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The Relationship Between Foreign Direct Investment, Economic Growth, Energy Consumption and Co2 Emissions: Evidence from ARDL Model with a Structural Break for Turkey

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ABSTRACT

This paper investigates the impact of foreign direct investments, energy consumption and economic growth on CO2 emissions in Turkey for the period of 1974-2015 by using autoregressive distributed lag (ARDL) model with a structural break. The robustness of the model is tested by using FMOLS, DOLS and CCR estimators. The findings reveal a long-run relationship between the variables, and show that FDI contributes positively to CO2 emissions, validating pollution haven hypothesis. Economic growth (measured by GDP) has a significantly positive relationship with CO2 emissions whereas impact of its squared on CO2 emissions is also significant but negative which confirms Environmental Kuznets Curve (EKC) hypothesis. Energy consumption is also positively associated with CO2 emissions, implying that larger levels of energy consumption lead to a higher environmental degradation. The dummy variable including the structural break is similarly statistically significant and positive. It is concluded that because of FDI inflows engender an increase in carbon emissions, Turkey should adopt cleaner technologies to avoid environmental pollution.

Keywords: CO2 emissions, pollution haven hypothesis, foreign direct investment, energy, economic growth.

JEL Classification Codes: O13, O44, Q56

INTRODUCTION

Environmental issues in economics are typically ignored until the late 1980s, but the topic has secured an increasing interest among economists for a few decades. The environment which we live in is affected by various sorts of economic activity. The industry, households, governments, the institutions and the state of technology altogether construct an economy that operates within the environmental system. The environment provides the aforementioned economic system with inputs of raw materials, energy and natural resources which are eventually transformed by economic system into outputs (Hanley et al., 2013). As a result, the environment is regarded as an economic asset that is crucial to the operation of the economic system. Although the higher economic activity may lead major improvements in human life, it arises through a tradeoff in use of environmental resources, resulting in increased scarcity (Barbier, 2011). The depletion of natural resources is a matter of interest and it is widely acknowledged that economic activity is in some forms are related with this depletion. Natural resources are becoming increasingly scarce over time and thus it is important to consider how to leave a clean and safe environment for future generations. The extensive interest on the awareness on environmental degradation has found an expansion area with the influential paper of Grossman and Krueger (1991) which assumes an inverted-U shaped relationship between income and environmental pollution. However, the ongoing debate on the nexus between income and environmental pollution is still contentious (Panayotou, 1997; Stern, 2004; Apergis and Payne, 2009). Obviously, income is not the sole factor in influencing environmental quality. Several other factors such as exponential energy consumption (Menyah and Wolde-Rufael, 2010; Zakari et al., 2021), foreign direct investment inflows (He, 2006; Tang, 2015; Solarin et al., 2017), trade openness (Shahbaz et al., 2013b; Zhang et al., 2017), urbanization (Hossain, 2011; Lv and Xu, 2019), corruption (Cole, 2007; Sinha et al., 2019; Go et al., 2021) and financial development (Sadorsky, 2011; Omri et al., 2015; Bekhet et al., 2017) are also directly related with the environmental quality of a country.

Turkey has experienced a significant increase in energy consumption, CO2 emissions and foreign direct investments during the last few decades. CO2 emissions (metric tons per capita) have been almost quadrupled in the last five decades. CO2 emissions were measured as 1.22 metric tons per capita in 1970, and the employed quantity was 5.01 metric tons per capita in 2018. Greenhouse gas emissions of Turkey increased significantly during the period of 1990-2010, primarily

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due to CO2 emissions, and according to Carbon Dioxide Information Analysis Center (CDIAC) of the United Nation (UN)'s data of 2008, Turkey was among the top 25 CO2 emitting countries in the world (Seker et al., 2015; Mutafoglu, 2012). The noticeable increase in CO2 emissions is mostly induced by increased rate of energy consumption. In 1970, the energy consumption has measured as 522.2 kg of oil equivalent per capita and it was estimated as 1651.3 kg of oil equivalent per capita in 2015 (World Bank, 2022). According to the International Energy Agency, the industry in Turkey is highly energy-intensive and is admitted as one of the most energy-intensive among OECD countries (Isiksal et al., 2019). Although, it has had some fluctuating performances, particularly during periods of crisis, foreign direct investment inflows have followed a similar path, with FDI (foreign direct investment) inflows accounting for 34 percent of GDP in 1970 and 105 percent of GDP in 2020. A brief glance to Turkish economy reveals that it has encountered several structural changes during the last half-century. In the early 1980s, Turkey has started to implement liberalization policies which resulted in significant economic growth emanated by considerable increase in international trade, financial sector inflows and foreign direct investments. This makes Turkey as an important case involving the relevant variables.

As a major tool on transferring technology, financial capital and other skills, foreign direct investments (FDIs) have three types of impacts on host country that they are economic political and social. The political effects focus mostly on the insecurity of national independence and the social effects are primarily concerned with the possibility of cultural transformation of society and creation of foreign elite in host country. Economic effects, on the other hand, imply a variety of outcomes in terms of output, the balance of payments and market structure (Moosa, 2002). The majority of the studies agree that FDI contributes to economic growth via providing capital, increasing productivity, creating new job probabilities and boosting competitiveness (De Mello, 1999; Mallampally and Sauvant, 1999; Hermes and Lensink, 2003; Batten and Vo, 2009; Faras and Ghali, 2009; Alfaro et al., 2010; Chee and Nair, 2010; Choong et al., 2010; Lee, 2013; Iamsiraroj, 2016). However, some studies have explained that there is no direct impact of FDI on growth (Carkovic and Levine, 2002; Durham, 2004) or the occurrence of positive effects of FDI on welfare and growth requires the presence of other factors or preconditions, such as a specific level of human capital stock or adequate level of investment in the absorption of foreign technologies and skills (Borensztein et al., 1998; Blomström and Kokko, 2003; Mencinger, 2003; Akinlo, 2004). Although the nexus between foreign direct investment and growth is highly debated, the economic effects of FDI mainly neglect to consider environmental issues (Pazienza, 2014). However, there is a direct impact of FDI on environmental degradation and the contributions on this area have extended during the last decades.

