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Pollution haven hypothesis

Revisiting the pollution haven hypothesis within the context of the environmental Kuznets curve

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Abstract

Purpose – This purpose of this study is to explore the impact of global trend of economic integration and interconnectedness which has drawn the attention of world economies and their implications on trade inflow. This trajectory has its impact, either positive/negative, on key macroeconomic indicators, to say the least on environmental sustainability, especially emerging economies. To this end, the need to explore the connection between foreign direct investment (FDI) inflow and energy consumption amidst the wave of economic globalisation is timely and pertinent for the case of Turkey.

Design/methodology/approach – This study seeks to explore the interaction between the outlined variables in a carbon-income framework for annual time series data from 1970 to 2016. A series of econometrics strategies was used consisting of unit root tests to examine the stationarity properties of the highlighted series. Subsequently, Pesaran's Bounds testing technique is used to explore the long-run equilibrium relationship between the highlighted variables in conjunction with the Johansen cointegration test. For long-run regression coefficients, Pesaran's autoregressive distributed lag and dynamic ordinary least squares methodology are used, and innovative accounting approaches are used to explore the responsiveness of each variable on another.

Findings – Empirical results validate the pollution haven hypothesis (PHH) in the long run for the case of Turkey. Thus suggesting that FDI inflow induced environmental degradation in Turkey. Additionally, this study observed that renewable energy, on the contrary, improves the quality of the environment. This study also affirms the presence of the environmental Kuznets curve phenomenon, indicating that Turkey, at its early stage of economic trajectory, emphasis is on economic growth rather than environmental quality. This suggests a need for more deliberate action(s) by the government administrators to pursue cleaner FDI inflow and energy technologies and strategies to foster a clean environment in Turkey and a cleaner ecosystem at large.

Originality/value – This study is unique in its choice of variables which is in line with the United Nations Sustainable Development Goals (SDGs) agenda to be achieved by 2030 and is very limited in the extant literature. From the economic perspective, the effect of the PHH is of interest especially to ascertain the extent the interplay among the variables has on the economy of Turkey. The empirical insights on PHH hypothesis have received less documentation in the extant literature especially for emerging economy like Turkey. Thus,

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this study seeks to revisit this theme for Turkey with aim to presents environmentally sustainable strategies without compromise for economic growth. Thus, this study seeks to revisit this theme.

Keywords Environmental sustainability, Pollution haven hypothesis, Carbon-reduction strategies, Renewable energy Turkey

Paper type Research paper

Abbreviations

ADF = Augmented Dickey–Fuller;
PHH = Pollution haven hypothesis;
PP = Philips and Perron;
FDI = Foreign direct investment;
ARDL = Autoregressive distributed lag;
ACI = Akaike Information Criterion;
DOLS = dynamic ordinary least squares;
GDP = Gross domestic product;
EKC = Environmental Kuznets curve;
ECT = Error correction term;
SDG = Sustainable Development Goals.

1. Introduction

For most emerging economies, the mixture of foreign direct investment (FDI), economic globalisation and renewable energy consumption is a significant element in the growth and development process of the economies (Asongu *et al.*, 2018; Joshua and Bekun, 2020). Besides the obvious reasons of creating capital and more employment, it is capable of stimulating and multiplying economic growth through efficiency by firms who provide cutting-edge innovations and technological solutions in the management practices (Guadalupe *et al.*, 2012; Javorcik and Poelhekke,2017; Koçak and Şarkgüneşi, 2018; Shahbaz *et al.*, 2019). FDI has both direct and indirect connections with gross domestic product (GDP) growth. However, there seems to be questions about its environmental implications. Studies have theorised that, in developed countries, multinational co-operations often relocate "dirty" sectors to developing and emerging economies with far fewer environmental treaties and standards to maximise the profit of the weaknesses developing and emerging blocs. This is known as the pollution haven hypothesis (PHH).

The relationship between economic globalisation, FDI, renewable energy consumption and the environment can take different dimensions. First, a deliberate measure instituted to combat degradation of environmental sustainability may deter economic globalisation as most of the global actors, especially in the multinational, would prefer less-environmental conscious countries to exploit and get away with it; FDI would be discouraged because foreign corporations may identify destinations where regulations of the environment are very minimal if not absent, and renewable energy firms would prefer to operate within a framework where the environmental regulations are not stringent; hence, they are not held accountable for environmental degradation. However, the effect of these variables on the environment can either be positive or negative. The positive effect can be when the global actors, foreign and renewable energy firms, adopt less-polluting production techniques, modern types of equipment and technologies to intentionally displace polluting domestic firms and organizations as well as compelling them to adopt clean and friendly environmental measures given the presence of the foreign counterparts. The negative effect is when the global actors, foreign and, renewable energy firms, deliberately take steps such as relocating or establishing their base in specific destinations to take advantage of the not well-structured environment regulating framework through outsourcing their polluting operations to the domestic firms.

In recent times, the debate over the impact of economic globalisation, FDI, renewable energy consumption and environmental sustainability has been controversial and dominated the literature with no clear position (Asongu and Le Roux,2017; Omri *et al.*, 2019; Eluwole *et al.*, 2020). The plausible explanation on inconsistence in the literature is credited to countries selection explored, variances in econometrics estimation techniques and data. The investigation into PHH is from the behaviour and tendency of global industries with pollution-intensive capacities who explore and degrade environmental sustainability of a location, then relocate to another area that is environmentally viable and friendly with relaxed rules to exploit (Wagner and Timmins, 2009). It is expedient to explore the empirical insights into the PHH tendencies given the mix of variables under consideration.

Taking a critical look from the theoretical standpoint, the interaction between FDI, renewable energy consumption and globalisation on the environment generates three effects: scale, composition and technique effects. The continuous increase in the economic activities over time to intentional changes in the industrial structure in the economy, such that there is guaranteed greater output per time, vis-à-vis the use of advanced technologies and innovations in driving a cleaner environment, reduces pollution while output is intensified. Whereas two outstanding hypotheses would be necessary for investigating the nexuses and effect on Turkey, this study will pay critical attention to the empirical insights from the PHH as it readily predicts a negative impact of FDI majorly on the environment. However, the pollution halo hypothesis, as the second hypothesis, predicts a relationship between FDI and environmental sustainability (Etokakpan *et al.*, 2020).

