0}^{n1} \delta_{1k} \Delta \mathrm{CO}_{2_{t-k}} + \sum_{k=0}^{n2} \delta_{2k} \Delta \mathrm{GDP}_{t-k} \\ &+ \sum_{k=0}^{n3} \delta_{3k} \Delta \mathrm{GDP}^2_{t-k} + \sum_{k=1}^{n4} \delta_{4k} \Delta \mathrm{EC}_{t-k} \\ &+ \sum_{k=0}^{n5} \delta_{5k} \Delta \mathrm{URB}_{t-k} + \sum_{k=0}^{n6} \delta_{6k} \Delta \mathrm{TR}_{t-k} \\ &+ \sum_{k=0}^{n7} \delta_{7k} \Delta \mathrm{FD}_{t-k} + \tau \mathrm{ECT}_{t-1} + \mu_t \end{aligned} \quad (5)$$

$$\begin{aligned}\Delta \mathrm{URB}_t = \delta_0 &+ \sum_{k=0}^{n1} \delta_{1k} \Delta \mathrm{CO}_{2_{t-k}} + \sum_{k=0}^{n2} \delta_{2k} \Delta \mathrm{GDP}_{t-k} \\ &+ \sum_{k=0}^{n3} \delta_{3k} \Delta \mathrm{GDP}^2_{t-k} + \sum_{k=0}^{n4} \delta_{4k} \Delta \mathrm{EC}_{t-k} \\ &+ \sum_{k=1}^{n5} \delta_{5k} \Delta \mathrm{URB}_{t-k} + \sum_{k=0}^{n6} \delta_{6k} \Delta \mathrm{TR}_{t-k} \\ &+ \sum_{k=0}^{n7} \delta_{7k} \Delta \mathrm{FD}_{t-k} + \tau \mathrm{ECT}_{t-1} + \mu_t \end{aligned} \quad (6)$$

$$\begin{aligned}\Delta \mathrm{TR}_t = \delta_0 &+ \sum_{k=0}^{n1} \delta_{1k} \Delta \mathrm{CO}_{2_{t-k}} + \sum_{k=0}^{n2} \delta_{2k} \Delta \mathrm{GDP}_{t-k} \\ &+ \sum_{k=0}^{n3} \delta_{3k} \Delta \mathrm{GDP}^2_{t-k} + \sum_{k=0}^{n4} \delta_{4k} \Delta \mathrm{EC}_{t-k} \\ &+ \sum_{k=0}^{n5} \delta_{5k} \Delta \mathrm{URB}_{t-k} + \sum_{k=1}^{n6} \delta_{6k} \Delta \mathrm{TR}_{t-k} \\ &+ \sum_{k=0}^{n7} \delta_{7k} \Delta \mathrm{FD}_{t-k} + \tau \mathrm{ECT}_{t-1} + \mu_t \end{aligned} \quad (7)$$

$$\begin{aligned}\Delta \mathrm{FD}_t = \delta_0 &+ \sum_{k=0}^{n1} \delta_{1k} \Delta \mathrm{CO}_{2_{t-k}} + \sum_{k=0}^{n2} \delta_{2k} \Delta \mathrm{GDP}_{t-k} \\ &+ \sum_{k=0}^{n3} \delta_{3k} \Delta \mathrm{GDP}^2_{t-k} + \sum_{k=0}^{n4} \delta_{4k} \Delta \mathrm{EC}_{t-k} \\ &+ \sum_{k=0}^{n5} \delta_{5k} \Delta \mathrm{URB}_{t-k} + \sum_{k=0}^{n6} \delta_{6k} \Delta \mathrm{TR}_{t-k} \\ &+ \sum_{k=1}^{n7} \delta_{7k} \Delta \mathrm{FD}_{t-k} + \tau \mathrm{ECT}_{t-1} + \mu_t \end{aligned} \quad (8)$$

where τ measures the speed of adjustment to obtain an equilibrium in the event of shock(s) to the system and ECT_{t-1} is the lagged error correction mechanism attained from the long-run equilibrium relationship. The VECM allows us to capture both the short-run and long-run Granger causality. The short-run causal effects can be obtained by the Wald statistics of the lagged explanatory variables, while the Wald statistics on the coefficient of the lagged error correction term (ECT_{t-1}) indicates the significance of the long-run causal effect.

