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What is the link between renewable&non-renewable energy, foreign direct investment, economic growth, and ICT on Ecological Footprint? Evidence of Environmental Kuznets Curve from European Union Countries and Turkey

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Abstract The purpose of this paper is to investigate the role of FDI, ICT, fossil, and renewable energy consumption on EFP in 25 EU countries and Turkey. In this context, we set up panel threshold models by using data over the 1990-2014 period to test environmental Kuznets curve (EKC) and Pollution Haven Hypothesis (PHH) in these countries. Contrary to previous EKC studies in the literature, the current study employs the more comprehensive indicator of environmental quality than emissions (namely, ecological Footprint, EFP) and examines the role of FDI and ICT on EFP for the first time in the EU countries and Turkey. Moreover, we analyzed the threshold effects of ICT and FDI on other variables. Our results found evidence supporting the EKC and PHH hypothesis when the ICT has been used as a threshold variable. Moreover, our study reveals that while FDI inflow and fossil energy worsen the environmental deterioration, ICT and renewable energy positively affect the environmental quality in EU and Turkey. Policy implications have been presented in the conclusion part.

Key words: Environmental Kuznets Curve, Foreign direct investment, Ecological Footprint, Turkey, European Union.

JEL: Q01, Q43, Q56

Introduction

The interaction between the environment and economic growth has been examined since the report "The Limits to Growth" in early 1970s. The concerns about global warming and climate change have been debated for a long time as well. Since greenhouse emissions (GHGs) are emitted primarily from increasing fossil fuels and/or energy consumption, development of environmentally friendly energy sources (solar, wind, geothermal, bioenergy, etc.) has become key to ensure sustainable economic development. Following the pioneering study of Grossman and Krueger (1991, 1995), the nexus between environment, economic development, and energy has been studies in the framework of environmental Kuznets Curve hypothesis (hereafter EKC). The EKC hypothesis argue that there is an inverted U-shaped relationship between environmental deterioration and economic growth. This hypothesis claims that at the early stage, economic growth makes environmental degradation worse, but after a certain level of per capita income (called "the turning point"), economic growth enhances the environmental quality.

As argued by Panayotou (2003), the inverted U-shape of EKC emerges due to the mixture of scale, composition, and technique effect. At the initial stage of economic development, pollution accelerates due to industrialization and resource exploitation (scale effect). However, as income increases, output mix changes from agrarian to industrial and finally to service economy that pollutes less (composition effect). Moreover, "cleaner" technologies are replacing "dirtier" technologies in the output creation process (technique effect). In other words, in the first stage, output increase requires higher level of means of production, such as natural resources, but after the turning point, environmental quality is expected to improve due to increased environmental awareness and eco-friendly technologies (Destek, 2021).

Testing EKC hypothesis gained importance in last three decades since it solves the environmental degradation problem as a concept. If EKC is valid, then environmental deterioration will not pose a problem as long as countries achieve certain level of income (Harvieux and Darne, 2003; Caglar et.al., 2021). Inverted U-shaped relationship between economic growth and environmental pollution has been empirically tested by different methodologies for different countries and country groups by many studies, but the obtained results are mixed. While some studies validated the EKC hypothesis (see Ang, 2017; Kasman and Duman, 2015; Saqib and Benhmad, 2021; among others), some others could not find evidence supporting EKC hypothesis (see Lindmark, 2002; Arango-Miranda et.al., 2018). In most of EKC studies, environmental deterioration has been represented by CO_2 emissions. However, this is an important shortcoming in EKC studies since environmental degradation cannot be captured by GHG emissions only. Environmental degradation, however, also appears in other sources such as soil, water, oil, forest, etc. (Destek et.al., 2018). As stated by Stern (2004) and Arrow et.al. (1996), CO_2 emissions tend to decrease due to the technological progress and environmental measures taken by governments, but this may not be the case for all types of environmental degradation and/or pollution. In other words, while EKC hypothesis is valid for CO_2 emissions, it may not be valid for other environmental resources. Hence, when CO_2 emissions is used to represent the environmental quality, obtained results would be misleading for efficient policy design towards sustainable development (Destek et.al.,2018 Caglar et.al., 2021; Altintas and Kassouri, 2020).