There are several studies on the relationship between FDI and the environment in many countries with conflicting results but very few regarding the empirical insights of revisiting the PHH for Turkey using economic globalisation index and renewable energy consumption variables as additional variables to circumvent the bias associated with omitted variables. This study is unique in its choice of variables, which is in line with the United Nations Sustainable Development Goals (SDGs) agenda to be achieved by 2030 because it is very limited in the extant literature. The present study is carried out in a carbon-income environment within the context of environmental Kuznets curve (EKC). From the economic perspective, the effect of the PHH is of interest especially, to ascertain the extent of the interplay of a relationship among the variables and its impact on the economy of Turkey given that empirical insights from the hypotheses are inconclusive. Also, given the attention in the extant literature, although less documentation is available for the case of Turkey (the study interest), the study seeks to revisit the PHH in an EKC environment as to whether the PHH is valid or the pollution halo hypothesis holds. Additionally, the current study used a battery of econometrics analysis for the robustness of estimation and policy crafting.

2. Literature review

The discussion between globalisation, FDI and environmental sustainability has assumed a prominent position in the energy-environment literature, and it is ongoing with contentious momentum. The dynamics regarding the combination of these variables do not produce a linear direction but rather take diverse dimensions with no particular consideration and conclusion. The outcomes suggest a multidimensional approach with different standpoints (Wang, 2019; Bekun *et al.*, 2020). There has been no consensus on the impact of FDI on climate change. For example, Salehnia *et al.* (2020), while testing Porter and the PHH with economic variables and CO_2 emissions using data between 2004 and 2018 from 14 Middle East and North Africa countries (MENA) countries in a cross-country panel quantile regression method, discovered that FDI harms CO_2 emissions. Also, a similar result was found by Karimov (2020) while using data between 1970–2014 in analysing the empirical relationship among FDI, GDP, CO_2 emissions, renewable energy contribution in the context of EKC and PHH regarding Turkey using augmented Dickey–Fuller (ADF) unit root, Phillips–Peron, Johansen cointegration and Granger causality tests. The results indicate that FDI harms the sustainable development of the Turkish economy. Peng (2018) also confirmed the negative effect of FDI on climate change in a spatial econometric analysis of the influence of FDI on China Haze pollution considering 31 provinces while using data from 2006 to 2015. Using data for India between 1981 and 2011 in analysing the causality relationship between FDI and air pollution using the Granger causality test, Kumar and Chander (2016) show that FDI has a significant negative impact on the air quality in India. Evidence of FDI's negative impact on climate change has not only been true for MENA and Asian countries, but also for African countries. Aliyu and Ismail (2015) analysed the relationship between FDI and pollution haven using pooled mean group method for 19 African countries with data from 1990 to 2010. The result indicates that energy intensity associated with FDI inflows has a significant increasing effect on greenhouse gas emissions across the sample countries.

FDI growth has been observed to have a positive correlation with climate change. This phenomenon has been evident in many studies. Using data between 1971 and 2014 for Pakistan, Nadeem *et al.* (2020) analysed the relationship between inward FDI and environmental degradation using an autoregressive distributed lagged (ARDL) model. The results indicate that FDI inflow positively correlates with carbon dioxide emissions. Ayadi *et al.* (2019) also found that FDI inflow highly and positively correlates with carbon dioxide emissions. This result is from a study conducted in Nigeria using data between 1970 and 2017 in an ARDL model framework. A similar outcome was presented by Terzi and Pala (2020) for Turkey, using data between 1974 and 2011 in the study to ascertain the validity of the PHH. The results observed from different studies in different countries show that FDI inflow positively correlates with carbon dioxide emissions (Solarin *et al.*, 2017; Sun *et al.*, 2017; Yildirim *et al.*, 2017; Shahbaz *et al.*, 2018).

Despite many studies indicating that FDI positively correlates to climate change, other studies show no correlation between the two variables. Blanco *et al.* (2013), in their analysis on the impact of FDI on CO_2 emissions, used data from 18 Latin American countries between 1980 and 2007 in a panel Granger causality analysis. The finding indicates no robust evidence that FDI causes CO_2 emissions. Contrary to this result, Yildirim (2014), in a study considering 76 countries with data from 1980 to 2009 on energy use, CO_2 emissions, energy consumption, economic growth and FDI, found mixed results changing from country to country. This result is similar to that presented by Usman and Manap (2010) in a study on FDI and multinational corporations on sustainable development in Nigeria. See Appendix Table A1 for a summary of studies related to the theme investigated, the variables, bloc or countries specific, timeframe with different techniques of estimation used and outcomes.

Following the above literature survey, this study intends to explore the following hypotheses:

H1. Does foreign direct investment mitigate ecological degradation in Turkey?

H2. Does green (renewable) energy usage in Turkey reduce environmental degradation?

H3. Does economic globalisation in Turkey enhance environmental damage?

Answers to these highlighted research questions will help position the study area towards its environmental sustainability target without compromise for economic growth

3. Methodology

3.1 Data and model specification

Our analysis used data from the yearly time series of 1970–2016 because of their availability. The variables involved in this study include per capita CO_2 (metric tons), FDI net arrivals (percentage GDP), actual GDP per capita (constant US$2010), renewable energy usage (percentage of total final energy consumption) and economic globalisation (KOF Globalisation Index). The data are from the World Bank's Development Indicators (World Development Index, 2020) except economic globalisation obtained from KOF Globalization Index (2018). The accessibility of data on all factors provided the basis for the timespan.

The aim is to investigate the influence of FDI, economic growth, clean energy usage and economic globalisation on Turkey's CO_2 emission. The overall CO_2 emission model is:

$$CO_{2t} = f\left(GDP_{t,} GDP^2{}_t FDI_t, REC_t, EG_t\right) \tag{1}$$

From equation (1), CO_2 emission denotes carbon dioxide pollution, FDI stands for foreign direct investment, GDP denotes economic growth, REC represents renewable energy intake, EG denotes economic globalisation and *t* denotes the timeframe for the estimation.