We investigate the impact of foreign direct investments, energy consumption and economic growth on CO2 emissions by using autoregressive distributed lag (ARDL) modeling approach to cointegration with a structural break. The study assumes that there is at least one structural break in certain specific periods for each variable because the investigation spans a reasonably long-period. The main aim of the study is to explore the relationship between environment, foreign direct investments, economic growth and energy consumption by including a structural break to the analysis. The study also aims to explain whether pollution haven hypothesis is valid by investigating the impact of FDI on CO2 emissions. Although there are several studies using ARDL methodology, this study differs from the literature by including a structural break to ARDL model as an exogenous variable. The following chapter includes a literature review on the nexus of related variables. The third chapter presents the basic methodologies used in the analysis and continues with the findings. The study is finalized with conclusion chapter.

LITERATURE REVIEW

Environmental degradation related issues such as energy consumption, economic growth, foreign direct investment, financial development or trade openness are highly popular among economists and there are increasing number of studies attempting to explore new aspects of this area. Several new theories have emerged as a result of the contribution of these studies. The investigation of the relationship between income and environment has caused Environmental Kuznets Curve (EKC) to be discovered which suggests an inverted-U shaped association between economic growth and environmental degradation (Grossman and Krueger, 1991). Some studies have validated EKC hypothesis (Acaravci and Ozturk, 2010; Ren et al., 2014; Boluk and Mert, 2015; Shahbaz et al., 2018), whereas others have found no support for it (Chandran and Tang, 2013; Al-Mulali et al., 2015; Dogan and Turkekul, 2016). The relevant literature on Turkey has also yielded conflicting results. Gurluk and Karaer (2004)'s study is among the first which investigates the relationship between economic growth and CO2 emissions, and they find an inverted-U type relationship over the period 1975-2000. Basar and Temurlenk (2007), on the other hand, discover an N-shaped relationship and find no evidence for the validity of EKC hypothesis in Turkey between 1950 and 2005. By using the Johansen cointegration methodology, Akbostanci et al. (2009) find a unique long-run relationship between economic growth and CO2 emissions, but reject the validity of EKC hypothesis and suggest a monotonically increasing relationship for the period of 1968-2003. Katircioglu and Katircioglu (2018) support the increasing relationship for Turkey in the period of 1960-2013, demonstrating that the association between economic growth and CO2 emissions is not inverted-U shaped. By using an ARDL approach, Halicioglu (2009) proposes a long-run relationship between economic growth and CO2

Table 1. Studies on the relationship between GDP, EC, FDI and CO2 emissions for Turkey

Author(s)	Period	Variables	Methodology	Results
Halicioglu (2009)	1960-2005	GDP, CO_2, EC, TRA	ARDL bound test	No support on EKC hypothesis.
Ozturk and Acaravci (2010)	1968-2005	GDP, CO_2, EC, EMP	ARDL bound test	No evidence on supporting EKC hypothesis.
Mutafoglu (2012)	1987-2019	GDP, CO2, FDI	Johansen cointegration, Granger causality	No evidence of FDI-led growth and supporting evidence on PHH.
Kocak (2014)	1960-2010	GDP, CO2	ARDL bound test	EKC hypothesis is not supported in the long-run.
Balibey (2015)	1974-2011	GDP, CO2, FDI	Johansen cointegration test, Granger causality	A long term relationship exists between variables and an increase in FDI causes an increase in CO2 emissions.
Seker et al. (2015)	1974-2010	GDP, CO_2, EC, FDI	ARDL, ECM, Granger causality	Although it is relatively small, FDI has positive impacts on CO2.
Gokmenoglu and Taspinar (2016)	1974-2010	GDP, CO_2, EC, FDI	ARDL bound test, Toda-Yamamoto causality	Economic growth, energy consumption and foreign direct investments are long-run determinants of environmental degradation.
Kaya et al. (2017)	1974-2010	GDP, CO2, FDI, TRA	ARDL, Granger causality	FDI has a negative impact on CO2 in short run, but affects positively in long run.
Kilicarslan and Dumrul (2017)	1974-2013	CO2, FDI	Johansen cointegration test, VECM model	PHH is valid.
Kizilkaya (2017)	1970-2014	GDP, CO_2, EC, FDI	ARDL bound test.	No significant relationship between FDI and CO2 emissions.
Ozturk and Oz (2017)	1974-2011	GDP, CO_2, EC, FDI	Maki cointegration test, Granger causality	EKC hypothesis is valid. FDI has positive effects on environment, validating pollution halo hypothesis both in long- and short-run.
Kocak and Sarkgunesi (2018)	1974-2013	GDP, CO2, FDI, EC	Maki cointegration test, DOLS, Hacker and Hatemi-J test	Long-run relationship between the variables and pollution haven hypothesis is valid in Turkey.
Haug and Ucal (2019)	1974-2014	GDP, CO2, FDI, TRA, POP, FD	Linear and non-linear ARDL	Increases in FDI have no significant impacts on CO_2 emissions in long-run. Increases in imports cause an increase in CO2.
Isiksal et al. (2019)	1980-2014	GDP, CO_2, EC, FDI, TRA, RIN	ARDL bound test, Hatemi-J cointegration test	The EKC hypothesis and PHH are valid.
Mert and Caglar (2020)	1974-2018	FDI, CO2	Hidden cointegration tests	Increases in FDI cause a decrease in CO2 both in long and short-run. Supports the validity of asymmetric pollution halo hypothesis.
Bildirici (2021)*	1975-2017	GDP, CO_2, EC, FDI, TER	Pedroni, Kao and Westerlund cointegration tests	FDI contributes to GDP and increases environmental pollution.
Agboola et al. (2022)	1970-2020	GDP, CO_2, EC, FDI, URB	Dynamic ARDL	Supports the validity of PHH in short run and the pollution halo in long run.