Empirical results

Unit root test

This study applies two different unit root tests to the time series data on carbon dioxide (CO_2) emission, real output (GDP), the square of real output (GDP^2), energy consumption (EC), urbanization (URB), trade openness (TR), and financial development (FD) in order to exploit the integration properties of the analyzed variables. As mentioned earlier, the ARDL approach to cointegration is a reliable method only if the time series is either I(0) or I(1). The results are given in Table 1.

The conventional augmented Dickey–Fuller (ADF) unit root test indicates that urbanization is stationary at level; however, CO_2, GDP, energy consumption, trade openness, and financial development have unit root at levels but become stationary in their first differences. Thereafter, the Zivot–Andrews (ZA) unit root test with one structural break is used to confirm the findings of the ADF unit root test. According to the results obtained from the ZA unit root test, only urbanization does not have a unit root at level; on the other hand, gas emissions, GDP, EC, TR, and FD are not stationary at levels but become stationary in their first differences. Both the ADF unit root test and the ZA unit root test reach the same conclusion. In short, urbanization is determined to be I(0) while CO_2, GDP, energy consumption, trade, and financial development are determined to be I(1). Because neither of the analyzed variables I(k) where $k>1$, we can proceed to the bounds testing for cointegration.

ARDL approach to cointegration

Given that carbon dioxide emissions, real output, the square of real output, energy consumption, urbanization, trade, and financial development are either I(0) or I(1), Eq. 2 is estimated based on the ARDL approach to cointegration. Table 2 represents the calculated F-statistic and lower and upper critical bounds for 5 % level. The critical value bounds in Table 2 are computed by stochastic simulations using 20,000 replications because the actual critical values for relatively small sample sizes can potentially differ from the critical values posted in Pesaran et al. (2001). Regarding the estimated model, $f(CO_2/GDP, GDP^2, EC, URB, TR, FD)$, in which gas emissions are the response variable while GDP, the square of GDP, energy consumption, urbanization, trade, and financial development are the explanatory variables, the null hypothesis of no cointegration can be rejected in favor of the alternative hypothesis of cointegration at 5 % level of significance because the calculated F-statistic is far greater than, I(1), the 5 % upper critical bound. Baek (2015) suggests that the negative and statistically significant lagged error correction term (ECT_{t-1}) can be used as an alternative method to pin down the cointegration relationship between the variables. As shown in Table 3, the coefficient estimate of ECT_{t-1} is −0.76, which is negative and statistically significant at 1 % level. Therefore, we can claim the existence of cointegration and, thus, the long-run relationship between CO_2, GDP, GDP^2, EC, URB, TR, and FD. Henceforth, the estimation results that we estimate in the next section are assumed to be economically meaningful, accurate, and consistent.

Table 1 Unit root analysis

	CO_2	GDP (GDP^2)	EC	URB	TR	FD
ADF-test						
Level	−3.20	−2.81	−3.17	−3.58[b]	−2.30	−2.32
Δ	−4.71[a]	−5.28[a]	−4.48[a]	–	−6.53[a]	−8.16[a]
ZA-test						
Level	−3.62 (1969)	−4.53 (2005)	−3.71 (1979)	−5.04[c] (1971)	−5.15[a] (1973)	−4.61 (1983)
Δ	−6.31[a] (1983)	−6.01[a] (1983)	−6.28[a] (1984)	–	−7.89[a] (1975)	−9.82[a] (1982)
Decision	I(1)	I(1)	I(1)	I(0)	I(1)	I(1)

Δ is the first difference term. Years in the parenthesis are the structural break dates. Lag lengths are selected based on the Akaike information criterion (AIC)