After the investigations of Shahbaz *et al.* (2016) and Solarin *et al.* (2017), all factors are expressed to their normal log except FDI, allowing the approximate elasticity parameters to be analysed. The linear framework suggested is:

$$\ln CO_{2t} = \beta_0 + \beta_1 \ln GDP_t + \beta_2 GDP^2{}_{t,} + \beta_3 \ln FDI_t + \beta_4 \ln REC_t + \beta_5 \ln EG_t + \varepsilon_t \tag{2}$$

The intercept is represented by β_0, while "β_1, β_2 … β_5" denote the coefficients to be evaluated. CO_2 emission stands for explanatory variable and ecological deterioration measure for this analysis. The association regarding FDI and CO_2 emission suggests whether or not the PHH exists. A positive FDI–CO_2 interaction approves the legitimacy of the PHH (Onifade *et al.*, 2021; Gyamfi *et al.*, 2022a) whereas, adverse association shows vice versa (Tang and Tan, 2015; Acheampong *et al.*, 2019).

Related to Sarkodie and Strezov (2019), Bekun (2022) and Bekun *et al.* (2021a), these analyses involved economic development in the FDI–CO_2 emission model. Economic advancement could raise the need for energy-intensive commodities. Moreover, the social culture development phase correlated with industrial development is projected to expand energy consumption, which results in increased carbon dioxide pollution. Under the EKC theory, the association regarding economic development and CO_2 emission has received considerable attention. The EKC theory notes that ecological pollution worsens in early stages of economic growth before it exceeds a specific per capita income standard, after which it starts to decline. Following Grossman and Krueger's (1991) initial research, several investigations examined the validity of the EKC theory, leading to conflicting findings (Gyamfi *et al.*, 2022b). To test the relevance of the EKC, the observational studies typically involve GDP as well as its square in CO_2 emission estimation presented as a function of:

$$\ln CO_{2t} = \beta_0 + \beta_1 \ln GDP_t + \beta_2 \ln GDP^2{}_t + \beta_3 \ln FDI_t + \beta_4 \ln REC_t + \beta_5 \ln EG_t + \varepsilon_t \tag{3}$$

3.2 Empirical sequence

3.3 Stationarity check

The initial issue is to explore the parameter stationarity because time series variables are considered non-stationary (Nelson and Plosser, 1982)and can end in spurious findings that are inaccurate for assumptions. We administered traditional stationarity checks like ADF and Philips and Perron (PP) techniques. The ADF and PP experiments investigate the serial association of the stationarity null hypothesis of the first difference sequence. The main benefit of the PP estimation above the ADF estimation is that the expectation of homoscedasticity is not a basic precondition in PP estimations.

3.4 Cointegration estimation

After examining the stationarity of the parameters and finding that none of the parameters incorporated of I(2) or higher, the ARDL-bound estimation method introduced by Pesaran *et al.* (2001) was used to analyse whether a co-integration association existed among the parameters. Unlike many co-integration experiments (like Engle and Granger, 1987), the ARDL method tackles possible endogeneity problems by assuming all variables are endogenous. Also, it has many benefits compared to Johansen (1988) co-integration analysis, as it is relevant to time series incorporated at level, first difference or both, and again was identified as much more efficient for few scale samples.

However, to establish robustness purposes, given that all parameters were considered at the first difference, the Johansen's (1988) cointegration estimation is also conducted. This estimation can predict an additional cointegration association with two or more time series and suggests that both factors are endogenous. This estimation depends on calculating maximum probability and recommends two analyses called the trace test and the maximum self-value check. The null theory of the trace analysis implies that the number of cointegrating vectors $r = n$, whereas the null hypothesis of the estimation is $r = n$, justifying the level of the matrix underestimates in addition to the number of cointegrating equations.

3.5 Autoregressive distributed lag analysis

Based on the earlier statement, our current analysis uses Pesaran *et al.* (2001) ARDL technique. The ARDL (p,q) structure has an overall equation of:

$$\mathrm{Y_t} = \varphi_0 + \sum_{i=1}^{p} \eta_{\mathrm{i}} \mathrm{Y_{t-i}} + \sum_{i=0}^{q} \delta_{\mathrm{i}} \mathrm{X_{t-i}} + \varepsilon_{\mathrm{t}} \tag{4}$$

where φ_0 represents the intercept, $\mathrm{Y_t}$ is the dependent factors, $\mathrm{X_t}$ denotes the vector of independent factors, η_{i} denotes the scale vector, δ_{i} denotes the coefficient vector, p and q denote the lags of the dependent in addition to independent factors, while ε_{t} denotes the error term.

The ARDL template in equation (5) separates short- as well as long-run projections in the error correction mechanism listed below:

$$\mathrm{Y_t} = \varphi_0 + \varsigma(\mathrm{Y_{t-1}} - \mathrm{KX_t}) + \sum_{i=0}^{p} \eta_{\mathrm{i}}{}^{*} \Delta \mathrm{Y_{t-i}} + \sum_{i=0}^{q} \delta_{\mathrm{i}}{}^{*} \Delta \mathrm{X_{t-i}} + \varepsilon_{\mathrm{t}} \tag{5}$$

where $\varsigma = -\left(1 - \sum_{i=0}^{p} \eta_{\mathrm{i}}\right)$ and $\mathrm{K} = \sum_{i=0}^{q} \delta_i / \varsigma$.s δ_{i} * denote the short-run evaluation, ς represent the error correction and Δ is the difference operation.

In this analysis, adopting Pesaran *et al.* (2001), focused on equation (3), as described, the generalised ARDL fashion template is:

$$\ln CO_{2t} = \beta_0 + \sum_{i=0}^{q} \alpha_i \ln (CO_2)_{t-i} + \sum_{i=0}^{q1} \beta_{1,i} \ln GDP_{t-i} + \sum_{i=0}^{q2} \beta_{2,i} \ln GDP^2{}_{t-I}$$
$$+ \sum_{i=0}^{q3} \beta_{3,i} FDI_{t-i} + \sum_{i=0}^{q4} \beta_{4,i} \ln REC_{t-i} + \sum_{i=0}^{q5} \beta_{5,i} \ln EG_{t-i} + \varepsilon_t \quad (6)$$

whereby p proofs are the lag of the dependent variable; q1, q2, q3, q4 and q5 proofs are the lags of the regressors; β_0 is the intercept; and α_i, β_1, β_2, β_3, β_4 and β_5 are the factors for investigation.