*This paper investigates not only Turkey, also three other countries (China, India and Israel). Explanations for variables are GDP= economic growth, EC= energy consumption, CO2= Carbon dioxide emissions, FDI= foreign direct investment, TR= trade openness, EMP= employment, CF= capital formation, POP= population density, RIN= real interest rates, URB= urbanization, TER= terrorism, FD= financial development.

emissions. However, the findings of the study do not support EKC hypothesis. Omay (2013) and Tirgil et al. (2021) find an N-shaped relationship for Turkey which contradicts EKC hypothesis. Ozcan et al. (2018) also find no evidence on supporting EKC for the period of 1961-2013 for Turkey. Balibey (2015) finds an inverted-U shaped relationship, but after a turning point, when increased income causes an increase in pollution, the association becomes an N-shaped in long-run. Pata (2018, 2019), on the other hand, confirms EKC hypothesis for Turkey by using both ARDL and bootstrap ARDL cointegration tests. There are also several more studies for Turkey that

employ a variety of other variables for environment such as SO2 (Elgin and Oztunali, 2014; Karahasan and Pinar, 2021; Tirgil et al., 2021) or ecological footprint (Dogan et al., 2020; Sharif et al., 2020; Bulut, 2021) and the findings of these studies are also contradictory. The findings of Elgin and Oztunali (2014), Sharif et al., (2020) and Bulut (2021) support EKC hypothesis, whereas Dogan et al. (2020) find no evidence for it. Finally, Karahasan and Pinar (2021) find a U-shaped relationship between economic growth and environment, while Tirgil et al. (2021) assume an inverted N-shaped relationship.

There have also been numerous studies on the relationship between environmental degradation and energy consumption, with income being one of the key variables in these analyses. The interrelated relation between these variables has caused the expansion of the literature. Kraft and Kraft (1978)'s influential paper on economic growth and energy consumption is one of the early papers and it resulted in a considerable increase in studies on environmental degradation. Soytas (2007) for the U.S., Menyah and Wolde-Rufael (2010) for South Africa, Zhang and Chang (2009) for China, Pao and Tsai (2010) for BRIC countries, Alam et al. (2012) for Bangladesh, Chandran and Tang (2013) for ASEAN-5 economies, Shahbaz et al. (2013a) for Indonesia, Boutabba (2014) for India, Al-Mulali et al. (2015) for Vietnam, Alshehry and Belloumi (2015) for Saudi Arabia, Omri et al. (2015) for MENA countries, Gokmenoglu and Taspinar (2016) and Balli et al. (2020) for Turkey, Ssali et al. (2019) for 6 Sub-Saharan African countries, Bekun et al. (2019) for South Africa, Adebayo and Akinsola (2021) for Thailand, Abbas et al. (2021) for Pakistan and Ahmed et al. (2022) for 22 OECD countries are some examples of these studies. Most basically, higher energy demand is linked to higher environmental pollution in these studies and they found a causal relationship between energy consumption and environmental pollution.