The motivation of this paper is to examine the EKC hypothesis for the EU countries using more comprehensive indicator than GHGs - namely EFP. There are few studies that investigates the link between economic growth and EFP, however, previous studies did not consider the role of foreign direct investment (hereafter FDI) and information and communication technologies (hereafter ICT) for the EU countries and Turkey. As stated by Acharya (2009), FDI can also affect the environmental quality since FDI inflows lead scale, composition, and technique effects in hosting country. The interaction between FDI and the environment is argued under two competing hypotheses. If FDI-led growth creates additional pollution, pollution haven hypothesis (hereafter PHH) will be valid, however, if FDI inward improves the environmental quality, then pollution Haloes hypothesis will be valid (Cole and Fredrikson, 2009). Like FDI, information and communication technologies (hereafter ICT) can help remedy the environmental degradation by eliminating unnecessary transportation cost, creating efficient production practices and awareness of environment, and stimulating environmentally friendly technologies (Caglar et.al, 2021; Mert and Boluk; 2019). To the best of our knowledge, current study is the first attempt that analyzes the nexus between economic growth, renewable and non-renewable energy, FDI, ICT, and EFP in the EKC framework for the EU countries and Turkey. We focus on the EU countries and Turkey since they still face increasing amounts of emissions and waste, poor water quality and forest degradation, etc. (EEA, 2022). Since Turkey is a candidate country for the EU membership, results of the study will contribute to efficient policy design for energy and environmental area towards EU membership process. Finally, we employ the panel threshold regression model for several different reviews. The first is to examine the validity of the EKC hypothesis. Another one is to test whether PHH and/or Pollution Haloes hypothesis are valid. Also, the model in the study is to determine the different effects of energy consumption types (renewable and fossil) on environmental quality. These investigations are based on the results of two panel threshold regression models created over two different threshold variables (namely FDI and ICT).

The rest of the paper is organized as following. The second section reviews the literature and summarizes the results of previous empirical studies. The third section presents the data and econometric modelling process. The fourth section provides obtained results. The final section concludes and discusses some policy recommendations.

Theoretical premises

The EKC hypothesis between economic growth and CO_2 has been tested for the EU countries and Turkey using different explanatory variables (like energy use, renewable energy, trade openness, urbanization, financial development, etc.) and econometric approaches. However, while some of them found evidence in favor of EKC (see Coondoo and Dinda, 2008; Lopez-Menendez et.al., 2014; Kasman and Duman; 2015, Al-Mulali et.al., 2016; Dogan and Seker, 2016; Ahmed et.al., 2016; Pablo-Romero and Sanchez-Broza, 2017; Halicioglu, 2009; Seker et.al., 2015; Ozatac et.al., 2017), some others did not validate the EKC for these countries (see Akbostancı et.al., 2009; Acaravci and Ozturk, 2010; Bölük and Mert, 2014; Abid, 2017). Moreover, PHH and pollution Haloes hypotheses were investigated by many studies in the EKC framework (see Acharya, 2009; Muhammet et.al., 2011; Hitam and Borhan, 2012; Tamazian et.al., 2009; among others). Like EKC hypothesis, the relationship between FDI inflow and environmental quality is also ambiguous. Hence, it can be said that there is no consensus on the validation of EKC hypothesis and effects of socio-economic drivers between economic growth and CO_2 emissions.

Contrary to previous EKC studies on emissions, there are limited numbers of research papers that focus on the nexus between economic growth and ecological footprint for the EU countries and Turkey. For example, Destek et.al. (2018) investigated the role of economic growth, renewable and non-renewable energy consumption, and trade openness on EFP using annual data from 1980 to 2013. The authors found no evidence in favor of EKC hypothesis in 15 EU countries. Moreover, their results show a contributing effect of renewable energy and trade openness in mitigating the environmental degradation. Using the panel smooth transition regression (PSTR) model and data set over the 1990-2013 period for 26 EU countries, Aydin et.al. (2019) analyzed the link between economic growth and EFP. Authors found mixed results based on the different kinds of ecological sub-parts of EFP. Altıntaş and Kassouri (2020) tested the EKC hypothesis in 14 EU countries by using heterogeneous panel model over the 1990-2014 period and two different indicators of environmental quality, CO_2 emissions and EFP. Their results validated the existence of EKC when EFP is used for environmental degradation. However, EKC is not confirmed when environmental pollution was represented by CO_2 emissions. Alola et.al. (2019) analyzed the interaction between EFP, real GDP, trade openness, fertility rate, as well as renewable and non-renewable energy consumption in 16 EU member states for the 1997-2014 period. Their results confirmed deteriorating effect of non-renewable energy and GDP on environmental sustainability. However, they found that RE consumption improves EFP in these countries. Using FMOLS and DOLS, Adedoyin et.al. (2020) investigated the role of R&D spendings on EFP in 16 EU countries over the 1997-2014 period. Moreover, authors reveal that there is feedback relationship between EFP, R&D expenditure, renewable and non-renewable energy, and RE decreases the EFP.

