Environmental Science and Pollution Research (2021) 28:38563–38572
https://doi.org/10.1007/s11356-021-13476-7

RESEARCH ARTICLE

Does the pollution haven hypothesis prevail in Turkey? Empirical evidence from nonlinear smooth transition models

Umit Bulut[1] · Gulbahar Ucler[1] · Roula Inglesi-Lotz[2]

Received: 4 January 2021 / Accepted: 11 March 2021 / Published online: 18 March 2021

Abstract

The pollution haven hypo thesis (PHH) postulates that foreign direct investment (FDI) inflows can increase environmental deterioration in developing countries as multinational firms tend to transfer their dirty industries to these countries. Turkey, as a developing economy, has witnessed intense FDI inflows over the last decades. Within this scope, the goal of this paper is to examine whether the pollution haven hypothesis (PHH) prevails in Turkey within the scope of the environmental Kuznets curve (EKC) hypothesis over the period 1970–2016. To that end, the paper employs unit root and cointegration methods based on the nonlinear smooth transition models. The empirical findings of the paper indicate that both hypotheses are valid in Turkey. The findings also imply that environmental quality in Turkey is negatively related to electricity production from renewable energy sources.

Keywords Foreign direct investment · Pollution haven hypothesis · Environmental Kuznets curve · Renewable energy · Nonlinear smooth transition models

Introduction

The literature has undoubtedly confirmed that one of the greatest obstacles for economic development is the insufficient capital accumulation for developing countries. Within this scope, foreign direct investment (FDI) can play a key role in the development process of these countries. FDI can be described as the expansion or the creation of firms which operate across national boundaries (Graham and Krugman 1993). The globalization trend that began in the 1980s accelerated the mobility of capital and FDI inflows towards economies (Akbas et al. 2013). Hence, FDI began to play an important role in financing current account deficits for countries with current account imbalances (Graham and Krugman 1993). On one hand, in addition to helping countries finance the current account deficits, FDI can (i) create new jobs and lower the unemployment rate, (ii) contribute to economic growth by improving productivity, (iii) close the technology gap between low-income and high-income economies, (iv) improve managerial skills, (v) create positive externalities, and (vi) develop countries' export markets (World Bank 1993; Anyanwu 2006; Acharrya 2009; Shahbaz et al. 2015). On the other hand, the influence of FDI inflows on environmental deterioration has been discussed in the environmental economics literature within the scope of the pollution haven hypothesis (PHH) over the past decades.

The PHH assumes that when advanced economies that are industrialized aim to expand and transfer their production capacity outside their physical borders, they do so after evaluating and choosing the most cost-effective country with regard to natural resources, labour, land, and tax system. The PHH focuses on the negative impact of FDI on environmental quality. The PHH postulates that multinational firms may be fascinated by weak environmental regulations in developing economies as there exist strict environmental regulations in developed economies stemming from the high environmental concerns in these countries (Akbostanci et al. 2007). Therefore, dirty industries can migrate from developed economies to developing

Responsible Editor: Philipp Gariguess

✉ Umit Bulut
ubulut@ahievran.edu.tr

[1] Department of Economics, Kirsehir Ahi Evran University, Kirsehir, Turkey

[2] Department of Economics, University of Pretoria, Pretoria, South Africa

economies (Baek 2016; Mert and Caglar 2020; Sarkodie and Strezov 2019a). Because of this migration, developing economies can be exposed to environmental destruction according to the PHH (Baek 2016; Zhang and Zhou 2016). Hence, FDI inflows can negatively affect the sustainable development process of a developing economy. On the contrary, some studies in the literature stress that multinational firms have more modern and environmental friendly technologies compared to the domestic firms (Jalil and Feridun 2011; Shahbaz et al. 2015). Hence, FDI may decrease environmental pollution in a country since multinational firms bring their cleaner technologies to the host country (Seker et al. 2015; Mert and Boluk 2016). This view is called the pollution halo hypothesis in the literature.

One can observe from the World Bank (2020) data that the Turkish economy has experienced large current account imbalances except for a few years during the period 1974–2019. Additionally, the magnitude of these imbalances increased in the last two decades. For instance, while the ratio of the current account balance to GDP was −1.69% over the period 1974–2000 on average, this ratio reached –3.65% during the period 2001–2019. Hence, the current account balance problem of the Turkish economy increased in the last years. On the other hand, the FDI inflows towards the Turkish economy dramatically increased in the last years. For instance, as per the World Bank (2020) data, while the total FDI inflows to the Turkish economy were 11 billion USD over the period 1974–2000, this figure was 222.7 billion USD during the period 2001–2019. Hence, based on these figures, one can make two implications for Turkey about the trend of FDI inflows towards the Turkish economy. First, FDI inflows played an important role in financing the current account deficits of the Turkish economy. Second, intensive FDI inflows to the Turkish economy may increase environmental deterioration in Turkey, implying the PHH may prevail for Turkey.