[a] Statistical significance at 1 % levels

[b] Statistical significance at 5 % levels

[c] Statistical significance at 10 % levels

Short-run and long-run estimates

The short-run and long-run estimates of GDP, the square of GDP, energy consumption, trade, urbanization, and financial development are reported in Table 3. Moreover, the coefficient estimates of the analyzed variables are economically equal to the elasticity of CO_2 with respect to GDP, GDP^2, EC, TR, URB, and FD, respectively, because the time series data are transformed into their logarithmic forms. Both the short-run and the long-run elasticity of carbon dioxide emissions with respective to GDP are negative and statistically significant, while the coefficient estimates of the square of GDP are statistically significant and positive both in the short run and long run. In other words, the short-run and long-run estimates of GDP are −1.63 and −2.13, respectively, and the short-run and long-run coefficient estimates of the square of GDP are +0.18 and +0.22, respectively. In the existence of the EKC hypothesis, the effect of GDP and GDP^2 on carbon dioxide emissions is expected to be positive and negative, respectively. Because it is not the case for the analyzed variables, the EKC hypothesis is not present in the USA. On the other hand, there is a U-shaped relationship between the level of income and gas emissions. Therefore, the increase in the level of GDP leads to environmental improvements until a certain level but then the increase

Table 2 Cointegration test results

Estimated model	F-statistic	5 % critical values	
		I(0)	I(1)
$f(CO_2/GDP, GDP^2, EC, URB, TR, FD)$	9.87[a]	2.73	4.09

[a] Statistical significance at 5 % level

Table 3 Estimated coefficients from ARDL model

Regressors	Coefficient	t ratio	
(A) Long-run estimates (dependent variable CO_2)			
GDP	−2.13[b]	−2.49	
GDP^2	0.22[b]	2.23	
EC	1.16[a]	32.17	
URB	0.43[c]	1.71	
TR	−0.08[a]	−4.26	
FD	0.04	0.80	
Constant	1.04	0.51	
(B) Short-run estimates (dependent variable ΔCO_2)			
ΔGDP	−1.63[b]	−2.41	
ΔGDP^2	0.18[b]	2.37	
ΔEC	0.89[a]	14.76	
ΔURB	0.33[c]	1.71	
ΔTR	0.02	0.83	
ΔFD	0.03	0.81	
ECT_{t-1}	−0.76[a]	−15.62	
Diagnostic tests			
Serial correlation			(0.87)
Functional form			(0.63)
Normality			(0.33)
Heteroscedasticity			(0.18)
R^2			0.96
DW			1.94
F - test			129.8[a]

The numbers in parenthesis under diagnostic tests are the p - values. DW is the Durbin–Watson test statistic. The proper lag length of the estimated ARDL model is (1,0,1,0,0,1,0) and selected based on AIC

[a] Statistical significance at 1 % level

[b] Statistical significance at 5 % level

[c] Statistical significance at 10 % level

Table 4 Granger causality analysis

Dependent variable	Short-run analysis						Long-run analysis
	ΔCO_2	ΔGDP (ΔGDP^2)	ΔEC	ΔURB	ΔTR	ΔFD	ECT_{t-1}
ΔCO_2	–	5.84^b	217.9^a	2.94^c	0.70	0.65	244.1^a
ΔGDP (ΔGDP^2)	5.91^c	–	3.78	7.39^b	9.06^a	6.60^b	2.45
ΔEC	152.6^a	7.29^a	–	0.78	0.11	0.39	18.12^a
ΔURB	22.14^a	14.40^a	3.86	–	5.07^c	0.63	11.98^a
ΔTR	0.69	10.79^a	0.03	3.50^c	–	5.79^c	0.68
ΔFD	0.11	2.65	0.57	3.81^c	7.90^a	–	24.34^a

Values are from Wald test based on the chi-square distribution

[a] Statistical significance at 1 % level

[b] Statistical significance at 5 % level

[c] Statistical significance at 10 % level

in the level of income causes environmental degradation. This finding is consistent with Chandran and Tang (2013), Baek (2015), Farhani and Ozturk (2015), and Al-Mulali et al. (2015a).