Table 1. Summary review of literature focusing on economic growth and EFP in EU and Turkey

Study	**Data period**	**Country**	**Explanatory variables**	**Econometric technique**	**Results**
Destek et.al. (2018)	1980-2013	EU-15	GDP, trade openness, renewable and non-renewable energy consumption	MG-FMOLS MG-DOLS DCCE-MG	No EKC
Aydin et.al. (2019)	1990-2013	EU-26	GDP	PSTR	Mixed results
Alola et.al. (2019)	1997-2014	EU-16	GDP, trade openness, fertility rate, renewable and non-renewable energy consumption	PMG-ARDL	No EKC testing Fossil energy and GDP deteriorates EFP, renewable energy improves EFP.
Altıntaş and Kassouri (2020)	1990-2014	EU-14	GDP, renewable energy, non-renewable energy	IFE, D-CCE	Yes, EKC for EFP. No EKC for CO_2.
Adedoyin et.al. (2020)	1997-2014	EU-16	R&D spending, renewable and non-renewable energy	FMOLS DOLS	No EKC testing. R&D and renewable energy improves EFP.
Destek (2021)	1970-2017	Turkey	GDP, urbanization, industrialization, human capital	NARDL	No EKC testing. Industrialization increases CO_2 but has no impact on EFP. Urbanization deteriorates environment. Human capital improves environmental quality.

Study	**Data period**	**Country**	**Explanatory variables**	**Econometric technique**	**Results**
Godil et.al. (2020)	1986-2018	Turkey	GDP, tourism, financial development, globalization	Quantile ARDL	EKC yes. All variables deteriorate the EFP.
Köksal et.al. (2020)	1961-2014	Turkey	GDP, shadow economic activities, trade openness, urbanization, financial development, energy consumption.	Cointegration	EKC mixed. Shadow economy, trade openness, financial development deteriorates EFP.
Kirikkaleli et.al. (2020)	1985-2017	Turkey	GDP, energy consumption, globalization, trade openness	DOLS FMOLS	No EKC testing. All variables contribute to environmental degradation.

Some of the empirical studies analyzed the link between economic growth and EFP in Turkey as well. For example, Destek (2021) investigated the impact of structural changes in industrialization on environmental quality. For this purpose, author analyzed the link between GDP, industrialization, urbanization, human capital, and two environmental quality indicators (CO_2 and EFP). Main finding of this study is that while deindustrialization reduces the CO_2 emissions, it has no significant impact on EFP. Using quantile ARDL, Godil et.al. (2020) investigated the role of tourism, financial development, and globalization on EFP in Turkey. The authors found that all explanatory variables deteriorate the environmental quality. Köksal et.al. (2020) examined the role of shadow economy on EFP in Turkey. Using two different EKC modelling, authors discussed the role of shadow economy, financial development, trade volume, urbanization, exchange rate, and trade openness on environmental quality in the 1961-2014 period. Authors found that a 1% increase in shadow economy increases EFP by around 1,008%. Similarly, Kirikkaleli et.al. (2020) analyzed the role of globalization on EFP in Turkey. Using DOLS and FMOLS, the authors found evidence supporting the deteriorating effect of globalization, trade openness, energy consumption and economic growth on EFP in 1985-2017 period for Turkey.