The ARDL approach, however, is used to separate short- and long-run results sing the corresponding unregulated error correction mechanism.

$$\Delta \ln CO_{2t} = \beta_0 + \sum_{i=1}^{r0} \lambda_{0,i} \Delta \ln (CO_2)_{t-i} + \sum_{i=0}^{r1} \lambda_{0,i} \Delta \ln GDP_{t-i}$$
$$+ \sum_{i=0}^{r2} \lambda_{0,i} \Delta \ln GDP^2{}_{t-i} + \sum_{i=0}^{r3} \lambda_{2,i} \Delta FDI_{t-i}$$
$$+ \sum_{i=0}^{r4} \lambda_{3,i} \Delta \ln REC_{t-i} + \sum_{i=0}^{r5} \lambda_{4,i} \Delta \ln EG_{t-i}$$
$$+ \mu_0 \ln (CO_2)_{t-i} + \mu_1 \ln GDP_{t-i} + \mu_2 \ln GDP^2{}_{t-i}$$
$$+ \mu_3 \ln FDI_{t-i} + \mu_4 \ln REC_{t-i} + \mu_5 \ln EG_{t-i} + \varepsilon_t \quad (7)$$

Given that β_0 is the intercept parameter; r0, r1, r2, r3, r4 and r5 correspond to the chosen optimum lags depending on AIC. λ shows the short-run variables and μ corresponds to long-run ARDL boosts. The cointegration association is tested using the F-test. The null hypothesis of $\mu 0 = \mu 1 = \mu 2 = \mu 3 = \mu 4 = \mu 5$ is checked against the alternate assumption of $\mu 0 \neq \mu 1 \neq \mu 2 \neq \mu 3 \neq \mu 4 \neq \mu 5$. Computed F-statistics were similar to Narayan's (2005) lower and upper critical values, which are better appropriate for small samples than Pesaran *et al.* (2001). When F-statistics are greater than the upper critical bound, we infer a cointegration association among parameters. However, if F-statistics slip below the critical lower and upper limits, there is no cointegration among parameters. After we find proof of cointegration interaction among parameters as well as establishing long-run estimations, the short-run estimates are investigated as follows:

$$\Delta \ln CO_{2t} = \beta_0 + \sum_{i=1}^{r0} \lambda_{0,i} \Delta \ln (CO_2)_{t-i} + \sum_{i=0}^{r1} \lambda_{0,i} \Delta \ln GDP_{t-i}$$
$$+ \sum_{i=0}^{r2} \lambda_{0,i} \Delta \ln GDP^2{}_{t-i} + \sum_{i=0}^{r3} \lambda_{2,i} \Delta FDI_{t-i}$$

$$+\sum_{i=0}^{r4} \lambda_{3,i}\ \Delta \ln REC_{t-i}+\sum_{i=0}^{r5} \lambda_{4,i}\Delta \ln EG_{t-i}$$

$$+\ \lambda_5 ECT_{t-1}+\ \varepsilon_t \tag{8}$$

where λ_7 demonstrates the lag error correction form approximation (ECT_{t-1}), and proves the short-run change pace to the long-run balance direction. To be accurate, the ECT_{t-1} factor must be significantly meaningful and negative.

4. Empirical result and discussions

This section presents the discussion of results accordingly. From Table 1, the descriptive statistics analysis indicates that GDP has the highest average value of 9.125 growth rate per year while the lowest mean value of per capita CO_2 emissions is estimated at 1.251 metric tons per year. However, the highest median value from the analysis indicates that economic growth is at maximum, indicating the economy grows on an average of 9.027 per year, whereas FDI is the lowest with a 0.688 inflow of investment per year. Furthermore, GDP has the highest maximum value of 9.551 in growth per year, whereas carbon dioxide emissions have the lowest with 1.513 metric tons realised per year.

Table 2 presents the analysis of correlation matrix results. We observed a strong positive relationship between the variables under consideration except for renewable energy

	$LnCO_2$	LnGDP	FDI	LnREC	LnEG
Mean	1.151	9.125	1.198	2.822	3.791
Median	1.213	9.027	0.688	2.819	3.846
Maximum	1.513	9.551	3.653	3.199	4.006
Minimum	0.995	8.811	0.305	2.312	3.416
Std. Dev.	0.177	0.234	0.940	0.269	0.167
Skewness	0.062	0.392	1.071	−0.018	−1.127
Kurtosis	1.646	1.900	3.321	1.726	3.154
Jarque-Bera	2.077***	2.055***	5.284***	1.827***	5.745***

Note: ***, ** and * are 1, 5 and 10% significant level, respectively

Table 1.
Descriptive statistic

Variables	$LnCO_2$	LnGDP	FDI	LnREC	LnEG
$LnCO_2$	1				
p-value	–				
LnGDP	0.978***	1			
p-value	(0.0000)	–			
FDI	0.648***	0.642***	1		
p-value	(0.0003)	(0.0003)	–		
LnREC	−0.949***	−0.930***	−0.710***	1	
p-value	(0.0000)	(0.0000)	(0.0000)	–	
LnEG	0.704***	0.651***	0.462**	−0.686***	1
p-value	(0.0000)	(0.0002)	(0.0152)	(0.0001)	–

Note: ***, ** and * are 1, 5 and 10% significant level, respectively

Table 2.
Correlation result

VARIABLES	ADF AT LEVEL $\pi\tau$	ADF AT LEVEL $\pi\vartheta$	ADF AT 1ST DIFF $\pi\tau$	ADF AT 1ST DIFF $\pi\vartheta$	PP AT LEVEL $\pi\tau$	PP AT LEVEL $\pi\vartheta$	PP AT 1ST DIFF $\pi\tau$	PP AT 1ST DIFF $\pi\vartheta$
$LNCO_2$	−0.366	−2.793	−5.583***	−5.472***	0.033	−2.831	−6.372***	−6.270***
LNGDP	1.147	−1.400	−4.430***	−4.698***	1.149	−1.400	−4.430***	−4.698***
FDI	−1.950	−2.438	−4.526***	−4.420***	−1.950	−2.438	4.504***	−4.374***
LNREC	−0.755	−2.927	−6.843***	−6.679***	−0.326	−2.881	−7.498***	−7.437***
LNEG	−2.970	−4.176	−4.371***	−4.585***	−2.587	−2.254	−5.142***	−6.470***

Unit root test

Notes: ***, ** and * are 1, 5 and 10% significant level, respectively. Significant level respectively; thus, $\pi\tau$ is with constant, $\pi\vartheta$ is with constant and trend

Table 3. Stationary analysis

consumption which indicates a negative relationship with carbon dioxide emissions. This relationship is necessary but not sufficient to validate the propositions established that outcomes of Pearson correlation give a glimpse of the nature of the relationship between the variables of interest. However, correlation analysis is not sufficient to establish causality relationship. Hence, other econometric analyses will be used to ascertain this position.