Starting from this point of view, this paper investigates whether the PHH prevails in Turkey using annual data over the period 1970–2016. The paper does so within an environmental Kuznets curve (EKC) framework that hypothesizes an inverted U-shaped relationship between income level and environmental deterioration. Additionally, the paper inspects the influence of renewable energy on the environmental destruction as renewables are considered as clean and eco-friendly energy sources. One can observe from the existing environmental economics literature that the previous papers make a very strong assumption while examining the validity of the PHH for Turkey. Accordingly, all of them employ linear time series methods without investigating the possible nonlinearity in the relationship between variables in the model. However, as Enders (2015) stresses, many time series variables exhibit nonlinear behaviours. Besides, the transition between regimes in a time series model may be smooth rather than sharp. Put differently, in a nonlinear model, the parameters may change slowly. These models are called smooth transition models and are considered as more realistic for economic data sets. Therefore, this paper contributes to the existing environmental economics literature. Accordingly, the distinctive feature of this paper is that it is the first paper that examines the validity of the PHH for Turkey by performing nonlinear time series estimation methods. Put differently, the key strength of the paper is that it employs nonlinear methods to examine the PHH for Turkey. While doing that, the paper employs smooth transition models to produce more efficient and unbiased outputs about the validity of the PHH in Turkey.

The rest of the paper is structured as follows: the second section gives the literature review. Model, data, and hypotheses are presented in the third section. The fourth section introduces the methods employed in the paper. Empirical findings are reported in the fifth section. The sixth section concludes the paper with a summary of the main findings and some implications.

Brief literature review

The empirical literature on the PHH estimation for Turkey is illustrated in Table 1. As is seen from the table, some papers, namely, Seker et al. (2015), Gokmenoglu and Taspinar (2016), Kocak and Sarkgunesi (2018), and Terzi and Pata (2020), find evidence in favour of the PHH in Turkey. Besides, some others explore that the PHH does not prevail for the Turkish economy (Mutafoglu 2012; Destek and Okumus 2019; Bulut 2020; Mert and Caglar 2020). When it comes to testing the EKC hypothesis, four out of eight papers consider the EKC hypothesis for Turkey (Seker et al. 2015; Gokmenoglu and Taspinar 2016; Kocak and Sarkgunesi 2018; Bulut 2020), and all of them confirm the validity of the EKC hypothesis for Turkey.

Additionally, only Bulut (2020) examines the impact of renewable energy on environmental deterioration within the scope of the PHH. He finds that renewable energy decreases environmental destruction, meaning renewable energy has positive impacts on environmental quality in Turkey. Finally, as was denoted in the previous section, all these papers perform linear estimation methods and do not take nonlinear relationships into account in the empirical analysis. Hence, a considerable contribution of the present paper to the extant environmental economics literature is that it is the first paper which considers nonlinear

Table 1 Empirical literature on the PHH estimation for Turkey

Author(s)	Period	Method	EKC estimation	RE investigation	Findings
Mutafoglu (2012)	1987–2009	Johansen cointegration/Granger causality	No	No	No PHH
Seker et al. (2015)	1974–2010	ARDL cointegration	Yes	No	PHH/EKC
Gokmenoglu and Taspinar (2016)	1974–2010	ARDL cointegration	Yes	No	PHH/EKC
Kocak and Sarkgunesi (2018)	1974–2013	DOLS estimator	Yes	No	PHH/EKC
Destek and Okumus (2019)	1982–2013	CCEMG estimator	No	No	No PHH
Bulut (2020)	1970–2016	ARDL cointegration, DOLS estimator	Yes	Yes	No PHH/EKC RE decreases environmental pollution.
Mert and Caglar (2020)	1974–2018	Hidden cointegration Asymmetric causality	No	No	No PHH
Terzi and Pata (2020)	1974–2011	Toda-Yamamoto Granger causality	No	No	PHH

PHH, pollution haven hypothesis; *EKC*, environmental Kuznets curve; *ARDL*, autoregressive distributed lag; *DOLS*, dynamic ordinary least squares; *RE*, renewable energy

relationships between FDI and environmental deterioration for Turkey.

Model, data, and hypotheses

Model and data set

Based on the previous discussion, this paper follows a nonlinear time series analysis to examine whether the PHH prevails in Turkey. The paper uses CO_2 emissions as the indicator of the environmental destruction. Accordingly, the paper considers the following empirical model:

$$\ln CO_{2t} = \alpha_0 + \alpha_1 \ln Y_t + \alpha_2 (\ln Y_t)^2 + \alpha_3 \ln FDI_t + \alpha_4 \ln RE_t + \varepsilon_t \quad (1)$$

where CO_2, Y, Y^2, FDI, RE, and ε indicate CO_2 emissions per capita (metric tons), GDP per capita (constant 2010 USD), the square of GDP per capita, foreign direct investments (net inflows, current USD), electricity production from renewable energy sources (GWh), and the error term, respectively (all variables are in their natural logarithms denoted by ln). The data are annual and cover the period from 1970 to 2016. While data for CO_2 emissions, GDP, and FDI are obtained from the World Development Indicators (WDI) World Bank (2020), data for renewable energy are sourced from the Turkish Statistical Institute (2020) (hereafter TSI).

Graphical observations for the variables are illustrated in Fig. 1. It can be observed from the figure that all series tend to increase over the sample period. The figure also exhibits that (i) environmental deterioration proxied by CO_2 emissions has increased in Turkey; (ii) Turkey has experienced many economic crises in certain years, such as 1978–1980, 1989, 1991, 1994, 1999, 2001, and 2008–2009; (iii) FDI inflows towards the Turkish economy have increased since 1980, when Turkey began to adopt liberal economic policies; and (iv) Turkey has utilized renewable energy sources further to produce electricity over time. Overall, the graphical analysis provides evidence that the series may not be stationary at level, implying time series properties, such as unit root and cointegration, of the variables should be investigated.