As seen in Table 1, only some of the studies focusing on the EFP test the EKC hypothesis and none of them analyze the impact of FDI and ICT in the EU countries and Turkey. Moreover, there is a lack of consensus in the literature about the validity of EKC hypothesis or the effects of other socio-economic factors on the environment. Hence, our study on the nexus of FDI-led EKC using EFP in these countries is the first of its kind.

Methodology

In this paper, a panel model has been employed to understand how economic growth, FDI, ICT, renewable and fossil fuel consumption affect the EFP in the EU countries and Turkey. The time span has been determined by the data availability. The dependent variable is selected as per capita EFP to represent environmental quality. EFP data is compiled from Global Footprint Network (GFN, 2021) and measured as global hectare (gha) per person. The data of other explanatory variables such as FDI (measured as net inflows USD), per capita GDP (measured as real GDP in terms of PPP based on 2017 USD), ICT (mobile cellular subscriptions, per 100 people), per capita renewable (REN) and fossil (FOS) energy consumption (measured as in kilotons of oil equivalent) are obtained from the open data platform of the World Bank (WB, 2022). All variables are expressed with natural logarithms to both reduce the risk of heteroscedasticity and to reach elasticity values. Data covers the years 1995-2014 from 25 countries. The reason why the end of the data period is 2014 is that the analysis technique used in this study requires a balanced panel data set. Renewable and fossil energy consumption data from Bulgaria, Croatia, Latvia, and Lithuania were available until 2014. For this reason, the end of the data period for balanced panel structure was determined as 2014. Summary statistics for data are presented in Table 2.

Table 2. Summary Statistics

	$lnefp_{it}$	$lngdp_{it}$	$lnfdi_{it}$	$lnict_{it}$	$lnren_{it}$	$lnfos_{it}$
Obs.	500	500	500	500	500	500
Mean	1.601	10.288	13.492	3.864	5.895	7.864
Std. Dev.	0.282	0.445	0.098	1.423	0.840	0.408
Min.	0.829	9.170	13.471	-3.232	4.039	6.709
Max.	2.199	10.994	14.738	5.148	7.863	8.628

The data set is balanced panel data, and the total number of observations is 500. The average value of the *lnefp* is 1.601, with the minimum value of 0.829 (Turkey) and the maximum value of 2.199 (Estonia). The mean value of *lngdp* of the overall panel is approximately 10.288. The minimum ln*gdp* value is approximately 9.170 (Latvia), while the maximum value is approximately 10.994 (Ireland). The average of *lnfdi* is approximately 13.5. In addition, the minimum value of *lnfdi* is 13.471 (Denmark) and the maximum value is 14.738 (Netherlands). It can be seen that the mean value of *lnict* is 3.864, the minimum value is3.232 (Romania) and the maximum value is 5.148 (Finland). Finally, when the amounts of energy consumption are examined, renewable energy consumption (*lnren*) averages 5.895, while fossil energy consumption (*lnfos*) averages 7.864. In addition, the minimum values of *lnren* and *lnfos* are 4.039 and 6.709, respectively. The maximum values (*lnren* and *lnfos*) are 7.863 and 8.628, respectively. These statistics show that renewable energy consumption is still well behind fossil energy consumption and renewable energy generation needs to be improved.

Given the importance of FDI and ICT on environmental quality, we enlarge EKC hypothesis by incorporating FDI inflows, ICT, and EFP in the nexus of energy-economic growth-environment for the EU countries and Turkey. Accordingly, the model used in the study is defined as follows:

(1) $$lnefp = f(lngdp, lngdp^2, lnren, lnfos, lnfdi, lnict)$$

In the model (1), the assumptions of unit effects and homogeneous slope coefficient are constructed. In addition, *lngdp*^{2} has been added to the model because of based on the EKC hypothesis. The EKC hypothesis is said to apply if the statistically significant coefficients of *lngdp* and *lngdp*^{2} are positive and negative marked, respectively. In general, the model provides the opportunity to test the EKC hypothesis through EFP, as well as to measure the impact on environmental quality in terms of energy consumption types (renewable and fossil). Therefore, *lnren* is expected to have a negative effect on EFP, while *lnfos* is expected to have a positive effect. In addition, the model also provides the effect of FDI and ICT on environmental quality. Especially if the effect of FDI on EFP is positive, pollution haven hypothesis is determined to be valid, but if the effect is negative, pollution haloes hypothesis is valid. A similar setup can be made for ICT. The development of ICT is determined to influence improving or worsening environmental quality.

