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Impact of Foreign Direct Investment on Renewable Energy Consumption: Findings from Bootstrap ARDL with a Fourier Function

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ABSTRACT

Renewable energy consumption (REC) is viewed to be a core component for delivering sustainable economic growth. It is broadly acknowledged that REC can significantly contribute to lessening the burden of carbon emissions on the environment and fostering economic progress. Although foreign direct investments (FDI) are perceived as a key catalyst of REC growth, in some cases they can cause negative effects on REC. While there are many studies in the literature exploring the effects of FDI on variables such as economic growth, employment and foreign exchange deficits, the amount of studies examining the effect of the FDI on REC is very limited. The existing study attempts to fill this knowledge gap concerning the relationship between FDI and REC in Türkiye. This research investigates the long-run impact of FDI on RECs in Türkiye for the period 1973-2022 using the bootstrap Fourier ARDL technique. Empirical analysis reveals that FDI affects REC negatively, while GDP has no effect. The study's conclusions confirm the Pollution Haven Hypothesis (PHVH) in Türkiye, suggesting that the country has emerged as a desirable destination for businesses seeking to relocate their operations and evade the strict environmental regulations in their home countries.

Keywords: Foreign Direct Investment, Renewable Energy Consumption, Fourier ARDL
JEL Classifications: F21, Q20, C32

1. INTRODUCTION

Energy is one of the critical triggers of nations' social, cultural, and economic development (White, 1943). It contributes significantly to sustainable development by increasing productivity, income, and employment opportunities (Rapu, 2015). Türkiye has experienced a significant increase in energy demand in the past few years, mainly due to factors like economic development and population growth. As per the information provided by the Turkish Statistical Institute (Turkstat), Türkiye has experienced an increase in gross domestic product (GDP) from $149 billion in 1990 to $717 billion in 2020. This growth has been accompanied by a corresponding increase in population from 56.5 million to 83.6 million over this time. Consequently, the Republic of Türkiye Ministry of Energy and Natural Resources (ETKB) report reveals that total final energy consumption spiked from 42.237 thousand tons of oil equivalent (toe) in 1990 to 113.701 thousand toes in 2020. According to The Electricity Generation Corporation (EÜAŞ) 2022 report, the energy demand of Türkiye is currently experiencing an upward trend; however, the country's fossil fuel resources are insufficient to meet this demand. As a result, Türkiye became a net energy importer in 2021; imports accounted for 78% of Türkiye's total energy consumption (EÜAŞ, 2022).

There is no denying that climate change poses a significant challenge in our era, and its effects on our communities are mainly adverse. Recent research has identified greenhouse gas (GHG) emissions, specifically those linked to human energy consumption, as one of the primary factors in rising climate change (Intergovernmental Panel on Climate Change [IPCC], 2023). As energy consumption continues to rise in the Turkish economy, so does the release of harmful GHG. Turkstat's data revealed a significant increase in GHG emissions from 220 million tons (mt) of carbon dioxide (CO_2) equivalent in 1990 to 524 mt CO_2 equivalent in 2020. In similar, the amount of GHG emissions per capita has also risen from 4.0 tons in 1990 to 6.3 tons in 2020.