Hypothesis development

The main purpose of this paper is to examine whether the PHH is valid for the Turkish economy. If $\alpha_3 > 0$ in Eq. 1, the PHH prevails in Turkey. Hence, we first propose the following hypothesis:

> **H1.** The FDI inflows towards the Turkish economy increase CO_2 emissions in Turkey, ceteris paribus.

The paper studies the first hypothesis within the theoretical framework of the EKC for Turkey. Grossman and Krueger

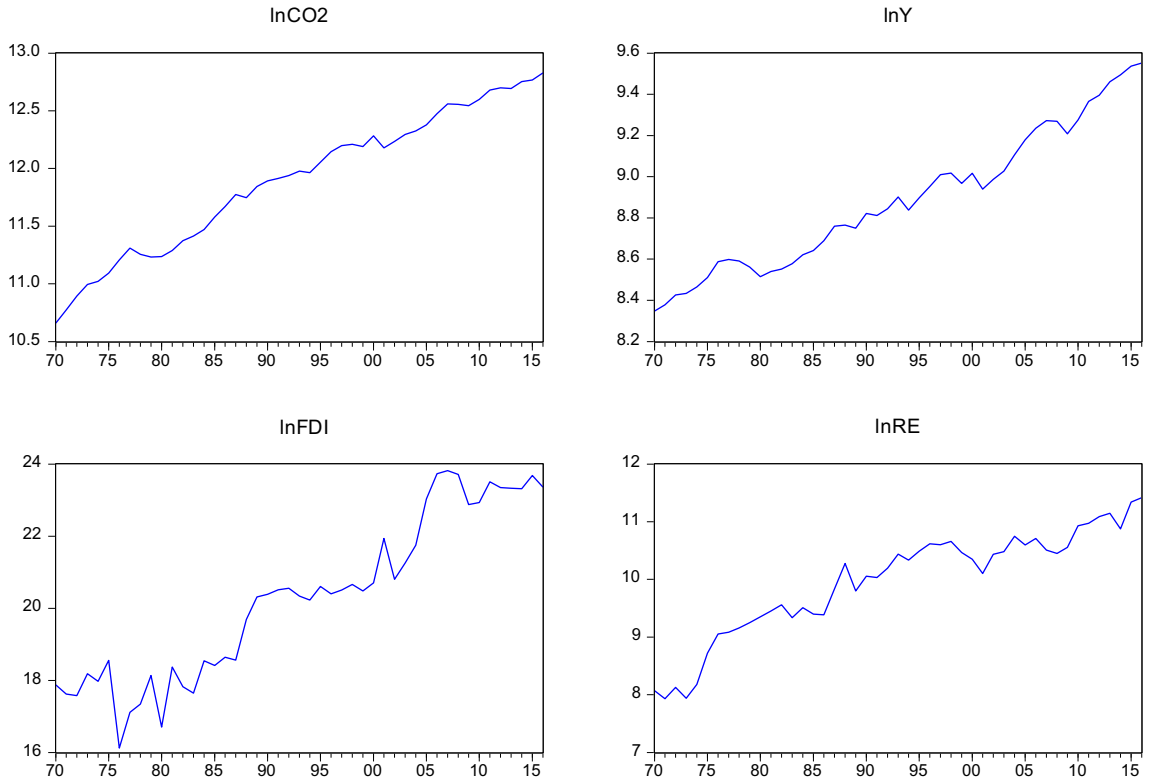

Fig. 1 Graphical presentation of the variables in the study

(1991, 1995) revised the study of Kuznets (1955), who examined the relationship between economic growth and income distribution, for environmental economics and developed the EKC hypothesis that focuses on the relationship between environmental quality and economic growth.

The EKC hypothesis assumes that fossil energy sources are heavily utilized in the first phases of the economic development process of a country as fossil energy sources are cheaper and in many cases in abundance than renewable energy sources (Sarkodie and Strezov 2019b). Therefore, the environmental deterioration in a country initially increases as lots of greenhouse gas (GHG) emissions and wastes come about (Ulucak and Bilgili 2018; Bulut 2019). Afterwards, dirty and old technologies are expected to be substituted with clean and new technologies after income reaches a threshold value as the demand for green technologies increases, more sources are allocated for research and development in the field, and the policies are more directed towards energy sustainability (Copeland and Taylor 2003; Bagliani et al. 2008). Besides, the structure of an economy shifts from pollution-intensive industries to technology-intensive industries (Ulucak and Bilgili 2018) as the economy grows. For this reason, the ECK hypothesis postulates there is an inverted U-shaped relationship between income and environmental degradation, meaning the environmental quality first decreases and then begins to increase after income reaches a threshold value (Dinda 2004; Pata 2018; Sun and Fang 2018). Overall, if $\alpha_1 > 0$ and $\alpha_2 < 0$, then the EKC hypothesis dominates. Hence, the following hypothesis is proposed in the paper:

H2. The EKC hypothesis is confirmed in Turkey for the period 1970 to 2016.

While explaining the arguments of the EKC hypothesis above, the paper denoted that the positive influence of the economic growth process on environmental quality arises from the use of renewable energy sources in economic activities along with the change in the structure of the economy. Renewable energy technologies are considered to be clean energy sources (Bilgili et al. 2016; Bulut and Inglesi-Lotz 2019). The optimal use of renewable energy sources can decrease environmental problems as minimum wastes are produced with the utilization of renewable energy sources (Panwar et al. 2011). For this reason, the last hypothesis, signifying $\alpha_4 < 0$, which will be tested in the paper is as the follows:

H3. Renewable energy decreases CO_2 emissions in Turkey, ceteris paribus.