Panel threshold regression model is preferred for the estimation of the model (1). One of the reasons for the use of this technique is that it allows a nonlinear structure in relationships between variables. Another motivation to use panel threshold regression model is to investigate validity of the EKC hypothesis and the effects of energy consumption type differ on environmental quality depending on FDI and ICT threshold values.

For this purpose, following Hansen (1999), fixed-effect panel threshold regression models (single-threshold) are employed as follows:

(2) $$lnefp_{it} = \alpha_1 + \beta_{1,k}X_{it}I(g_{it} < \delta) + \beta_{2,k}X_{it}I(g_{it} \geq \delta) + \phi_1 lnfdi_{it} + \mu_{1i} + \varepsilon_{it}$$

(3) $$lnefp_{it} = \alpha_2 + \theta_{1,k}X_{it}I(h_{it} < \lambda) + \theta_{2,k}X_{it}I(h_{it} \geq \lambda) + \phi_2 lnict_{it} + \mu_{2i} + e_{it}$$

where α_1 and α_2 represent constant term, X is independent variables, $\beta_{m,k}$ and $\theta_{m,k}$ (m=1,2; k=1, 2, 3, 4, 5) denote the slope coefficients. μ is the individual effect, while ε and e are the error terms. g and h in model (2) and model (3) denote threshold variables as *lnfdi* and *lnict*, respectively, δ and λ represent threshold parameter for both models, while I is the indicator function. As a result, models in their simple form (only slope coefficients) can be shown as follows (Wang, 2015):

$$lnefp_{it} = \begin{cases} \beta_{1,1}lngdp_{it} + \beta_{1,2}lngdp_{it}^2 + \beta_{1,3}lnren_{it} + \beta_{1,4}lnfos_{it} + \beta_{1,5}lnict_{it}, & lnfdi_{it} < \delta \\ \beta_{2,1}lngdp_{it} + \beta_{2,2}lngdp_{it}^2 + \beta_{2,3}lnren_{it} + \beta_{2,4}lnfos_{it} + \beta_{2,5}lnict_{it}, & lnfdi_{it} \geq \delta \end{cases}$$

$$lnefp_{it} = \begin{cases} \theta_{1,1}lngdp_{it} + \theta_{1,2}lngdp_{it}^2 + \theta_{1,3}lnren_{it} + \theta_{1,4}lnfos_{it} + \theta_{1,5}lnfdi_{it}, & lnict_{it} < \lambda \\ \theta_{2,1}lngdp_{it} + \theta_{2,2}lngdp_{it}^2 + \theta_{2,3}lnren_{it} + \theta_{2,4}lnfos_{it} + \theta_{2,5}lnfdi_{it}, & lnict_{it} \geq \lambda \end{cases}$$

Through this approach, it can be determined how FDI and ICT, which are frequently researched in the literature, affect environmental quality through EFP. It is also an important feature of an approach to address this interaction in a non-linear structure. However, to estimate the mentioned panel threshold regression models, the threshold effect should be tested. If it is concluded that there is no threshold effect, it is not correct to use panel threshold regression model. In the F test designed for this purpose, the null hypothesis represents no threshold effect (linear relationship) and the alternative hypothesis of threshold effect is valid (that is the nonlinear relationship) (Huang et.al., 2018; Wang and Wang, 2021). The F test statistic is calculated as follows:

(4) $$F = \frac{S_0 - S_1(\hat{\delta})}{\hat{\sigma}^2}$$

S_0 and S_1 are the sum of squares errors from linear and nonlinear models, respectively. $\hat{\delta}$ estimated threshold value and $\hat{\sigma}^2$ is a convergent estimate of σ^2 (Candelon, 2013).

Results

Unit root tests will be used to determine the stationary levels of the series. However, the unit root test to be preferred varies depending on whether there is a cross-sectional dependence. For this purpose, cross-sectional dependence tests (LM and CD tests) are carried out. According to the results seen in Table 3, the presence of cross-sectional dependence is determined for all variables.