The studies concerning the relationship between foreign direct investment and carbon emissions are abundant. A large number of these studies support the idea that increased foreign direct investment leads to an increasing rate of environmental degradation, especially if the environmental regulations are inadequate or non-existent (Pazienza, 2014). This concept is known as *pollution haven hypothesis* and scientific studies have been unable to provide systematic evidence of its presence and have produced controversial results. Several studies confirm the validity of pollution haven hypothesis (Bukhari et al., 2014; Shahbaz et al., 2015; Solarin et al., 2017; Mert et al., 2019; Essandoh et al., 2020; Mike, 2020; Balli et al., 2021). However, some other studies (Tamazian and Rao, 2010; Al-Mulali and Tang, 2013; Tang and Tan, 2015; Zhu et al., 2016; Jugurnath and Emrith, 2018; Salehnia et al., 2020) suggest that FDI reduces CO2 emissions, rejecting pollution haven hypothesis and arguing that FDI has positive impacts on economies of host countries. This view is mostly based on pollution halo hypothesis which contends that FDI helps developing countries to find the opportunity to improve cleaner technologies with investments on high-level research and development (Jalil and Feridun, 2011; Kocak and Sarkgunesi, 2018; Huynh and Hoang, 2019). The literature on pollution halo hypothesis is also contentious and presents a diverse nature (Balsalobre-Lorente et al., 2019; Mert and Caglar, 2020; Duan and Jiang, 2021; Kisswani and Zaitouni, 2021; Xu et al., 2021; Shinwari et al., 2022). According to He (2008), the relationship between FDI inflows and environmental pollution is significantly more complicated than a simple one-way relationship. FDI can enhance the production scale, transform the industrial structure, provide technical requirements and support host country to embrace advanced technology to control environmental degradation by increasing the income level. Therefore, FDI's impact on environment can be divided into three categories which are *scale, structure (composition) and technique effects* (Grossman and Krueger 1991; Copeland and Taylor 1994; Grossman, 1995; He, 2008; Pazienza 2014; Bakhsh et al. 2017). The scale effect implies the change in the scale of production which leads to a shift in pollution. The technique effect, on the other hand, depicts the change in pollution as a result of the use of environment-friendly technologies in production (Liang, 2014). The increment in the scale of the production will cause higher pollution levels, indicating that the scale effect is predicted to be hazardous to the environment. The technique effect refers to the utilization of cleaner technologies which are beneficial for environment (Pazienza, 2019). A growing number of studies investigate these effects. Bakhsh et al. (2017), for Pakistan during the period of 1980-2014, find that an increase in economic growth leads to an increase in pollutant emissions due to the results of technique and composition effects, using the 3SLS model. Pazienza (2019), for OECD countries, highlights the beneficial role of FDI on environment, mentioning that the scale of inflows increases, the impact of FDI decreases. He (2008), for China, concludes that scale and technique effects are the key operators of FDI's effects on environmental pollution. Pao and Tsai (2011), for BRIC countries, support the scale effect. Bin and Yue (2012), for Chinese industries, find that technological effect reduces emissions, while scale and composition effects increase emissions; however the impact of technological effect is greater than other two effects, indicating that pollution haven hypothesis is also not valid for China. Jun et al. (2018) apply the wavelet approach for China for the period of 1980-2016 and suggest that FDI causes CO2 both in short and long term and emphasize that China's participation to the World Trade Organization (WTO) in 2001 has accelerated the inflows of dirty industries, resulting in both scale and composition effects. *Table 1* denotes a literature review on economic growth, energy consumption, foreign direct investment and CO2 emissions for Turkey. As can be seen, ARDL is a common methodology among these studies. However, the results may differ. Although the majority of studies have discovered a long-term relationship between the relevant variables, the findings on both EKC and pollution haven hypotheses are controversial for Turkey.

DATA AND METHODOLOGY

The study includes the data of Turkey in the period of 1974-2015. The following model is defined to examine the relationship between CO2 emissions and foreign direct investment, economic growth and energy consumption:

$$lnCO2E_t = \alpha_0 + \alpha_1 lnFDI_t + \alpha_2 lnGDP_t + \alpha_3 lnGDP\hat{}2_t + \alpha_4 lnEnUse_t + \alpha_5 DU_t + \varepsilon_t \quad (1)$$

The data is obtained from World Bank database and the natural logarithms of the variables are taken to minimize skewness and make the relationship between economic variables more convenient to interpret. The dependent variable in the model is CO2 emissions (measured by CO2 emissions per capita) and we have four independent variables that they are foreign direct investment (measured by FDI inflows), economic growth (measured by GDP per capita), economic growth squared and energy consumption (measured by energy use per capita). DU_t is the dummy variable, denoting the break year and will be included in the model based on the results of the relevant unit root test. STATA 14.0 and EViews 12.0 software[1] are used to employ econometric analyses.

The simplest way to test unit root begins with AR(1) model which is $y_t = \rho + \alpha y_{t-1} + e_t,\ t = 1, 2\ldots$ and if ρ is left as unspecified, the null hypothesis of y_t has a unit root, H_0:α=1 and the alternative hypothesis is that H_1:α<1. When |α|<1, then y_t is a stable AR(1) process (Wooldridge, 2002, p. 578). Two of the most common unit root tests are the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests (Dickey and Fuller, 1979; Phillips and Perron, 1988). ADF is primarily concerned with the estimation of α. The null hypothesis is defined as α=0 and the alternative hypothesis is α<0. Δ denotes the first difference and t is the time trend (Glynn et al., 2007):

$$\Delta y_t = \rho + \beta_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-1} + e_t$$

We chose the optimal lag length according to the Schwert (1989)'s rule of thumb for determining the upper bound for k (k_{max}). Then, $k_{max} = 12\,(\frac{T}{100})^{1/4}$.

Zivot-Andrews unit root test with one structural break is then used. Although Dickey and Fuller (1979, 1981)'s unit root testing procedure is one of the most common methodology in economics, as Nelson and Plosser (1982) pointed out, current shocks will have a permanent effect on long-run level of most macroeconomic variables. Zivot and Andrews (1992) have developed Perron (1989)'s methodology and Perron (1989)'s unit root test allows a structural break for three alternative models. The crash model (A) allows for a shift in the intercept; the changing growth model (B) undertakes the change in the trend. The third model (C), on the other hand, considers the change both in the intercept and the trend. The null hypothesis of Perron test investigates whether the variable contains a unit root with drift by allowing an exogenous structural break at a time $1<T_B<T$. The alternative hypothesis is that the series is trend-stationary which denotes a one-time break in trend variable at time T_B. Zivot and Andrews (1992, p. 28) treat the structural break (T_B) as an endogenous occurrence and construct their regression equations to test unit root as;

$$y_t = \hat{\mu}^A + \hat{\theta}^A DU_t\left(\hat{\lambda}\right) + \hat{\beta}^A t + \hat{\alpha}^A y_{t-1} + \sum_{j=1}^{k} \hat{c}_j^A \Delta y_{t-j} + \hat{e}_t(A)$$

$$y_t = \hat{\mu}^B + \hat{\gamma}^B DT_t^*\left(\hat{\lambda}\right) + \hat{\beta}^B t + \hat{\alpha}^B y_{t-1} + \sum_{j=1}^{k} \hat{c}_j^B \Delta y_{t-j} + \hat{e}_t(B)$$

$$y_t = \hat{\mu}^C + \hat{\theta}^C DU_t\left(\hat{\lambda}\right) + \hat{\beta}^C t + \hat{\gamma}^C DT_t^*\left(\hat{\lambda}\right) + \hat{\alpha}^C y_{t-1} + \sum_{j=1}^{k} \hat{c}_j^C \Delta y_{t-j} + \hat{e}_t(C)$$