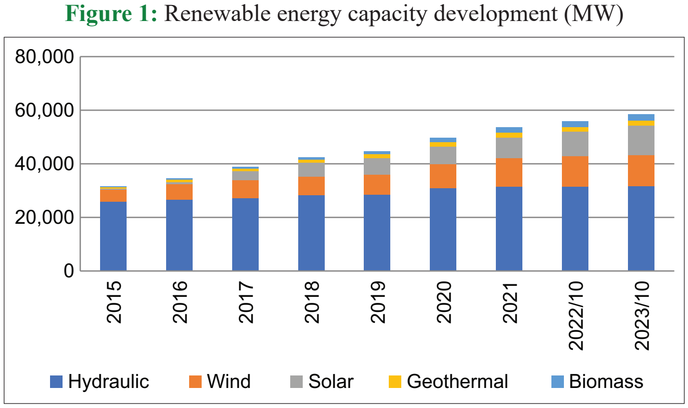
Türkiye's reliance on imported and fossil energy has significant implications for its macroeconomic stability and sustainable growth, given the volatility of exchange rates and energy prices. To bolster its energy security, the country must prioritize the production of clean, domestic energy. Although Türkiye does not possess significant fossil fuel reserves, its geographic location offers substantial capacity for harnessing renewable energy resources. Accordingly, investing in the renewable energy sector is a critical step towards reducing Türkiye's dependence on imported fossil fuels and realizing sustainable growth. Figure 1 displays the rise in Türkiye's renewable energy installed capacity over the years. The majority of the installed capacity consists of hydraulic energy, followed by wind, solar, geothermal, and biomass energy.

For nations grappling with financial constraints, transitioning towards renewable energy sources can take much work. Thus, it has become imperative for the private sector to participate in such investments rather than being a mere option (Donastorg et al., 2017). In this context, FDI is essential to help the renewable energy sector develop. It creates opportunities for host countries to acquire technology transfer and spillovers, which are crucial for the sector to grow and develop. Empirical evidence shows that FDI can be one of the critical catalysts for economic growth in developing countries with established financial markets and that this growth can, in turn, indirectly impact REC (Fan and Hao, 2020). According to the Europe Attractiveness Survey of May 2023, Türkiye's low-cost production opportunities give it a competitive edge over other European countries. As a result, inward FDI increased by 22% from 264 in 2021 to 321 in 2022, placing Türkiye in the fifth position in Europe in terms of inward FDI in 2022. Unfortunately, the renewable energy sector in Türkiye only received 3 FDIs in 2022 (EY, 2023). Upon examining Figure 2, it is evident that there is no observable correlation between REC and FDI. Hence, in an International Investors Association (YASED) January 2023 report, it is noted that \$0.8 billion of the overall FDI inflows were derived from debt instruments, whereas \$7.1 billion originated from investment capital inflows and \$5.6 billion from the sale of real estate to foreign nationals in 2022. Thus, real estate sales constituted 42.3% of the total FDI inflows (YASED, 2023).

The potential influence of FDI on the environment is a matter of ongoing discussion in academic circles. Numerous studies in energy economics have delved into the complex linkage among environmental pollution and FDI. Grossman and Krueger (1991) identified three mechanisms that explain how the FDI affects nature. The scale effect mechanism argues that economic activities will expand and pollution will increase due to trade and investment liberalization as long as these activities remain the same. In short, FDI can boost economic growth but harm the environment. The composition effect is a second effect by which FDI affects the economy. This mechanism postulated that FDI can influence the structure of industries and, as a result, the composition of industrial activities. However, whether this effect will lead to a net reduction or increase in pollution-intensive activities is still being determined. As per the third mechanism, referred to as the technique effect, FDI can help to mitigate pollution through technology transfer. Through this process, the technology can permeate the local economy, resulting in heightened demand for a cleaner environment as the region's income rises (Grossman and Krueger, 1991). The diagram shown in Figure 3 demonstrates the linkage between environmental degradation and FDI, which exhibits an inverted U-shaped trend. This reveal that should the influence of scale effect outweigh that of composition and technique effects, the PHVH holds. Thus, FDI has the potential to cause environmental degradation in the receiving state. Conversely, assuming the Pollution Halo Hypothesis (PHLH) is viable, FDI can introduce pollution-reducing technologies that, once adopted by local industries, can effectively combat environmental degradation.