Table 3. Cross-Sectional Dependence Tests

Variables	Breusch-Pagan LM Test	Pesaran CD Test
lnefp	1393.94***	23.732***
lngdp	4597.16***	66.598***
lngdp²	4586.18***	66.497***
lnren	4047.58***	55.899***
lnfos	2297.46***	31.342***
lnict	5812.12***	76.232***
lnfdi	1380.95***	30.508***

Note: (*), (**) and (***) show the significance level at 10%, 5% and 1% respectively.

Due to the cross-sectional dependence, it is preferred to use Pesaran's (2007) CIPS and Reese and Westerlund's (2016) PANICCA panel unit root tests. The panel unit root tests results presented in Table 4 show that all series are stationary at the level, given the results of both tests. Based on this result, panel regression model can be estimated; there is no need to investigate the cointegration relationship between variables.

Table 4. Panel Unit Root Tests

Variables	CIPS Test		PANICCA Test			Decision
	C	C & T	P_a	P_b	PMSB	
lnefp	-1.696	-2.729**	-23.397***	-8.346***	-2.781***	I(0)
lngdp	-3.061***	-2.815**	-11.129***	-5.084***	-2.226**	I(0)
lngdp²	-2.971***	-2.881**	-11.181***	-5.079***	-2.226**	I(0)
lnren	-2.622***	-3.291***	-15.859***	-6.185***	-2.356**	I(0)
lnfos	-1.842	-2.676*	-19.595***	-7.738***	-2.968***	I(0)
lnict	-3.203***	-3.843***	-10.157***	-4.523***	-1.935**	I(0)
lnfdi	-2.706***	-3.446***	-12.644***	-4.308***	-1.346*	I(0)

Note: (*), (**) and (***) show the significance level at 10%, 5% and 1% respectively.

In the estimation of panel regression model, it should be determined whether the slope coefficients are homogeneous or heterogeneous. For this purpose, the Delta tests

($\widetilde{\Delta}$ and $\widetilde{\Delta}_{adj}$) of Pesaran and Yamagata (2008) are employed. According to the results in Table 5, the null hypothesis of slope homogeneity cannot be rejected ($\widetilde{\Delta}_{adj}$ p-value approximately 10%).

Table 5. Slope Homogeneity Test

Delta Tests	Statistics	P-Value
$\widetilde{\Delta}$	1.034	0.301
$\widetilde{\Delta}_{adj}$	1.668	0.095

Based on the finding that slope coefficients are homogeneous, some tests presented in Table 6 have been carried out to decide which of the panel regression model types should be used. The first is the F test, which examines the presence of individual effects, and the other is the Hausman test, which examines which estimator should be preferred for panel regression model estimation in the presence of individual effects. When the results in Table 6 are examined, it is seen that there are individual effects, and the fixed effects model should be preferred for panel regression model estimation.

Table 6. Individual Effects Tests

Tests	Statistics	P-Value
F-Test (Individual Effect)	64.79	0.000
Hausman Test (Fixed Effect & Random Effect)	30.41	0.000

In this study, a different approach was preferred to the effects of *lnfdi* and *lnict* on environmental quality. The validity of the EKC hypothesis and the effects of energy usage (renewable or fossil) differences on environmental quality differ during periods when *lnfdi* and *lnict* are above and below the specified threshold values. From this motivation, it is preferred to use the panel threshold model, which is a nonlinear approach that includes the fixed effects. First, does the estimated threshold values for *lnfdi* and *lnict* have a statistically significant threshold effect? It is possible to see the answer to this question in Table 7. The threshold values for the *lnfdi* and *lnict* are statistically significant at 5% and 10%, respectively. Accordingly, the important threshold values are 13.475 for *lnfdi* and 4.690 for *lnict*.