DU_t is the dummy variable which implies a shift in intercept and DT^*_t defines a shift in the trend occurring in time T_B. $DU_t(\lambda)$=1 if t>T_B and 0 otherwise. $DT^*_t(\lambda)$=t-T_B if t>T_B, 0 otherwise. Similar to Perron (1989)'s approach, Model A includes a one-time shift in the intercept. Model B is concerned with the change in a broken trend. Finally, model C checks the stationarity of the series by taking into account the change of both intercept and broken trend (Rahman and Saadi, 2008).

After employing the unit root tests, we used Pesaran & Shin (1998) and Pesaran et al. (2001)'s autoregressive distributed lag (ARDL) model to investigate long- and short-run cointegration between variables. Since ARDL model is more indifferent whether the variables are stationary at $I(0)$ or $I(1)$, it is more effective than the previous approaches. Thus, we rewrite the equation (1) in ARDL model form is shown below:

$$\Delta InCo2E_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1,i} \Delta InCo2E_{t-i} + \sum_{i=0}^{q} \alpha_{2,i} \Delta InFDI_{t-i} +$$

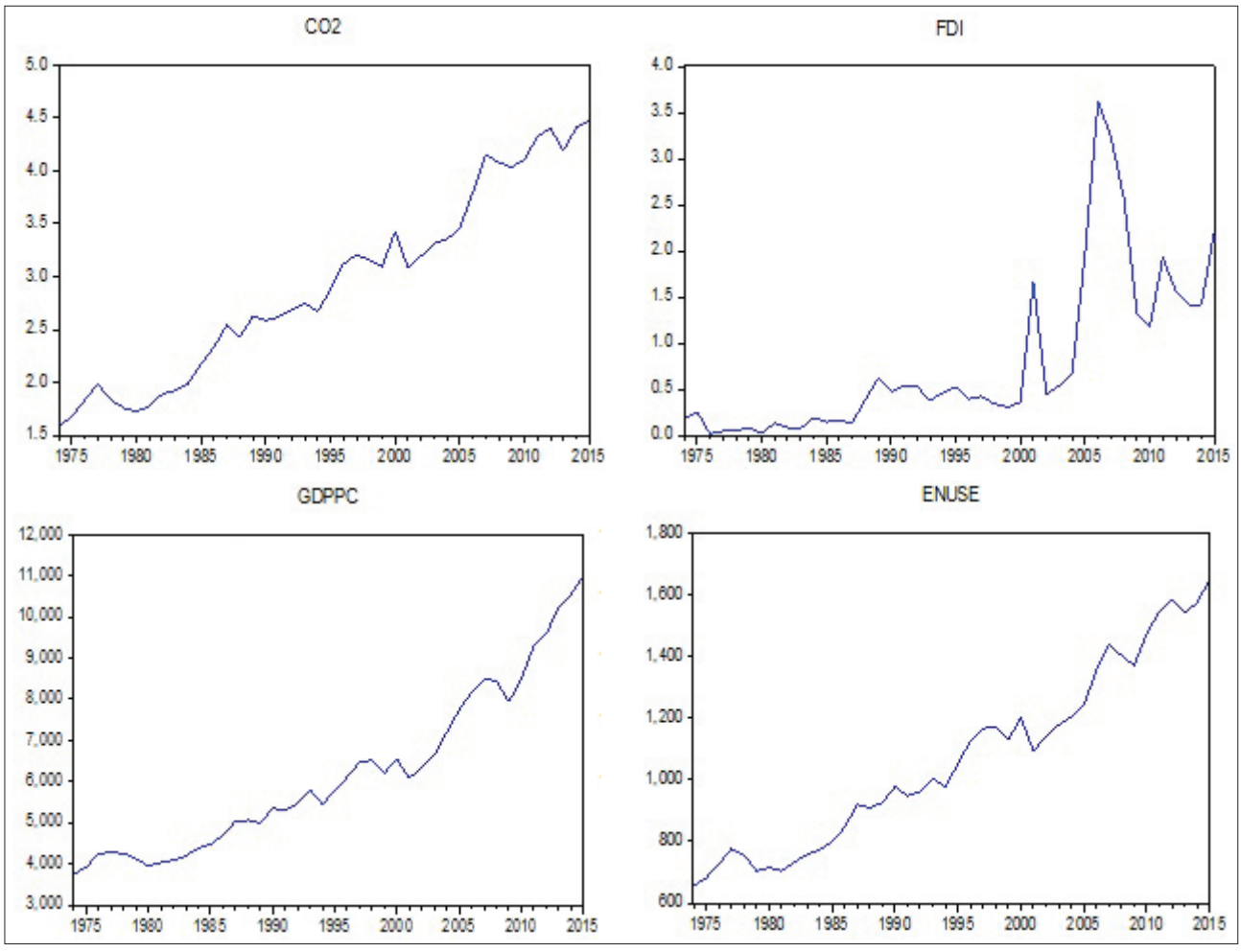
$$\sum_{i=0}^{v} \alpha_{3,i} \Delta lnGDPpC_{t-i} + \sum_{i=0}^{y} \alpha_{4,i} \Delta lnGDPpC\hat{}2_{t-i} + \sum_{i=0}^{w} \alpha_{5,i} \Delta lnEnUSE_{t-i} +$$

$$\alpha_6 DU_j + \alpha_7 lnFDI_{t-1} + \alpha_8 lnGDP_{t-1} + \alpha_9 lnGDP\hat{}2_{t-1} + \alpha_{10} lnEnUse_{t-1} + \nu_t$$