Figure 2 exhibits the relationships in the proposed hypotheses.

Last but not least, we aim to test these hypotheses within a nonlinear framework as the previous papers ignore the

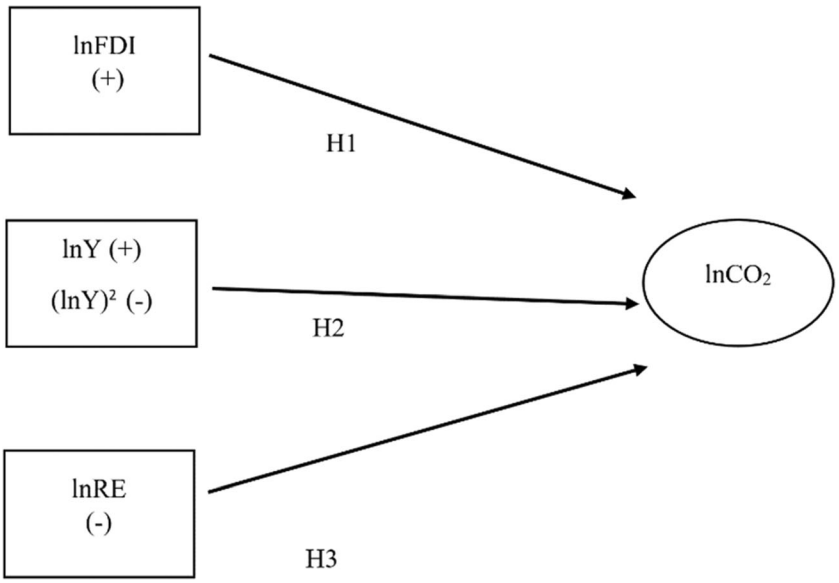

Fig. 2 Hypotheses of the study: relationship to the dependent variables

possible nonlinearity about the relationship in the empirical model. Hence, we will test the hypotheses above after testing the linearity hypothesis.

Econometric methodology

Unit root test

Kapetanios et al. (2003) (hereafter Kapetanios et al. (2003)) produce a unit root test to test for the null hypothesis of a unit root process against the alternative hypothesis of a nonlinear exponential smooth transition autoregressive (ESTAR) process that implies stationarity. They first use the following ESTAR model:

$$y_t = \beta y_{t-1} + \gamma y_{t-1}\left[1-\exp\left(-\theta y_{t-d}^2\right)\right] + \varepsilon_t \quad (2)$$

Equation (2) can be rewritten as follows:

$$\Delta y_t = \varphi y_{t-1} + \gamma y_{t-1}\left[1-\exp\left(-\theta y_{t-d}^2\right)\right] + \varepsilon_t \quad (3)$$

where $\varphi = \beta - 1$.

They consider φ as 0 and d as 1 and present the following specific ESTAR model:

$$\Delta y_t = \gamma y_{t-1}\left\{1-\exp\left(-\theta y_{t-1}^2\right)\right\} + \varepsilon_t \quad (4)$$

They use a first-order Taylor series approximation for the ESTAR model and obtain the regression below:

$$\Delta y_t = \delta y_{t-1}^3 + \varepsilon_t \quad (5)$$

They obtain the following *t*-statistic (t_{NL}) for $\delta = 0$ against $\delta < 0$ as follows:

$$t_{NL} = \widehat{\delta}/\text{s.e.}\left(\widehat{\delta}\right) \quad (6)$$

where $\widehat{\delta}$ and $\text{s.e.}\left(\widehat{\delta}\right)$ respectively denote the ordinary least squares (OLS) estimation of δ and the standard error of $\widehat{\delta}$. If t_{NL} statistic is greater than the critical values, then the null hypothesis of a unit root is rejected, meaning the series is stationary.

Cointegration test

Kapetanios et al. (2006) (hereafter Kapetanios et al. (2006)) produce a cointegration test via nonlinear exponential smooth transition (ESTR) error correction models. They test the null hypothesis of no cointegration against the alternative of ESTR cointegration. They stress that the small-sample performance of their nonlinear cointegration test is better than those of linear Engle and Granger (1987) and Johansen (1995) cointegration tests. After using some mathematical and statistical models, they obtain the following ESTR error correction model:

$$\Delta y_t = \phi u_{t-1} + \gamma u_{t-1}\left(1-e^{-\theta(u_{t-1}-c)^2}\right) + \omega'\Delta x_t + \sum_{i=1}^{p}\psi_i'\Delta z_{t-i} + e_t \quad (7)$$

$$\Delta x_t = \sum_{i=1}^{p}\Gamma_{xi}\Delta z_{t-i} + \varepsilon_{xt} \quad (8)$$

$$\widehat{u}_t = y_t - \widehat{\beta}_x' x_t \quad (9)$$

where $\widehat{\beta}_x$ is the OLS estimation of β_x. One of the test statistics used by Kapetanios et al. (2006) is called t_{NEG}. They estimate the following model to produce the t_{NEG} statistic:

$$\Delta\hat{u}_t = \delta\hat{u}_{t-1}^{3} + \sum_{i=1}^{p}\varphi_i\Delta\hat{u}_{t-i} + \varepsilon_t \quad (10)$$

The null hypothesis of no cointegration is defined as H_0: $\delta = 0$. If the t_{NEG} statistic is greater than the critical values, then the null hypothesis of no cointegration is rejected, meaning there exists cointegration in the empirical model.