The results in Table 3 show that energy consumption has positive impact on gas emissions in the USA both in the short run and long run. More precisely, a 1 % increase in EC stimulates CO_2 by 0.89 and 1.16 % in the short run and long run, respectively, at 1 % level of significance. This outcome is line with that of most studies in the literature such as Ang (2007, 2009), Halicioglu (2009), Jalil and Feridun (2011), Kanjilal and Ghosh (2013), Ozturk and Acaravci (2013), Shahbaz et al. (2013a, b), Al-Mulali et al. (2015a, b), Kasman and Duman (2015), and Farhani and Ozturk (2015). The long-run and the short-run elasticity estimates of CO_2 with respect to urbanization are expected to be positive in the developed countries referring to Hossain (2011) and Farhani and Ozturk (2015). In more detail, a 1 % rise in URB increases gas emissions by 0.33 and 0.43 % in the short run and long run, respectively, at 10 % level of significance. This is consistent with the study of Kasman and Duman (2015) and Farhani and Ozturk (2015). According to Halicioglu (2009), the expected sign of the coefficient on trade is ambiguous since it depends on development stage of an economy. In addition, the effect of trade on gas emissions is usually negative in the developed countries. As shown in Table 4, a 1 % increase in trade openness leads to statistically significant decrease in CO_2 by 0.08 % in the long run at 1 % level of significance; however, the short-run elasticity estimate of gas emissions with respect to trade is not statistically significant at 10 % level of significance. The short-run and long-run findings are in line with those found by Halicioglu (2009), Jalil and Mahmud (2009), and Al-mulali et al. (2015b). As it is consistent with the studies of Jalil and Feridun (2011) and Ozturk and Acaravci (2013) which show that financial development has no statistically significant impact on environmental quality, Table 3 indicates that the short-run and long-run elasticity estimates of CO_2 with respect to FD are not statistically significant for the USA at 10 % level of significance.

The estimated model also passes several diagnostic tests as given in Table 3. Serial correlation test is based on the Lagrange Multiplier test of residual, functional form is based on Ramsey's RESET test using the square of the fitted values, normality test is based on the test of Skewness and Kurtosis of