Furthermore, Table 3 displays the results of ADP and PP unit root tests to validate the stationarity properties of the series under investigation. We observed from the results that series are non-stationary at levels. However, at the first difference, all the variables are stationary. This implies that the variables under investigation are integrated of I(1) at a 1% significance level. The PP unit root test further validates the ADF unit root test that the order of integration of the variables is I(1). However, the ADF and PP unit root tests are plagued with the inability to capture structural breaks in the series, thereby providing misleading and ambiguous outcomes. Also, Zivot and Andrews (ZA) unit root test provides the unique ability to accommodate single unknown structural breaks in the series under investigation as presented in Table 4. In considering the ZA unit root test selection, the null hypothesis is the basis of consideration given the break date selection while using the *t*-statistics vis-à-vis the critical values of the ADF unit root test. The identified break dates are inconsonant with significant political and socioeconomic landmarks witnessed in Turkish history.

The outcome from the ARDL cointegration analysis from Table 5 indicates that the F-stat. (5.348) is greater than the upper bound critical values at a 1% significance level (5.06). This study used the Akaike Information Criterion (AIC) for the optimum lag selection of 2 as the most parsimonious model. The AIC is chosen ahead of other criteria based on the data set used for this study. However, it establishes proof of long-run association among the variables. Nevertheless, there was a confirmation from the Johansen test results for robustness, as reported in Tables 7

VARIABLES	AT LEVEL	BREAK YEAR	AT 1ST DIFF	BREAK YEAR
$LNCO_2$	−0.9320	2010	−5.9860***	2003
LNGDP	−3.7654	2000	−5.6736***	2009
FDI	−0.8684	2004	−6.0411**	2006
LNREC	−1.2998	2011	−14.6375***	2001
LNEG	−0.9425	1984	−4.2548**	1995

Note: ***, ** and * are 1, 5 and 10% significant level ,respectively

Table 4. Zivot Andrews unit root test (with structural break date)

and 8. The Johansen robustness test with trace statistics and the Max–Eigen statistics reveal three co-integrating vectors of 5% and 10% significance levels, respectively (Table 6).

Having identified a co-integration connection among parameters, we also extracted long-term projections of FDI, GDP, clean energy usage and economic globalisation. Table 7 offers the long-run outcomes of this analysis.

From the estimation, it is observed that there is a positive and significant association between FDI and carbon dioxide emissions levels in Turkey. It revealed that a 1% rise in FDI will increase carbon dioxide emissions by 0.056%. The result affirms the PHH within

Table 5. ARDL bounds test to cointegration analysis

Model	*F*-Statistic	Lag length	Conclusion
$LnCO_{2t}$ = f(LnGDP, FDI, LnREC, LnEG)	5.348***	1, 1, 1, 1, 0	Cointegration
Significant level	I(0) Bound	I(1) Bound	
1%	3.74	5.06	
5%	2.86	4.01	
10%	2.45	3.52	

Note: *** is 1% significant level, respectively

Table 6. Robustness check Johansen Fisher cointegration test

Hypothesis No. of ce(S)	Fisher stat (from trace)	*p*-value	Fisher stat (from max-eight)	*p*-value
r ≤ 0	52.19**	(0.0408)	0.68*	(0.0784)
≤1	23.37*	(0.0546)	0.40*	(0.0825)
r ≤2	10.33*	(0.0749)	0.25**	(0.0425)
r ≤3	3.065	(0.9639)	0.09	(0.9718)
r ≤4	0.50	(0.4757)	0.02	(0.4757)

Note: ** and * are 1% and 5% significant level, respectively

Table 7. ARDL long-run estimation outcome (1, 1, 1, 1, 0)

Variables	Long run Coefficient	Std. error	*t*-statistic
LnGDP	1.6745***	0.3796	4.4109
$LnGDP^2$	−0.0321***	0.0010	−2.9536
FDI	0.0097**	0.0138	0.6990
LnREC	−0.1817**	0.1379	−1.3173
LnEG	0.0560*	0.0686	0.8172
Constant	−14.3866***	3.6303	−3.9626
F-statistic	121.451***		
Diagnostic estimations	Chi-square	*p*-value	
Serial correlation LM	3.21	(0.3438)	
Heteroskedastic ARCH	1.742	(0.2943)	
Jarque-Bera	1.734	(0.345)	
Ramsey Reset	0.215	(0.454)	

Notes: ***, ** and * are 1, 5 and 10% significant level, respectively. All the diagnostics estimation has an order of 1

Turkish economy and aligns with the analysis from Nasir *et al.* (2019) and Gyamfi *et al.* (2021a) but fails to confirm the outcomes of Zhu (2016) and Waqih *et al.* (2019). The finding indicates increased FDIs lead to higher pollution in Turkey. A plausible reason is that fewer environmental controls meant the nation attracted intensive-polluting factories via FDI. Much of the nation's FDI is focused on the manufacturing and infrastructure building industries, which are significant carbon-emitting sectors. Furthermore, as FDI is widely considered one of the main factors of socioeconomic development in emerging nations, the positive influence of FDI on pollution suggests that the scale influence is stronger than the technological influence in Turkey. The scale influence means that the country's FDI has contributed to expanding development and energy usage and, in turn, CO_2 emissions (Pazienza, 2019). Thus, through FDI, the Turkish administration should improve its environmental policies and concentrate on sustainable industries.