Empirical findings

The paper first employs both the traditional Broock et al. (1996) (hereafter BDS) nonlinearity test and the Terasvirta (1994) nonlinearity test that is particularly developed for nonlinear smooth transition models. If the null hypothesis of linearity is rejected, we can perform nonlinear smooth transition methods.

Table 2 presents the results for the BDS and Terasvirta (1994) nonlinearity tests. Accordingly, panel A and panel B of the table, respectively, give the findings for the BDS and the Terasvirta (1994) tests. As is seen, the null hypothesis of linearity is rejected with regard to both tests, meaning the nonlinear smooth transition Kapetanios et al. (2003) unit root and the Kapetanios et al. (2006) cointegration methods explained above can be employed.

The findings of the Kapetanios et al. (2003) unit root test are reported in Table 3. Accordingly, the null hypothesis of a unit root cannot be rejected at level, while it is rejected at first difference. Hence, the Kapetanios et al. (2003) unit root test discovers that all variables in the empirical model are integrated of order one and that the cointegration relationship in the model can be examined through the Kapetanios et al. (2006) cointegration test.

Table 2 Results of nonlinearity tests

Panel A: BDS test					
Variable	Dimensions				
	2	3	4	5	6
$lnCO_2$	0.191* (0.000)	0.329* (0.000)	0.424* (0.000)	0.495* (0.000)	0.545* (0.000)
lnY	0.174* (0.000)	0.284* (0.000)	0.357* (0.000)	0.406* (0.000)	0.444* (0.000)
$(lnY)^2$	0.171* (0.000)	0.276* (0.000)	0.346* (0.000)	0.390* (0.000)	0.426* (0.000)
lnFDI	0.147* (0.000)	0.237* (0.000)	0.290* (0.000)	0.323* (0.000)	0.336* (0.000)
lnRE	0.176* (0.000)	0.300* (0.000)	0.390* (0.000)	0.455* (0.000)	0.500* (0.000)
Panel B: Terasvirta (1994) test					
Test statistic			Prob. value		
4.684**			0.0149		

* and **, respectively, indicate 1 and 5% statistical significance. Values in parentheses show prob. values.

Table 3 Kapetanios et al. (2003) unit root test

Variable	Test statistic	
	Level	First difference
$lnCO_2$	5.744	−2.225**
lnY	4.407	−4.728*
$(lnY)^2$	2.311	−2.201***
lnFDI	1.506	−2.065***
lnRE	1.582	−4.379*

*, **, and ***, respectively, indicate 1, 5, and 10% statistical significance.

Table 4 depicts the results for the Kapetanios et al. (2006) cointegration test along with the long-run parameters of the independent variables in the model. Accordingly, the findings obtained from the Kapetanios et al. (2006) cointegration test are given in panel A of the table. As is seen, the null hypothesis of no cointegration can be rejected, implying there exists cointegration in the model and the long-run parameters can be estimated. Panel B of the table presents the long-run parameters. Accordingly, lnY, $(lnY)^2$, lnFDI, and lnRE have the estimations of 1.115, –0.026, 0.061, and 0.285, respectively. Additionally, all these coefficients are statistically significant. Hence, the empirical findings of the paper imply that both the EKC hypothesis and the PHH dominate in Turkey. Besides, the findings yield that electricity production from renewables has a negative effect on environmental quality in Turkey.

Overall, the output of this paper for the EKC hypothesis corresponds to those of Seker et al. (2015), Gokmenoglu and Taspinar (2016), Kocak and Sarkgunesi (2018), and Bulut (2020). Besides, specifically, the findings of the paper for the PHH concur with those of Seker et al. (2015), Gokmenoglu and Taspinar (2016), Kocak and Sarkgunesi (2018), and Terzi and Pata (2020) and contradict with those of Mutafoglu (2012), Destek and Okumus (2019), Bulut (2020), and Mert and Caglar (2020). Finally, the empirical findings of this paper for renewable energy are not consistent with those of Bulut (2020).

Table 4 Kapetanios et al. (2006) cointegration test and long-run parameters

Panel A: Kapetanios et al. (2006) cointegration test			
Test statistic	−3.703***		
Panel B: Long-run parameters			
Variable	Coefficient	Std. error	*t*-statistic
lnY	1.115*	0.047	23.486
$(lnY)^2$	−0.026**	0.010	−2.579
lnFDI	0.061*	0.016	3.666
lnRE	0.285*	0.032	8.746

*, **, and ***, respectively, indicate 1, 5, and 10% statistical significance.

Conclusion

This paper examined whether the PHH was confirmed in Turkey over the period 1970–2016, within an EKC hypothesis framework assessing in parallel the role that renewable energy can play on environmental degradation for the country. The paper first performed linearity tests and determined nonlinear estimation methods must be employed instead of linear methods. Second, the paper performed a nonlinear ESTAR unit root test and detected all the variables in the model were integrated of order one (I(1)). Third, the paper carried out a cointegration test based on the nonlinear ESTAR error correction model and explored there occurred cointegration in the model. Finally, the paper estimated long-run parameters. The findings indicated that both the PHH and the EKC hypotheses were confirmed in Turkey and that electricity production from renewable energy sources had negative impacts on environmental quality in Turkey.