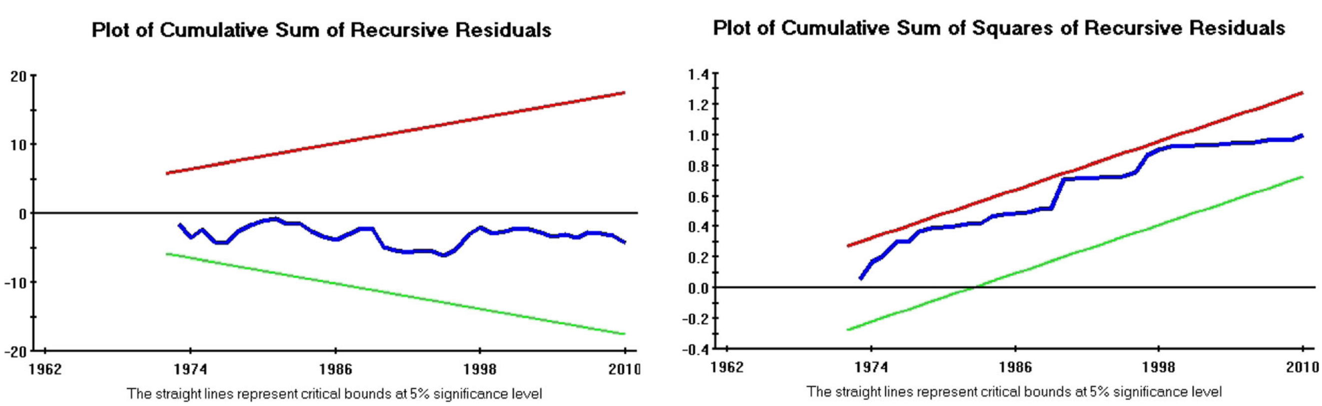

Fig. 1 CUSUM and CUSUMQ stability tests

residuals, and heteroscedasticity test is based on the regression of squared residuals on squared fitted values. We cannot reject the null hypotheses that there is no serial correlation, no heteroscedasticity, and no functional form misspecification and normality of disturbances at 10 % significance level because the related p values are far greater than 0.10. In addition, we have no evidence on serial correlation, heteroscedasticity, misspecification, and non-normality. Furthermore, the high value of R^2 (0.96) implies that the adjustment of the model in Eq. 2 is fairly perfect. Because the Durbin–Watson statistic is close to 2, we have enough evidence to reject the null hypothesis of autocorrelation between residuals in the estimated model. The statistically significant F- test confirms the joint significance of explanatory variables in the ARDL model. The last identification related to the goodness of fit of the model is stability tests. For this purpose, we perform cumulative sum (CUSUM) and cumulative sum of squares (CUSUMQ) tests. As seen in Fig. 1, the estimated parameters are stable over time since the plot of CUSUM and CUSUMQ test statistics fall within the 5 % boundaries.

Granger causality test

In light of the evidence of cointegration relationship among the analyzed variables, it is an interest for researchers to perform the Granger causality test so as to pin down appropriate economic policies, environmental policies, and energy strategies by understanding the directions of causality between CO_2, GDP (GDP^2), EC, TR, URB, and FD. Henceforth, the Granger causality in the vector error correction mechanism is used to exploit the directions of causality between the aforementioned variables as well as to decompose the directions of causality into the short run and long-run effects.

The results obtained from the VECM Granger causality test are reported in Table 4. In the short run, there is bidirectional causality between (1) CO_2 and GDP, (2) gas emissions and energy consumption, (3) carbon dioxide emissions and urbanization, (4) GDP and urbanization, (5) trade and urbanization, (6) financial development and trade, and (7) income and trade openness. In addition, we have enough evidence to support one-way causality running (1) from GDP to energy consumption, (2) from financial development to income, and (3) from urbanization to financial development. Lastly, no causality is determined between (1) CO_2 and trade openness, (2) carbon dioxide emissions and FD, (3) energy consumption and urbanization, (4) EC and trade, and (5) energy consumption and FD. In the long run, there is an evidence of four causal relationships, namely (1) from GDP, EC, URB, TR, and FD to CO_2; (2) from gas emissions, income, trade, urbanization, and financial development to energy consumption; (3) from CO_2, GDP, EC, TR, and FD to URB; and (4) from carbon dioxide emissions, income, energy consumption, TR, and URB to financial development.

These findings are consistent with those found in the preceding section. More precisely, energy consumption is found to have impact on environmental degradation both in the short run and long run. In addition, an increase in the level of energy use does not cause income. Thus, the USA may decrease energy consumption without harming the GDP for the sake of environmental quality. Furthermore, the government may encourage and financially support the institutions, universities, and researchers to propose project on increasing the efficiency of energy and on the application of the methods of environmental protection. As expected, income (the square of income) has causal relationship with gas emissions. This also supports the presence of the U-shaped relationship between CO_2 and GDP in the USA. Although trade openness and financial development do not cause the Granger environmental quality in the short run, TR and FD have impact on it in the long run. Also, urbanization is found to be a cause of gas emissions and income. Moreover, trade and financial development influence GDP as well. Henceforth, the US government should take into account the importance of trade openness, urbanization, and financial development in controlling for the level of GDP and pollution.

Conclusions

This study examines the relationship between carbon dioxide emissions, energy consumption, real output, the square of real output, trade openness, urbanization, and financial development in the USA for the period 1960–2010. To analyze this relationship, we use unit root tests to find out the stationarity properties of the analyzed variables, the ARDL bounds testing approach to explore the possible cointegration between the variables, and short-run and long-run estimates, Granger causality test based on VECM, to reveal the short-run and long-run causal relationships between analyzed variables.