According to the test, the null hypothesis which implies no cointegration, H_0:α_6=α_7=α_8=α_9=α_{10}=0 and the alternative hypothesis is H1: $\alpha_6 \neq \alpha_7 \neq \alpha_8 \neq \alpha_9 \neq \alpha_{10} \neq 0$.

Finally, we employed Phillips and Hansen (1990)'s Fully Modified OLS (FMOLS) and Stock and Watson (1993)'s Dynamic OLS (DOLS) regressions to obtain efficient results for cointegrated variables. Both regressions are useful long-run estimators as they do not include endogeneity, small sample bias and serial correlation (Ahmad and Du, 2017). The robustness of the coefficients is assessed by using Park (1992)'s Canonical Cointegrating Regression

[1] ADF and PP unit root tests and FMOLS, DOLS regressions and CCR are estimated with EViews, Zivot-Andrews unit root tests and ARDL model are ran with Stata, and ARDL model is estimated by using Kripfganz & Schneider (2018)'s ARDL command. The optimal lag is chosen automatically due to the Akaika Information Criteria. For detailed information on the step of the analysis, see Kripfganz & Schneider (2018).



(CCR) which permits asymptotic Chi-square testing together with normal mixture distribution and deals with the problem of nonscalar nuisance parameters (Khan et al., 2020).

FINDINGS

The graphs depict the performances of time-series variables. As can be seen, CO2 variable has tended to decline, especially prior to the 1980 liberalization policies and following the 2001 economic crisis. FDI, on the other hand, has increased dramatically since the early 2000s. However, the performance of FDI is more volatile than the performance of other variables in the study. GDP and energy consumption variables also denote an increasing pattern and show a similar performance like CO2 emissions.

The findings of the traditional unit root tests (ADF and PP) revealed that the variables are stationary at their first difference, with the exception of FDI. FDI is stationary at I(0) at 1% level of significance. The findings indicate that CO2 emissions, GDP, GDP^2 and energy consumption variables are stationary at their first difference at the 1% level of significance. The assumption of null hypothesis of these tests assumes that the variable is non-stationary, while the alternative hypothesis implies the stationarity of the variable. We performed the unit root tests with a model including both trend and intercept, and the findings are summarized in *table 2*. The results confirm the applicability of ARDL model which is indifferent to the stationarity of the variables at $I(0)$ or $I(1)$.

Then, we employed Zivot-Andrews unit root test with a structural break and the findings are shown in *table 3*. Zivot-Andrews unit root test results demonstrate that all series are stationary in their first difference at least at 1% significance level both in model A and in model C. The results reveal that FDI is stationary at $I(0)$ at 5% level of significance in model A and model C and I(0) at 1% level of significance in model B. According to model C, which includes both the change in time trend and intercept, the statistically significant time break for $CO2$ emissions is 1981, which is also the same time break for GDP variables. Turkey implemented considerable trade liberalization policies in 1980, which will have an impact on crucial variables in the following years.

After employing the unit root tests, we estimated whether some series are bound together to understand the long-run relationship between the series. ARDL bound test procedure is appropriate whether the variables are integrated of $I(0)$ or $I(1)$ (Pesaran et al., 2001). According to ARDL bound test, the null hypothesis is $H_0^F:(\alpha = 0) \cap \sum_{j=0}^{q} \beta_j = 0$ and the alternative hypothesis is $H_1^F:(\alpha \neq 0) \cap \sum_{j=0}^{q} \beta_j \neq 0$.

Table 2. The findings of ADF and PPP unit root tests

Test-stat	***Level***		***1st Difference***	
Variables	*ADF*	*PP*	*ADF*	*PP*
lnCO2E	-2.988 (0.147)	-3.111 (0.117)	-6.785* (0.000)	-8.170* (0.000)
lnFDI	-4.622* (0.003)	-4.580* (0.004)	-	-
lnGDPpC	-1.868 (0.652)	-1.868 (0.653)	-6.279* (0.000)	-6.276* (0.000)
lnGDPpC^2	-1.678 (0.743)	-1.678 (0.743)	-6.282* (0.000)	-6.279* (0.000)
lnEnUSE	-3.136 (0.111)	-3.252*** (0.089)	-6.586* (0.000)	-7.157* (0.000)

Note: *, ** and *** shows 1%, 5%, 10% level of significance, respectively. Schwarz Information criterion is used and prob-values are shown in parenthesis. Test critical values are -4.192, -3.521 and -3.191 for 1%, 5% and 10% level of significance respectively.