In theory, FDI inflows can positively affect the development process of a country as FDIs have many benefits for the host country. Indeed, many papers in the literature yield some empirical findings about the positive effects of FDIs on the Turkish economy. For instance, studies indicate that FDI inflows positively affect economic growth by increasing total factor productivity and technological diffusions (Gunaydin and Tatoglu 2005; Ozturk and Kalyoncu 2007; Arisoy 2012) or through an increase in exports (Eryigit 2012; Tapsin 2016); while some others explore FDI inflows decrease the unemployment rate (Gocer et al. 2013; Gunsen 2015; Ercakar and Guvenoglu 2018; Karimov et al. 2020). However, despite these benefits of FDI inflows to the Turkish economy, FDI appears to increase environmental deterioration in Turkey based on the empirical findings.

In Turkey, the Environment Law No. 2872 came into effect for environmental management and protection in 1983. Then, in 1993, the directive for the environmental impact assessment (EIA) was published. According to Article 10 of the Environment Law, an institution or enterprise which may lead to environmental problems because of its planned activity has to prepare an EIA report that introduces the project. Unless this project is approved, it cannot be permitted. Accordingly, the EIA is a process to assess the beneficial and adverse environmental influences of a project (Elvan 2018) in the country. Hence, the EIA system can be considered as a considerable tool aiming to prevent the negative environmental impacts of a project and to protect the environment before these negative impacts occur (Coskun and Turker 2011). However, in practice, it is very hard to argue that the EIA system in Turkey is efficient and unbiased. For instance, the EIA regulation has been revised many times since 1993 because of the pressures of the investors and project owners (Elvan 2018). Additionally, the public participation is not sufficient even though it is very important for the EIA regulation (Coskun and Turker 2011). Besides, the authorized firms and the investors prepare the EIA report together, which may result in tendentious decisions (Elvan 2018). It is with no doubt that this paper supports FDI inflows for the Turkish economy as FDIs have many benefits. However, FDI inflows appear to not only finance the current account deficit and positively affect economic growth and employment but also threaten the environmental sustainability in Turkey. Therefore, this paper argues that for the goal of environmental sustainability, an unbiased and efficient EIA mechanism should be designed in Turkey, and policymakers in Turkey should consider not only economic but also environmental impacts of FDI inflows. Otherwise, FDI inflows can threaten environmental sustainability while contributing to macroeconomic stability in Turkey.

As per Turkish Statistical Institute (2020) data, in electricity production, the share of hydro was 60.3%, while the share of other renewables, namely, solar, wind, geothermal, and biomass, was 0.1% in 1988 in Turkey. In the following years, the share of hydro dramatically decreased, while the share of other renewables did not change too much. For instance, the shares of hydro and other renewables in electricity generation were 24.7 and 0.3% in 2000, implying fossil energy sources dominated electricity production in Turkey. Afterwards, renewable energy policies in Turkey aimed to increase electricity production from renewables. For example, the Electricity Market Law in 2001, the Law on Utilization of Renewable Energy Sources for the Purpose of Generating Electrical Energy in 2005, and the Amendments to the Electricity Market Law in 2008 came into force to encourage electricity production from renewable energy sources (Bulut and Muratoglu 2018).

Additionally, many policies, such as incentives to promote the use of local equipment, incentives for energy crops, incentives to reinforce international electricity interconnections, land usage fee incentives, and feed-in tariff scheme, are implemented in Turkey for electricity production from renewables (Bulut and Muratoglu 2018; Republic of Turkey Ministry of Energy and Natural Resources 2014). Due to these legal arrangements and policies, the share of renewable energy sources not including hydro reached 12.7% in Turkey, while the share of hydro was 19.7% in 2018. Hence, these figures mean that fossil energy sources, particularly coal and natural gas, still dominate the energy mix of Turkey, and that increases in the share of other renewables in electricity production cannot offset the decrease in the share of hydro in electricity production. As was denoted in the section on hypotheses, the

optimal utilization of renewables is likely to decrease environmental deterioration. Within this scope, some papers in the literature try to explain why renewable energy cannot improve environmental quality. Accordingly, Jager-Waldau (2007), Lewis and Wiser (2007), Apergis et al. (2010), and Li et al. (2020) stress that renewable energy is not able to improve environmental quality when the renewable energy industry is in its early stage of development, leading to a lower share of renewable energy sources in total energy supply compared to fossil energy sources. Besides, Dong et al. (2018) emphasize that the coefficient of renewable energy can be affected by the share of renewable energy in the total energy supply. Hence, in Turkey, the share of renewable energy may not have reached a threshold value where a renewable energy begins to decrease CO_2 emissions. Chiu and Chang (2009) test this argument and find that the share of renewable energy in total energy supply must be at least 8.39% in China before the positive impact of renewable energy on environmental quality shows up. Moreover, the International Energy Agency (2009) (hereafter IEA) argues that stronger financial incentives can be needed for renewable energy. Additionally, Nemet and Kammen (2007) highlight the importance of R&D expenditures for renewable energy sources. Within this frame, it can be observed from the IEA (2021) data that the research, development, and demonstration (RD&D) expenditures for renewable energy increased in the last years, while they were very low for many years in Turkey. For instance, RD&D expenditures for renewable energy sources were 1 million USD in 1994; they reached only 4 million USD in 2009. In addition, they were 35 million USD in 2014 and increased to 74 million USD in 2018. Hence, more resources should be allocated for the development and diffusion of renewables in Turkey.

Therefore, this paper argues that the negative coefficient of renewable energy in the empirical analysis may stem from the low share of renewables in electricity production and that the Turkish government should proceed to stimulate electricity production from renewables and to boost RD&D expenditures. Hence, when the share of other renewables in electricity production reaches a certain level and offsets the decrease in the share of hydro, renewables can improve environmental quality in Turkey as renewables are much cleaner compared to fossil energy sources.