According to the results obtained from augmented Dickey–Fuller and Zivot–Andrews unit root test, we claim that urbanization is stationary at level and CO_2, energy consumption, real output, the square of real output, trade openness, and financial development are stationary at first differences. Then, the ARDL approach to cointegration test indicates that the analyzed variables are cointegrated at 5 % level of significance. The short-run and long-run estimates show that energy consumption is the main cause of CO_2 emissions in the USA. In addition, urbanization has positive impact on gas emissions. Furthermore, the estimates of real output and the square of real output suggest that there is strong evidence against the existence of an EKC-type relationship in the USA.

Last, the Granger causality analysis presents that there is strong causal relationship between gas emissions and real output, energy consumption, and urbanization both in the short run and long run. By putting together the results from the short-run and long-run estimates, and Granger causality tests, the US government should take into account the importance of trade openness, urbanization, and financial development in controlling for the levels of GDP and pollution. While the above analysis provides interesting insights, it should be noted that the development of efficient energy policies likely contributes to lower CO_2 emissions while preserving real GDP. A promising extension of this work would be to consider the energy supply, rural development, and other environmental variables for the case of the USA.

References

Akbostancı E, Türüt-Aşık S, Tunç G (2009) The relationship between income and environment in Turkey: is there an environmental Kuznets curve? Energy Policy 37(3):861–867

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

Alkhathlan K, Javid M (2013) Energy consumption, carbon emissions and economic growth in Saudi Arabia: an aggregate and disaggregate analysis. Energy Policy 62:1525–1532

Al-mulali U, Lee JY (2013) Estimating the impact of the financial development on energy consumption: evidence from the GCC (Gulf Cooperation Council) countries. Energy 60:215–221

Al-mulali U, Sheau-Ting L (2014) Econometric analysis of trade, exports, imports, energy consumption and CO2 emission in six regions. Renew Sust Energ Rev 33:484–498

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

Al-mulali U, Tang CF, Ozturk I (2015b) Does financial development reduce environmental degradation? Evidence from a panel study of 129 countries. Environ Sci Pollut Res 1–10

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

Ang JB (2007) CO2 emissions, energy consumption, and output in France. Energy Policy 35(10):4772–4778

Ang JB (2009) CO2 emissions, research and technology transfer in China. Ecol Econ 68(10):2658–2665

Aslan A (2014) Electricity consumption, labor force and GDP in Turkey: evidence from multivariate Granger causality. Energy Sources Part B: Econ Plan Pol 9(2):174–182

Aslan A, Apergis N, Topcu M (2014) Banking development and energy consumption: evidence from a panel of Middle Eastern countries. Energy 72:427–433

Baek J (2015) Environmental Kuznets curve for CO2 emissions: the case of Arctic countries. Energy Econ 50:13–17

Bastola U, Sapkota P (2015) Relationships among energy consumption, pollution emission, and economic growth in Nepal. Energy 80:254–262

Boutabba MA (2014) The impact of financial development, income, energy and trade on carbon emissions: evidence from the Indian economy. Econ Model 40:33–41

Chandran VGR, Tang CF (2013) The impacts of transport energy consumption, foreign direct investment and income on CO2 emissions in ASEAN-5 economies. Renew Sust Energ Rev 24:445–453

Dickey DA, Fuller WA (1979) Distribution of the estimators for autoregressive time series with a unit root. J Am Stat Assoc 74(366a):427–431

Dogan E (2014) Energy consumption and economic growth: evidence from low-income countries in Sub-Saharan Africa. Int J Energy Econ Pol 4(2):154–162

Dogan E (2015a) Revisiting the relationship between natural gas consumption and economic growth in Turkey. Energy Sources Part B: Econ Plan Pol 10(4):361–370

Dogan E (2015b) The relationship between economic growth and electricity consumption from renewable and non-renewable sources: a study of Turkey. Renew Sustain Energy Rev 52:534–546

Engle RF, Granger CW (1987) Co-integration and error correction: representation, estimation, and testing. Econometrica: J Econo Soc 251–276