As predicted, the findings confirmed that economic growth has a direct effect on Turkey's CO_2 emission. This means that a percentage increase in GDP results in a corresponding increase in carbon dioxide emissions pollutant by 0.362%. This outcome affirms most early investigations like Solarin *et al.* (2017), Sarkodie and Strezov (2019), Bekun *et al.* (2021b), Gyamfi *et al.*. (2021b) and Ibrahiem and Sameh (2021).This finding shows that global prosperity impacts Turkey's environmental efficiency poorly. A potential reason is that the state's socioeconomic practices include unsustainable fossil fuel (such as coal, natural gas and oil) burning for domestic, profitable and industrial uses, culminating in increased pollution. Moreover, with raised GDP per capita, people grow richer and boost their appetite for energy-intensive goods. Turkey legislators are encouraged to lessen the country's reliance on fossil fuel intake and build measures to lower energy-intensive commodity production.

Furthermore, a statistically significant negative relationship is observed between renewable and environment at 5% level rejection level. It was discovered that transition to more conservative (renewable) sources of energy guarantees a better environment irrespective of the location of the economy. These align with the findings of Dong *et al.* (2017), Steve *et al.* (2021), Gyamfi *et al.*. (2022c), Ghosh (2022), de Oliveira Sousa *et al.* (2022) and Tuna *et al.* (2022). This is consistent with what the authors predicted, and it supports the theoretical assumption that using renewable energy sources like wind, solar and hydropower improves ecological health in Turkey. Furthermore, there is a positive association between economic globalisation and pollution, indicating that a 1% increase in globalisation leads to a 0.145% rise in pollution. The outcome suggests that openness of trade with the outside world is creating more environmental issues for the country and does not agree with the work of Rudolph and Figge (2017), which states that globalisation decreases emissions. This demonstrates that the emerging economies have suffered some environmental deterioration as a result of opening up to the rest of the globe. The speed with which some advanced country investors enter emerging markets with carbon-intensive economic activity is indicative of the laxity on environmental laws present in some of the emerging nations. Generally speaking, this lowers environmental standards.

Table 8 shows the outcomes of the short-run analysis. From the table, most of the variables from the model revealed a positive relationship with CO_2 emission except renewable energy consumption showing a negative association with the environment. However, the GDP was observed statistically insignificant at a 10% level of significance. Furthermore, ECT was observed to be negative and explains the rate at which the long-run association among the parameters in the model will converge in this study case on an annual frequency at a 1% significance level. Following Narayan and Narayan (2010), we infer the relevance of the EKC phenomenon in Turkey as the short-run elasticity of GDP per capita (0.711) exceeds its long-run elasticity (0.362). Increased wages in the world have helped to improve pollution across the period. Some emerging nations, namely, Ghana (Solarin *et al.*, 2017), Indonesia (Kurniawan and Managi, 2018) and Pakistan (Rahman *et al.*, 2019), have examined the existence of the EKC theory. The diagnostic test validates the adequacy of the fitted model under investigation for policy formulation and direction. The results of the diagnostic tests all confirm that the fitted model does not violate any of the assumptions of the classical linear regression model including serial correlation, heteroscedasticity, normality and the misspecification bias as reported at the bottom of Table 9.

4.1 Sensitivity check: dynamic ordinal least square technique

For purposes of reliability verification, Saikkonen (1992) and Stock and Watson (1993) technique, which is dynamic ordinary least squares (DOLS), is used to test the long-term association among variables as reported in Table 9. The DOLS estimation method helps with the inherent simultaneity bias and is most suitable for small samples using lags and results inside the explanatory variables, relative to other similar estimating approaches.

The outcome displayed in Table 9 reveals that a percentage increase in FDI will increase carbon dioxide emissions (pollution) by 0.0487%. The positive relationship between FDI and CO_2 emission gives credence and validates the presence of PHH within Turkey's economy. This implies that the more FDI finds its way into the Turkish economy, the more the environment depletes. Again, as GDP rises by 1%, the carbon dioxide emissions (pollution) also rise by 2.6287%. On the contrary, there is an inverse relationship between the carbon dioxide emissions and GDP^2, the negative relationship implies the presence of EKC in Turkey. An increase in GDP square will lead to a decrease in environmental degradation. This occurs when the square of GDP is negatively related to environmental degradation. This result validates the

	Short run		
Variables	Coefficient	Std. error	*t*-statistic
ECM(−1)	−0.7032***	0.1357	−5.1811
D(LnGDP)	1.1775***	0.1965	5.9922
D($LnGDP^2$)	−0.0000***	0.0000	−3.7831
D(FDI)	−0.0096	0.0088	−1.0988
D(LnREC)	0.1278	0.0801	1.5950
D(LnEG)	0.0394	0.0480	0.8205

Note: ***, ** and * are 1, 5 and 10% significant level, respectively

Table 8. ARDL short-run estimation outcome

Variables	Coefficient	Std. error	*t*-statistic
LnGDP	2.6287***	0.4460	5.8940
$LnGDP^2$	−6.54E-**	1.37E-	−4.7687
FDI	0.0487**	0.0211	2.3069
LnREC	−0.2199*	0.0814	−2.6997
LnEG	0.1117*	0.1771	0.6309
Constant	−22.2665***	3.6141	−6.1609
R^2	0.9982		
Adjusted R^2	0.9868		

Note: ***, ** and * are 1, 5 and 10% ,significant level respectively

Table 9. Dynamic ordinary least squares (DOLS)

existence of EKC, which strongly suggests that Turkey as a nation, has adopted cleaner energy sources, such that after the initial increase in carbon dioxide emissions given the increase in GDP, subsequent increase in GDP square will result in the decline of CO_2 emission. There is a significant negative association between renewable energy intake and environmental pollution. This is further illustrated, by noting that, as clean energy increases by 1%, environmental pollution decreases by 0.2199%. This is insightful for the country under investigation. Finally, economic globalisation has positive and significant interaction with carbon dioxide emissions. The result reveals that a percentage rise in economic globalisation increases environmental degradation by 0.1117%. All these outcomes further show the robustness of the model and affirm the ARDL estimations.

Subsequently, this study applies innovation accounting stated in Rafindadi and Usman (2019) to verify the short- and long-run results. This technique adopts the combination of the forecast error variance decomposition (FEVD) and impulse response function (IRF). Table 10 shows the outcomes of FEVD, using ten periods ahead of the sample period. Specifically, the FEVD of the emissions of CO_2 due to its innovative shock is 44.10%. Except CO_2 emissions own innovative shock, renewable energy consumption shows highest contribution to the FEVD of the emissions of CO_2 with 37.78%. Then, this is followed by economic globalisation with FEVD of 8.29% and GDP growth with 6.72% and the lowest contributor to FEVD of CO_2 emissions explains FDI with 3.11% explained by its innovative shocks. In a similar development, it is required to further explore the relevant and significant shocks.