Finally, the paper invites further possible researches which may employ nonlinear estimation methods for testing the PHH and the EKC hypothesis and for examining the impact of renewable energy on environmental quality as linearity is a very strong assumption for an econometric time series analysis. For instance, future papers may employ other nonlinear methods, such as threshold autoregressive models, self-exciting threshold autoregressive models, momentum threshold autoregressive models, and Markov regime switching models. In this way, the findings of these papers can help policymakers in Turkey exploit efficient empirical findings and design strong energy and environmental policies.

Availability of data and materials The data sets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Author contribution Umit Bulut: Conceptualization, formal analysis, methodology, project administration, and writing—original draft and review and editing. Gulbahar Ucler: Conceptualization, data curation, investigation, and writing—original draft. Roula Inglesi-Lotz: Supervision, validation, and writing—original draft.

Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

References

Acharrya J (2009) FDI, growth and environment; evidence from India on CO2 emission during the last two decades. J Econ Dev 34:43–58

Akbas YE, Senturk M, Sancar C (2013) Testing for causality between the foreign investment, current account deficit, GDP and total credit: Evidence from G7. Panoeconomicus 60:791–812

Akbostanci E, Tunc GI, Turut-Asik S (2007) Pollution haven hypothesis and the role of dirty industries in Turkey's exports. Environ Dev Econ 12:297–322

Anyanwu JC (2006) Promoting investment in Africa. Afr Dev Rev 18: 42–71

Apergis N, Payne JE, Menyah K, Wolde-Rufael Y (2010) On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth. Ecol Econ 69:2255–2260

Arisoy I (2012) The impact of foreign direct investment on total factor productivity and economic growth in Turkey. J Dev Areas 46:17–29

Baek J (2016) A new look at the FDI-income-energy-environment nexus: dynamic panel data analysis of ASEAN. Energy Policy 91:22–27

Bagliani M, Bravo G, Dalmazzone S (2008) A consumption-based approach to environmental Kuznets curves using the ecological footprint indicator. Ecol Econ 65:650–661

Bilgili F, Ozturk I, Kocak E, Bulut U, Pamuk Y, Mugaloglu E, Baglitas HH (2016) The influence of biomass energy consumption on CO2 emissions: a wavelet coherence approach. Environ Sci Pollut Res 23:19043–19061

Broock WA, Scheinkman JA, Dechert WD, LeBaron B (1996) A test for independence based on the correlation dimension. Econ Rev 15: 197–235

Bulut U (2019) Testing environmental Kuznets curve for the USA under a regime shift: the role of renewable energy. Environ Sci Pollut Res 26:14562–14569

Bulut U (2020) Environmental sustainability in Turkey: an environmental Kuznets curve estimation for ecological footprint. Int J Sustain Dev World Ecol. https://doi.org/10.1080/13504509.2020.1793425

Bulut U, Inglesi-Lotz R (2019) Which type of energy drove industrial growth in the US from 2000 to 2018? Energy Rep 5:425–430

Bulut U, Muratoglu G (2018) Renewable energy in Turkey: great potential, low but increasing utilization and an empirical analysis on renewable energy-growth nexus. Energy Policy 123:240–250

Chiu CL, Chang TH (2009) What proportion of renewable energy supplies is needed to initially mitigate CO_2 emissions in OECD member countries? Renew Sust Energ Rev 13:1669–1674

Copeland BR, Taylor MS (2003) Trade and environment: theory and evidence. Princeton University Press, New Jersey

Coskun AA, Turker O (2011) Analysis of environmental impact assessment (EIA) system in Turkey. Environ Monit Assess 175:213–226

Destek MA, Okumus I (2019) Does pollution haven hypothesis hold in newly industrialized countries? Evidence from ecological footprint. Environ Sci Pollut Res 26:23689–23695

Dinda S (2004) Environmental Kuznets Curve hypothesis: a survey. Ecol Econ 49:431–455

Dong K, Hochman G, Zhang Y, Sun R, Li H, Liao H (2018) CO_2 emissions, economic and population growth, and renewable energy: empirical evidence across regions. Energy Econ 75:180–192

Elvan OD (2018) Analysis of environmental impact assessment practices and legislation in Turkey. Environ Sci Pol 84:1–6

Enders W (2015) Applied econometric time series, fourth edn. Wiley, Hoboken

Engle RF, Granger CW (1987) Co-integration and error correction: representation, estimation, and testing. Econometrica 55:251–276

Ercakar ME, Guvenoglu H (2018) The effect of foreign direct investment on the unemployment: the application of Turkey (1980-2016). J Soc Sci Mus Alparslan Univ 6:349–356

Eryigit M (2012) The long run relationship between foreign direct investment, export and gross domestic product: panel data implications. Theor Appl Econ 10:71–82

Gocer I, Mercan M, Peker O (2013) Export, foreign direct investment and unemployment: the case of Turkey. Bus Econ Res J 4:103–120

Gokmenoglu K, Taspinar N (2016) The relationship between CO2 emissions, energy consumption, economic growth and FDI: the case of Turkey. J Int Trade Econ Dev 25:706–723

Graham EM, Krugman P (1993) The surge in foreign direct investment in the 1980s. In: Froot K (ed) Foreign direct investment. University of Chicago Press, Chicago, pp 113–136

Grossman GM, Krueger AB (1991) Environmental impacts of a North American free trade agreement. NBER Work Pap 3914

Grossman GM, Krueger AB (1995) Economic growth and the environment. Q J Econ 110:353–377