Farhani S, Ozturk I (2015) Causal relationship between CO2 emissions, real GDP, energy consumption, financial development, trade openness, and urbanization in Tunisia. Environ Sci Pollut Res 1–14

Farhani S, Chaibi A, Rault C (2014) CO2 emissions, output, energy consumption, and trade in Tunisia. Econ Model 38:426–434

Fodha M, Zaghdoud O (2010) Economic growth and pollutant emissions in Tunisia: an empirical analysis of the environmental Kuznets curve. Energy Policy 38(2):1150–1156

Halicioglu F (2009) An econometric study of CO2 emissions, energy consumption, income and foreign trade in Turkey. Energy Policy 37(3):1156–1164

Hamit-Haggar M (2012) Greenhouse gas emissions, energy consumption and economic growth: a panel cointegration analysis from Canadian industrial sector perspective. Energy Econ 34(1):358–364

Hossain MS (2011) Panel estimation for CO2 emissions, energy consumption, economic growth, trade openness and urbanization of newly industrialized countries. Energy Policy 39(11):6991–6999

Islam F, Shahbaz M, Ahmed AU, Alam MM (2013) Financial development and energy consumption nexus in Malaysia: a multivariate time series analysis. Econ Model 30:435–441

Iwata H, Okada K, Samreth S (2010) Empirical study on the environmental Kuznets curve for CO2 in France: the role of nuclear energy. Energy Policy 38(8):4057–4063

Jalil A, Feridun M (2011) The impact of growth, energy and financial development on the environment in China: a cointegration analysis. Energy Econ 33(2):284–291

Jalil A, Mahmud SF (2009) Environment Kuznets curve for CO2 emissions: a cointegration analysis for China. Energy Policy 37(12): 5167–5172

Jayanthakumaran K, Verma R, Liu Y (2012) CO2 emissions, energy consumption, trade and income: a comparative analysis of China and India. Energy Policy 42:450–460

Kanjilal K, Ghosh S (2013) Environmental Kuznet's curve for India: evidence from tests for cointegration with unknown structural breaks. Energy Policy 56:509–515

Kasman A, Duman YS (2015) CO2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: a panel data analysis. Econ Model 44:97–103

Komal R, Abbas F (2015) Linking financial development, economic growth and energy consumption in Pakistan. Renew Sust Energ Rev 44:211–220

Lau LS, Choong CK, Eng YK (2014) Investigation of the environmental Kuznets curve for carbon emissions in Malaysia: do foreign direct investment and trade matter? Energy Policy 68:490–497

Lee CC, Lee JD (2009) Income and CO2 emissions: evidence from panel unit root and cointegration tests. Energy Policy 37(2):413–423

Martínez-Zarzoso I, Maruotti A (2011) The impact of urbanization on CO2 emissions: evidence from developing countries. Ecol Econ 70(7):1344–1353

Nasir M, Rehman FU (2011) Environmental Kuznets curve for carbon emissions in Pakistan: an empirical investigation. Energy Policy 39(3):1857–1864

Omri A, Daly S, Rault C, Chaibi A (2015) Financial development, environmental quality, trade and economic growth: what causes what in MENA countries. Energy Econ 48:242–252

Osabuohien ES, Efobi UR, Gitau CMW (2014) Beyond the environmental Kuznets Curve in Africa: evidence from panel cointegration. J Environ Pol Plan 16(4):517–538

Ozturk I (2010) A literature survey on energy–growth nexus. Energy Policy 38(1):340–349

Ozturk I, Acaravci A (2010) CO2 emissions, energy consumption and economic growth in Turkey. Renew Sust Energ Rev 14(9):3220–3225

Ozturk I, Acaravci A (2013) The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. Energy Econ 36:262–267

Pesaran MH, Shin Y, Smith RJ (2001) Bounds testing approaches to the analysis of level relationships. J Appl Econ 16(3):289–326

Saboori B, Sulaiman J, Mohd S (2012) Economic growth and CO2 emissions in Malaysia: a cointegration analysis of the environmental Kuznets curve. Energy Policy 51:184–191