Furthermore, Lütkepohl and Schlaak (2018) suggest the use of IRF analysis, which is the second part of the innovation accounting tests and shows the reaction of the dependent variable to the external shocks from the explanatory variable used for the current study. As disclosed in Figure 1, the response of CO_2 to its standard deviation (SD) shock is positive over FEVD. Similarly, CO_2 emission to an SD shock to GDP growth is also positive. This suggests that, at first, emissions increase at initial stage of the forecast horizon and subsequently maintain a relatively fixed level over time. This outcome resonates with the results of the positive nexus between GDP growth and emission level previously established. This suggests that, although the turning point of economic growth is achieved in Turkey, the number of emissions may not decline, linked to weak environmental policies and the dependence on fossil fuel energy consumption. We also observed from IRF analysis that energy consumption responds to CO_2 emissions positively. However, we see that one SD shock to renewable energy consumption shows an inverse relationship with CO_2 emission for the study FEVD. This aligns with the need for more investments in clean and renewable energy sources. Thus, the policy drive from the IRF conforms to the result of previous analysis of GDP growth, that FDI and energy from fossil fuel induce emission

Period	S.E	LnCO_2	LnGDP	LnFDI	LnREC	LnEG
1	0.051182	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.062394	90.84323	0.223490	4.442502	3.445715	1.045063
3	0.073233	78.71157	0.496432	5.797790	10.81159	4.182619
4	0.083218	67.44780	0.903503	5.383245	19.29271	6.972749
5	0.090976	59.37593	1.642744	4.637573	26.07994	8.263820
6	0.096837	54.00919	2.666573	4.108248	30.48835	8.727634
7	0.101580	50.48261	3.799460	3.750085	33.20913	8.758721
8	0.105823	47.98570	4.879607	3.496219	35.03835	8.600124
9	0.109923	45.94522	5.859477	3.295200	36.48400	8.416108
10	0.114030	44.10375	6.724350	3.107616	37.77650	8.287779

Table 10. Error forecast variance decomposition

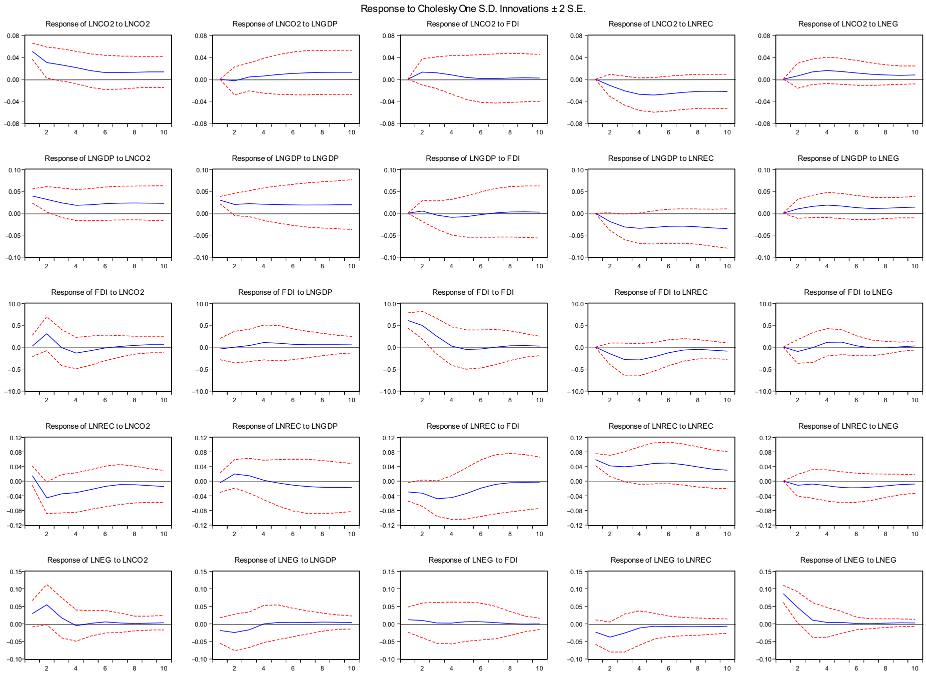

Figure 1.
Impulse response analysis

preposition. The vector error correction model (VECM) Granger Causality is presented in Table 11.

Table 11 reports the VECM Granger causality test is important in offering a variable's contemporaneous value using its predictability ability and its past realisation on another variable within the period under investigation. It is interesting to observe one-way causality flowing from economic growth, FDI and renewable energy intake to carbon dioxide emissions. These causality results have implications for the Turkish economy. For instance, the economic expansion-induced CO_2 emissions aligns with the earlier outcome of ARDL, which it is instructive given the insight that Turkey as an emerging economy deals with activities that will grow the various sectors of its economy even though some of these

Table 11.
VECM Granger causality estimation analysis

Standard error (SE)	Chi-sq	*p*-value
$LnCO_2 \rightarrow LnGDP$	1.9000	(0.3867)
$LnGDP \rightarrow LnCO_2$	0.2105***	(0.0001)
$LnCO_2 \rightarrow FDI$	1.5456	(0.4617)
$FDI \rightarrow LnCO_2$	8.9040**	(0.0117)
$LnCO_2 \rightarrow LnREC$	2.1074	(0.3486)
$LnREC \rightarrow LnCO_2$	15.0137***	(0.0005)
$LnCO_2 \rightarrow LnEG$	1.0100	(0.6035)
$LnEG \rightarrow LnCO_2$	3.6070	(0.1647)

Note: *** and ** are 1% and 5% significant level, respectively activities may cause environmental degradation to an extent, after which environmental consciousness and awareness will set in. We also see FDI worsen the environment by inducing more carbon dioxide emissions. The stakeholders need to exercise caution while ensuring that the attracted foreign investment comes along with recent technology in their line of products to enhance a cleaner environment. Finally, renewable energy intake is observed to induce CO_2 emissions. This seems to negate the position that canvassed that renewable energy is the way forward to ensure a cleaner environment. At the initial phase of renewable energy intake, it is possible not to have the best technology and the technical know-how of processing renewable, especially given the switch. The absence of these elements seems to be responsible for increases in carbon dioxide emissions. However, over time, the situation will be different.