Table 3. The findings of Zivot-Andrews unit root test

Model A	***Level***		***1st difference***	
	t-stat	*Time break*	*t-stat*	*Time break*
lnCO2	-3.965(0)	1985	-6.655(0)*	1982
lnFDI	-5.169(0)**	1988	-9.493(0)*	1981
lnGDPpC	-2.777(0)	2004	-6.334(0)*	2003
lnGDPpC^2	-2.670(0)	2004	-6.352(0)*	2003
lnEnUse	-3.348(0)	2001	-6.391(0)	1998
Model B	***Level***		***1st difference***	
	t-stat	*Time break*	*t-stat*	*Time break*
lnCO2	-3.147(0)	1990	-6.429(0)*	1987
lnFDI	-4.939(0)*	2008	-10.146(0)*	1981
lnGDPpC	-3.155(0)	2002	-6.227(0)*	1981
lnGDPpC^2	-3.182(0)	2002	-6.227(0)*	1981
lnEnUse	-3.634(0)	1981	-6.242(0)*	1981
Model C	***Level***		***1st difference***	
	t-stat	*Time break*	*t-stat*	*Time break*
lnCO2	-4.446(0)	1985	-7.601(0)*	1981
lnFDI	-5.323(0)**	2005	-10.032(0)*	1983
lnGDPpC	-3.321(0)	2001	-6.910(0)*	1981
lnGDPpC^2	-3.352(0)	2001	-6.815(0)*	1981
lnEnUse	-3.891(0)	1985	-6.789(0)*	1982

Note: The values in parenthesis are lag orders. *, ** and *** shows 1%, 5%, 10% level of significance, respectively.

Table 4. ARDL bound test results

	Coef. (p-value)	10% I(0), I(1)	5% I(0), I(1)	1% I(0), I(1)
F-Stat	26.250 (0.000)	2.632, 3.863	3.185, 4.571	4.489, 6.228
t-stat	-10.619 (0.000)	-2.538, -3.648	-2.887, -4.054	-3.597, -4.870

Note: The critical values are belong Kripfganz & Schneider (2018).

If H_0^F is rejected, testing the null hypothesis of t-stat as $H_0^t: \alpha = 0$ versus $H_1^t: \alpha \neq 0$. The definitions of the test decisions are specified as follows: we do not reject H0F or H0t, respectively, if the test statistic is closer to zero than the lower bound of the critical values; and we reject the H0F or H0t, respectively, if the test statistic is more extreme than the upper bound of the critical values (Kripfganz and Schneider, 2018). The findings of ARDL bound test shown at *table 4* depict that the null hypothesis of no cointegration between the variables is rejected, as the F-stat and t-stat go over the upper bounds in all levels, implying the statistical evidence of the presence of long-run relationship between the variables.

Since we achieved a cointegration relationship between the variables, we then estimated the long- and short-run coefficients of foreign direct investment, economic growth, and energy consumption variables. After determining the optimal lag according to Akaike information criteria, the ARDL $(1, 0, 1, 1, 0)$ regression model is estimated. The results of the ARDL cointegration test is given at *table 5*.

As it can be seen, all of the short-run and long-run coefficients are statistically significant. The positive value of GDP per capita and the negative value of GDP per capita squared confirm the validity of EKC hypothesis for Turkey, implying that income has a positive impact on CO2 emissions until a certain income level, after which the impact reverses. In the long run, a 1% increase in energy consumption leads to a 1.01% increase in CO2 emissions. FDI variable is also statistically significant at 10% level, implying a positive contribution to CO2 emissions which supports pollution haven hypothesis in the long-run for Turkey. On the other hand, the dummy variable is also statistically significant at the 5% level, indicating that the structural break in 1981 produced an increase in CO2 emissions. It stands to reason that the implementation of liberalization

Table 5. Short and long-run coefficients of ARDL (1, 0, 1, 1, 0) model

	Coefficient	t-stat	Prob.
Long-run coefficients			
lnFDI	0,008 (0,005)	1.71	0.097***
lnGDPpC	3,257 (1.156)	2,82	0.008*
lnGDPpC^2	-0,182 (0.061)	-2,99	0.005*
lnEnUSE	1,012 (0.127)	7,98	0.000*
Short-run coefficients			
ΔlnFDI	0,009 (0,005)	1,71	0.097***
ΔlnGDPpC	9,535 (2,859)	3,33	0.002*
ΔlnGDPpC^2	-0,553 (0.163)	-3,40	0.002*
ΔlnEnUSE	1,165 (0.148)	7,85	0.000*
Dum81	0,037 (0.013)	2,76	0.010**
C	-23,685 (6,568)	-3,61	0.001*
R^2	0.875	Log likelihood	107.503
ECMt(-1)	-1,151 (0.108)	-10,62*	0.000
Diagnostic Tests			
Normality: Skewness/Kurtosis test, chi^2=1.34 (prob:0.5120)			
Serial correlation: Breusch-Godfrey LM test, chi^2=0.672(prob:0.4123)			
Heteroscedasticity: Breusch-Pagan / Cook-Weisberg test, chi^2=1.13 (prob: 0.2870)			
Functional form: Ramsey RESET test, F (3, 34)=2.21 (prob: 0.1050)			
CUSUM and CUSUMSQ: Stable			

Note: *, **, *** show 1%, 5%, 10% significance levels, respectively. The values in parentheses on coefficient column are standard errors.