Table 7. Threshold Effect Test

Threshold Variable	Threshold Value	RSS	MSE	F-Stat	P-Value	Critical Values*		
						10%	5%	1%
lnfdi	13.475	2.296	0.005	46.980	0.036	36.996	43.642	54.993
lnict	4.690	2.263	0.005	54.850	0.079	52.069	60.309	79.259

* *Bootstrap critical values were calculated from 1000 replicates.*

Considering the threshold values specified in Table 7, the models in equations (2) and (3) are estimated. According to the panel threshold regression model estimation results in Table 8, the EKC hypothesis is not valid in Model-1. However, in Model-2, where *lnict* is the threshold variable, the EKC hypothesis is valid at all levels of *lnict*. Furthermore, in Model-1, it is seen that fossil energy consumption increased and had a higher effect on *lnefp* during periods when *lnfdi* exceeded the threshold. Conversely, the effect of renewable energy consumption on *lnefp* decreases during periods when *lnfdi* exceeds the threshold. In Model-2, unlike Model-1, the increasing effect of fossil energy consumption on *lnefp* decreases during periods when *lnict* exceeds the threshold, and the reducing effect of renewable energy consumption increases.

Table 8. Estimation Results of Panel Threshold Model

Dependent Variable: *lnefp*				
Variable	Model-1		Model-2	
	lnfdi<13.475	*lnfdi>13.475*	*lnict<4.690*	*lnict>4.690*
lngdp	0.723 (1.347)	0.632 (1.335)	3.647** (1.410)	3.763** (1.431)
lngdp²	-0.0143 (0.0673)	-0.0153 (0.0661)	-0.159** (0.0720)	-0.155** (0.0717)
lnren	-0.0805** (0.0327)	-0.0759*** (0.0322)	-0.0663*** (0.0227)	-0.0776** (0.0371)
lnfos	0.370*** (0.0905)	0.505*** (0.0808)	0.430*** (0.107)	0.396*** (0.119)
lnict	-0.00517 (0.00827)	-0.00906 (0.00777)	-0.00826 (0.00814)	
lnfdi	0.149*** (0.0335)		0.197*** (0.0354)	0.0981*** (0.0273)
Constant	-8.768 (6.892)		-24.64*** (7.344)	
F-Statistics	230.02***		357.26***	
Obs.	500		500	
Groups	25		25	

*Robust standard errors in parentheses and *** p<0.01, ** p<0.05, * p<0.1* *lnfdi* and *lnict* coefficients show that while FDI positively affects EFP in both models, ICT has no statistically significant effect on EFP. These results show that while the high levels of FDI are an important factor that reduces environmental quality (and vice versa), ICT has a significant indirect (due to threshold effect) but positive effect on environmental quality.

Summary, recommendations

This paper envisaged and estimated a panel threshold model for 25 EU countries and Turkey for the period of 1995-2014, which linked EFP per capita with GDP per capita, renewable energy per capita, fossil energy per capita, FDI inflow, and ICT. Data availability may be assumed as a limitation of current study, however, our data period is still long enough to obtain important linkages between the variables. The main contribution of the current study was threefold: contrary to previous EKC studies, to analyze the EKC hypothesis by using more a comprehensive indicator of environmental quality than emissions, and to investigate the PHH hypothesis for the EU countries and Turkey. Thirdly, the role of FDI and ICT has been tested for these countries by using threshold modelling for the first time.

The obtained findings of our study can be summarized as follows. Since EKC is validated when the ICT is used for the threshold value, EFP increases with economic growth, then reaches a certain level (called the turning point) and tends to decline with greater level of economic development. According to the findings, however, ICT does not affect EFP. Despite this finding, it has been determined that other variables differ significantly in favor of environmental quality when ICT has a threshold variable.

The other important finding is that our results found evidence supporting the PHH hypothesis for 25 EU countries and Turkey. In any case, FDI and fossil energy increase environmental pressure in the analyzed countries. Therefore, FDI does not help reduce environmental pressures. Conversely, FDI inflow stimulates fossil energy utilization. Moreover, environmental regulations seem do not seem to play a promoting role on environmental quality. It's surprising to see this conclusion, since the EU has ambitious targets related to the environment and renewable energy in their energy mix.

Hence, the EU countries should tighten the environmental regulations on FDI inflow. Furthermore, since renewable energy consumption has positive impact on EFP, countries in the EU and Turkey should intensify the effective renewable energy incentives such as FITs, taxes, R&D, grants loans, etc., to increase the renewable energy deployment in energy mix. Therefore, we conclude that the findings of our research provide important information for policy makers both in the EU countries and Turkey.

Declarations

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