5. Concluding remark and policy implications

5.1 Concluding remark

Global world integration necessitates the need for trade flow across economies. This trade flow comes in the form of FDI as a green investment in the host country. Global trade volume has increased in record time, especially among developing and emerging economies. However, trade comes with environmental implications, and Turkey is no exception. The distinction from the previous studies is investigating the PHH in a carbon-income framework, incorporating key macro-economic indicators like economic globalisation, FDI and energy consumption from 1970 to 2016 for Turkey, which have received less documentation in the extant literature while using innovation accounting tests. The Pesaran's Bounds test alongside Johansen cointegration show a cointegration relationship between the highlighted variables. Our empirical results from the ARDL regression validate the PHH with FDI trade inducing environmental degradation in Turkey, with the global concern for climate change mitigation. A similar trend is observed between energy and economic growth, which increases environmental pollution.

5.2 Policy implications

These outcomes have inherent policy implications for the Turkey macroeconomic situation.

- There is a need to revamp the country's energy mix on its increased economic growth trajectory without compromising the quality of the environment. This position is evident in the results of the EKC phenomena established in this study. The concept highlights the emphasis on economic growth at initial stage of economic growth before a turning point where economic growth is not detrimental to the quality of the environment.
- Given the negative impact of FDI, GDP growth and energy consumption from fossil fuel sources in Turkey, an emerging country, we suggest the need for deliberate policy to mitigate the adverse effect of FDI inflow and non-renewable energy consumption.
- Overall, from a policy standpoint, there is a need to shift to renewable energy consumption adoption like photovoltaic sources, hydro energy and wind energy as well as the adoption of new technologies. On FDI trade inflow, there is a need for enforcement of the polluters paying fines, this concept will emphasise the need to enforce regulations on those who pollute the environment as subject to mitigating damaged environment.

Though this study examined the PHH for the case of Turkey by incorporating economic globalisation and energy consumption into the extant current, there is still a vacuum left unexplored as a future guide for other researchers to advance the body of knowledge on this theme. Thus, the need to emphasise demographic indicators like democracy or population in the PHH is a value-added to the literature using disaggregated data. The present study was limited in data availability at the micro level for more investigation on the key database. The focus on Turkey alone is another limitation as a case for an emerging bloc on the theme of EKC and PHH. Thus, motivating our suggestion for further study in other emerging blocs like Sub-Saharan African, MENA and E7 economies. Even with Turkey as a case study, the authors suggest N-Shape EKC for future studies.

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Appendix

Author(s)	Country	Period	Method	Results
Salehnia *et al.* (2020)	14 countries of the MENA	2004–2016	Panel Econometrics	The effect of FDI on the amount of CO_2 emissions is negative
Karimov (2020)	Turkey	1970–2014	ADF Unit Root, Philips–Perron, Johansen co-integration, and the Granger Causality tests	FDI has negative impact on sustainable development of Turkish economy
Nadeem *et al.* (2020)	Pakistan	1971–2014	ARDL	FDI inflow positively correlates with CO_2 emissions
Nathaniel *et al.* (2020)	Coastal Mediterranean Countries (CMCs)	1980–2016	Panel	The results suggest that the PHH does not hold for CMCs
Ayadi *et al.* (2019)	Nigeria	1970–2017	ARDL	FDI inflow highly and positively correlates with CO_2 emissions
Terzi and Pata (2019)	Turkey	1974–2011	Toda-Yamamoto augmented Granger Causality method	Effect of CO_2 emissions on FDI inflows supports the PHH
Liu *et al.* (2019)	China	1996–2015	Panel	There is no relationship between FDI and air pollution in China
Lorente *et al.* (2019)	MINT (Mexico, Indonesia, Nigeria and Turkey)	1990–2013	FMOLS, DOLS	The empirical results reveal an inverted-U shaped relationship between FDI inflows, economic growth and the ecological footprint.
Shahbaz *et al.* (2018)	France	1955–2016	Unit root test	FDI inflow positively correlates with CO_2 emission in France
Peng (2018)	31 provinces of China	2006–2015	The Spatial Econometric Analysis	FDI has a negative effect on Chinese haze pollution
Solarin *et al.* (2017)	Ghana	1980–2012	ARDL	GDP, FDI, urban population, financial development and international trade have a positive impact on CO_2 emissions, while institutional quality decreases emissions in Ghana
Yildirim *et al.* (2017)	Turkey	1974–2013	ARDL VECM analysis and Granger causality testing	When the long-term coefficient estimation results are examined, increase in real national income and energy consumption increase environmental pollution
Sun *et al.* (2017)	China	1980–2012	ARDL	The results of the bounds test show that there is a stable long-run relationship between chosen variables

(*continued*)

Table A1. Literature summary survey on the theme under consideration

Table A1.

Author(s)	Country	Period	Method	Results
Kumar and Chander (2016)	India	1981–2011	The Unit Root test, Johansen Co-integration test, and Granger-causality test	The findings show that FDI has significant and negative impact on air quality in India.
Aliyu and Ismail (2015)	19 African countries	1990–2010	Pooled Mean Group (PMG)	Energy intensity associated with FDI inflows has a significant increasing effect on the greenhouse gas emissions across the sample countries
Gökmenoğlu and Taspinar (2015)	Turkey	1974–2010	The Toda and Yamamoto (1995) causality test	Evidence of the validity of the pollution haven hypothesis in Turkey.
Yildirim (2014)	76 countries	1980–2009	Panel	Empirical tests produce changing results country by country
Blanco *et al.* (2012)	18 Latin American countries	1980–2007	Panel Granger causality tests	Findings provide no robust evidence that FDI causes CO_2 emissions
Blanco *et al.* (2011)	18 Latin American countries	1980–2007	Panel Granger causality tests	No robust evidence that FDI causes CO_2 emissions
Usman and Manap (2010)	Nigeria	1970–2005	ARDL	M[a]

Note: M here means mixed results on PHH; FMOLS = Fully modified ordinary least squares
Source: Author's compilation