Gunaydin I, Tatoglu E (2005) Does foreign direct investment promote economic growth? Evidence from Turkey. Multinatl Bus Rev 13:89–106

Gunsen I (2015) Automotive industry: economic effects of foreign direct investment in Turkey. Uludag J Econ Soc 34:19–34

IEA (2009) World Energy Outlook. https://www.iea.org/reports/world-energy-outlook-2009. Accessed 24 February 2021

IEA (2021) Data and statistics. https://www.iea.org/data-and-statistics?country=WORLD&fuel=Energy supply&indicator=TPESbySource. Accessed 23 February 2021

Jager-Waldau A (2007) Photovoltaics and renewable energies in Europe. Renew Sust Energ Rev 11:1414–1437

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

Johansen S (1995) Likelihood based inference in cointegrated vector autoregressive models. Oxford University Press, Oxford

Kapetanios G, Shin Y, Snell A (2003) Testing for a unit root in the nonlinear STAR framework. J Econ 112:359–379

Kapetanios G, Shin Y, Snell A (2006) Testing for cointegration in nonlinear smooth transition error correction models. Econ Theory 22:279–303

Karimov M, Paradi-Dolgos A, Pavlin RK (2020) An empirical analysis of the relationship between foreign direct investment and unemployment rate: evidence from Turkey. Eur Res Stud J 23:453–464

Kocak E, Sarkgunesi A (2018) The impact of foreign direct investment on CO_2 emissions in Turkey: new evidence from cointegration and bootstrap causality analysis. Environ Sci Pollut Res 25:790–804

Kuznets S (1955) Economic growth and income inequality. Am Econ Rev 45:1–28

Lewis JI, Wiser RH (2007) Fostering a renewable energy technology industry: An international comparison of wind industry policy support mechanisms. Energy Policy 35:1844–1857

Li P, Ouyang Y, Zhang L (2020) The nonlinear impact of renewable energy on CO_2 emissions: empirical evidence across regions in China. Appl Econ Lett 27:1150–1155

Mert M, Boluk G (2016) Do foreign direct investment and renewable energy consumption affect the CO_2 emissions? New evidence from a panel ARDL approach to Kyoto Annex countries. Environ Sci Pollut Res 23:21669–21681

Mert M, Caglar AE (2020) Testing pollution haven and pollution halo hypotheses for Turkey: a new perspective. Environ Sci Pollut Res 27:32933–32943

Mutafoglu TH (2012) Foreign direct investment, pollution, and economic growth: evidence from Turkey. J Dev Soc 28:291–297

Nemet GF, Kammen DM (2007) US energy research and development: declining investment, increasing need, and the feasibility of expansion. Energy Policy 35:746–755

Ozturk I, Kalyoncu H (2007) Foreign direct investment and growth: an empirical investigation based on cross-country comparison. Econ Internazionale 60:75–82

Panwar NL, Kaushik SC, Kothari S (2011) Role of renewable energy sources in environmental protection: a review. Renew Sust Energ Rev 15:1513–1524

Pata UK (2018) The influence of coal and noncarbohydrate energy consumption on CO2 emissions: revisiting the environmental Kuznets curve hypothesis for Turkey. Energy 160:1115–1123

Republic of Turkey Ministry of Energy and Natural Resources (2014) National renewable energy action plan for Turkey. https://www.ebrd.com/news/2015/ebrd-supports-turkeys-shift-to-renewable-energy.html. Accessed 24 November 2020

Sarkodie SA, Strezov V (2019a) Effect of foreign direct investments, economic development and energy consumption on greenhouse gas emissions in developing countries. Sci Total Environ 646:862–871

Sarkodie SA, Strezov V (2019b) A review on Environmental Kuznets curve hypothesis using bibliometric and meta-analysis. Sci Total Environ 649:128–145

Seker F, Ertugrul HM, Cetin M (2015) The impact of foreign direct investment on environmental quality: a bounds testing and causality analysis for Turkey. Renew Sust Energ Rev 52:347–356

Shahbaz M, Nasreen S, Abbas F, Anis O (2015) Does foreign direct investment impede environmental quality in high-, middle-, and low-income countries? Energy Econ 51:275–287

Sun S, Fang C (2018) Water use trend analysis: A non-parametric method for the environmental Kuznets curve detection. J Clean Prod 172:497–407

Tapsin G (2016) The relationship between foreign direct investment, export and economic growth in Turkey. J Bus Manag Econ 4:1–6

Terasvirta T (1994) Specification, estimation, and evaluation of smooth transition autoregressive models. J Am Stat Assoc 89:208–218

Terzi H, Pata UK (2020) Is the pollution haven hypothesis (PHH) valid for Turkey? Panoeconomicus 67:93–109

Turkish Statistical Institute (2020) Main statistics. http://www.turkstat.gov.tr/UstMenu.do?metod=temelist. Accessed 9 November 2020

Ulucak R, Bilgili F (2018) A reinvestigation of EKC model by ecological footprint measurement for high, middle and low income countries. J Clean Prod 188:144–157

World Bank (1993) Global economic prospects and the developing countries. http://pubdocs.worldbank.org/en/568591462827608813/Global-Economic-Prospects-1993.pdf. Accessed 24 November 2020

World Bank (2020) World Development Indicators (WDI). https://data.worldbank.org. Accessed 9 November 2020

Zhang C, Zhou X (2016) Does foreign direct investment lead to lower CO_2 emissions? Evidence from a regional analysis in China. Renew Sust Energ Rev 58:943–951