Table 6. FMOLS, DOLS and CCR results[2]

	FMOLS		***DOLS***		***CCR***	
	Coef. (Std. Err.)	*t-stat (prob.)*	*Coef. (Std. Err.)*	*t-stat (prob)*	*Coef. (Std. Err.)*	*t-stat (prob)*
lnFDI	0,014 (0,006)	2,280** (0.029)	0,012 (0,006)	1,868*** (0.069)	0,014 (0,006)	2,144** (0.039)
lnGDPpC	3,269 (1,413)	2,314** (0.026)	4,019 (1,450)	2,772* (0.008)	3,027 (1,555)	1,947*** (0.059)
lnGDPpC^2	-0,191 (0,074)	-2,571** (0.014)	-0,232 (0,076)	-3,058* (0.004)	-0,176 (0,081)	-2,176** (0.036)
lnEnUSE	1,160 (0,154)	7,497* (0.000)	1,132 (0,166)	6,810* (0.000)	1,160 (0,181)	6,395* (0.000)
C	-21,021 (5,820)	-3,611* (0.000)	-24,206 (5,936)	-4,078* (0.000)	-19,965 (6,345)	-3,146* (0.003)

Note: *, ** and *** shows 1%, 5%, 10% level of significance, respectively.

policies after the early 1980s would be accompanied by an increment in energy consumption, trade and foreign direct investment, all of which could eventually influence CO2 emissions. The statistically significant and negative lagged error correction term (ECT) coefficient represents that the deviations in the short run will be ameliorated by 151% per year in the long-run which indicates that the equilibrium will be ensured in less than a year. The final lines show the diagnostic test results, and there are no heteroscedasticity and serial correlation problems in the residuals and the normality results show that the residuals follow a normal distribution. Ramsey-Reset test confirms the reliability of the functional form of the model. Finally, the CUSUM and CUSUMSQ tests confirm the stability of the coefficients. The findings of the study are consistent with the results of Mutafoglu (2012), Balibey (2015), Gokmenoglu and Taspinar (2016), Kocak and Sarkgunesi (2018), Isiksal et al. (2019) and Bildirici (2021), while the study does not support the results of Halicioglu (2009), Acaravci and Ozturk (2010), Kizilkaya (2017) and Mert and Caglar (2020) for Turkey.

The cointegrated long-run coefficients can also be denoted by several regression tests and the study utilized fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) regressions, as well as canonical cointegrating regression (CCR). Despite there are few differences in significance levels of some variables, the regression results show that all variables are statistically significant, confirming the robustness of the coefficients and bolstering the long-run results of ARDL model in terms of sign and significance for all variables. The findings of the regressions also demonstrate that all variables have significantly positive impacts on CO2 emissions, with the exception of the GDP per capita squared which is also identical in ARDL model.

CONCLUDING REMARKS

The discussion on the relationship between economic growth, energy consumption, foreign direct investment and CO2 emissions has been popular, but contentious among economists for a long time. In the most fundamental sense, it is widely accepted that increased energy consumption leads to increased economic activity, which results in a reduction in environmental quality. The impact of foreign direct investments on CO2 emissions is similarly unclear, but growing numbers of studies suggest that an increase in foreign direct investments causes environmental degradation in economies with no strict environmental policies. By using an ARDL model with a structural break, the findings of the study reveal that there is a statistically significant long-run relationship between CO2 emissions and foreign direct investment, economic growth and energy consumption. The cointegrated long-run coefficients are also investigated and the robustness of the model is checked by FMOLS, DOLS and CCR estimators. The findings confirm EKC hypothesis and validate pollution haven hypothesis for the period of 1974-2015 in Turkey. EKC hypothesis argues that the environmental degradation will diminish after a threshold of a certain income level. The pollution haven hypothesis, on the other hand, implies that an increase in foreign direct investments may reinforce environmental pollution if there are weak or non-existent environmental regulations. Finally, because the considered period is marked by series of structural changes in the Turkish economy, a structural dummy variable has been included in the analysis. The aforementioned structural break is also statistically significant and it has an increasing effect on CO2 emissions after the break year. According to the findings, policymakers in Turkey should strengthen environmental regulations and invest more on environment-friendly technologies to ensure a sustainable future.

[2] The results of FMOLS, DOLS and CCR including the dummy variable is presented at the appendix 1. According to those findings, although FDI is statistically significant in both FMOLS and CCR, it is statistically insignificant in DOLS regression.

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Appendix

Appendix 1. FMOLS, DOLS and CCR results with dummy variable

(with dummy)	***FMOLS***		***DOLS***		***CCR***	
	Coef. (Std. Err.)	*t-stat (prob.)*	*Coef. (Std. Err.)*	*t-stat (prob)*	*Coef. (Std. Err.)*	*t-stat (prob)*
lnFDI	0,010 (0,005)	1,934*** (0.061)	0,007 (0,005)	1,455 (0.154)	0,010 (0,006)	1,724*** (0.094)
lnGDPpC	2,630 (1,161)	2,266** (0.029)	3,375 (1,229)	2,745* (0.009)	2,568 (1,300)	1,975*** (0.056)
lnGDPpC^2	-0,152 (0,061)	-2,483** (0.018)	-0,193 (0,065)	-2,989* (0.005)	-0,147 (0,068)	-2,167** (0.037)
lnEnUSE	1,097 (0,127)	8,594* (0.000)	1,089 (0,139)	7,842* (0.000)	1,089 (0,152)	7,142* (0.000)
Dum81	0,034 (0,012)	2,795* (0.008)	0,033 (0,013)	2,548** (0.015)	0,034 (0,012)	2,887* (0.007)
C	-17,996 (4,794)	-3,754* (0.000)	-21,258 (5,060)	-4,201* (0.000)	-17,720 (5,311)	-3,336* (0.002)

Note: *, ** and *** shows 1%, 5%, 10% level of significance, respectively.