Sadorsky P (2010) The impact of financial development on energy consumption in emerging economies. Energy Policy 38(5):2528–2535

Salahuddin M, Gow J (2014) Economic growth, energy consumption and CO2 emissions in Gulf Cooperation Council countries. Energy 73: 44–58

Shahbaz M (2013) Does financial instability increase environmental degradation? Fresh evidence from Pakistan. Econ Model 33:537–544

Shahbaz M, Lean HH (2012) The dynamics of electricity consumption and economic growth: a revisit study of their causality in Pakistan. Energy 39(1):146–153

Shahbaz M, Tiwari AK, Nasir M (2013a) The effects of financial development, economic growth, coal consumption and trade openness on CO2 emissions in South Africa. Energy Policy 61:1452–1459

Shahbaz M, Hye QMA, Tiwari AK, Leitão NC (2013b) Economic growth, energy consumption, financial development, international trade and CO2 emissions in Indonesia. Renew Sust Energ Rev 25: 109–121

Shahbaz M, Loganathan N, Zeshan M, Zaman K (2015) Does renewable energy consumption add in economic growth? An application of auto-regressive distributed lag model in Pakistan. Renew Sust Energ Rev 44:576–585

Sharma SS (2011) Determinants of carbon dioxide emissions: empirical evidence from 69 countries. Appl Energy 88(1):376–382

Skaza JS, Blais BS (2013) The relationship between economic growth and environmental degradation: exploring models and questioning the existence of an environmental Kuznets curve. Cent Glob Econ Stud Bryant Univ Work Pap (2013-05)

Smyth R, Narayan PK (2014) Applied econometrics and implications for energy economics research. Energy Econ

Soytas U, Sari R (2003) Energy consumption and GDP: causality relationship in G-7 countries and emerging markets. Energy Econ 25(1): 33–37

Soytas U, Sari R (2009) Energy consumption, economic growth, and carbon emissions: challenges faced by an EU candidate member. Ecol Econ 68(6):1667–1675

Soytas U, Sari R, Ewing BT (2007) Energy consumption, income, and carbon emissions in the United States. Ecol Econ 62(3):482–489

Tamazian A, Rao BB (2010) Do economic, financial and institutional developments matter for environmental degradation? Evidence from transitional economies. Energy Econ 32(1):137–145

Tamazian A, Chousa JP, Vadlamannati KC (2009) Does higher economic and financial development lead to environmental degradation: evidence from BRIC countries. Energy Policy 37(1):246–253

Tang CF, Tan BW (2014) The linkages among energy consumption, economic growth, relative price, foreign direct investment, and financial development in Malaysia. Qual Quant 48(2):781–797

Tiwari AK, Shahbaz M, Hye QMA (2013) The environmental Kuznets curve and the role of coal consumption in India: cointegration and causality analysis in an open economy. Renew Sust Energ Rev 18: 519–527

Wang SS, Zhou DQ, Zhou P, Wang QW (2011) CO2 emissions, energy consumption and economic growth in China: a panel data analysis. Energy Policy 39(9):4870–4875

Wolde-Rufael Y (2005) Energy demand and economic growth: the African experience. J Policy Model 27(8):891–903

Yavuz N (2014) CO2 emission, energy consumption, and economic growth for turkey: evidence from a cointegration test with a structural break. Energy Sources Part B: Econ Plan Pol 9(3):229–235

Zhang YJ (2011) The impact of financial development on carbon emissions: an empirical analysis in China. Energy Policy 39(4):2197–2203

Zhang XP, Cheng XM (2009) Energy consumption, carbon emissions, and economic growth in China. Ecol Econ 68(10):2706–2712

Ziaei SM (2015) Effects of financial development indicators on energy consumption and CO2 emission of European, East Asian and Oceania countries. Renew Sust Energ Rev 42:752–759

Zivot E, Andrews DWK (2002) Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis. J Bus Econ Stat 20(1):25–44