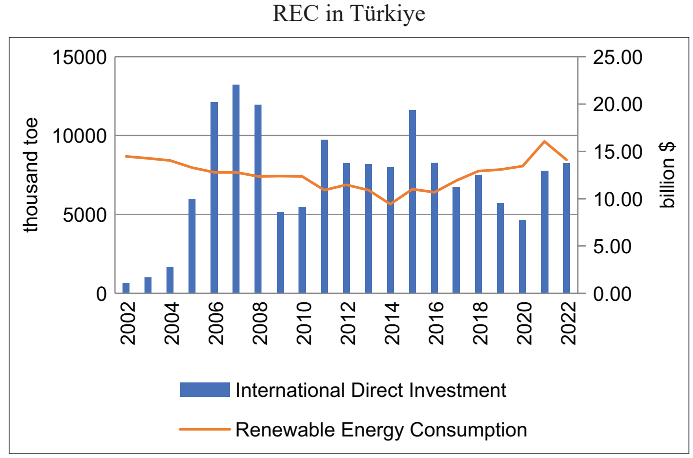
PHVH suggests that the less stringent environmental regulations found in developing countries could provide them with a competitive edge over developed nations. In the era of free trade, it has become a widespread practice for developed nations to relocate their high-pollution industries to countries with lower resource and wage costs, as well as less stringent environmental regulations. This phenomenon has resulted in the creation of safe

Figure 1: Renewable energy capacity development (MW)



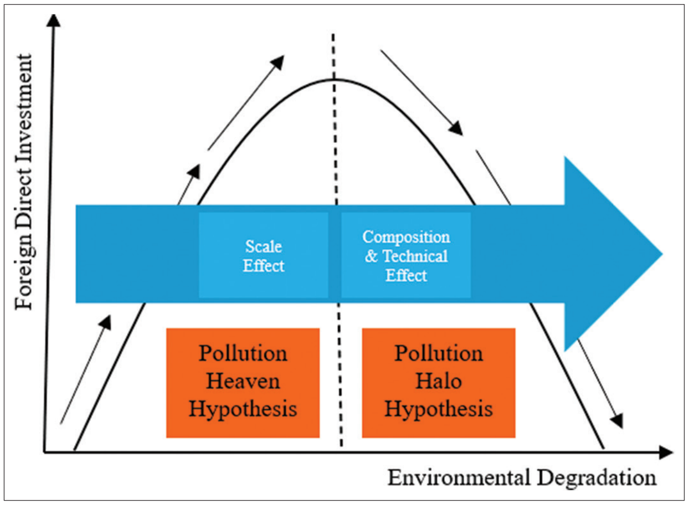
Source: Industrial Development Bank of Türkiye (TSKB), 2023

Figure 2: Development of international direct investment inflows and REC in Türkiye



Sources: YASED, 2024; ETKB

Figure 3: Impact of the PHVH and PHLH on the environment



Source: Usman et al., 2022

havens for pollution, which pose a threat to the global environment (Millimet and Roy, 2016; Dong et al., 2012; Dean et al., 2009; Hoffman et al., 2005; Cole, 2004; Copeland and Taylor, 2004; Birdsall and Wheeler, 1993). The PHVH theory suggests that the financial expenses incurred by companies can be influenced to a great extent by the environmental regulations imposed on them. This hypothesis assumes that the difference in production costs strongly incentivizes firms to relocate their output facilities. The rationale behind this view is that imposing stricter regulatory standards for environmental protection can increase production costs (Rezza, 2013).

There exists a substantial body of literature that provides evidence supporting the validity of the PHVH (Khan and Ozturk, 2020; Nasir et al., 2019; Shahbaz et al., 2019; Naz et al., 2018; Solarin et al., 2017; Sun et al., 2017), but, several studies contradict the PHVH or uphold the validity of the PHLH (Abdouli et al., 2018; Rafindadi et al., 2018; Sung et al., 2018; Zhu et al., 2016; Liang, 2014; Jalil and Feridun, 2011; Hanna, 2010; Kearsley and Riddel, 2010; Tamazian and Rao, 2010; Tamazian et al., 2009; De-Soysa and Neumayer, 2005; Husnain et al., 2024; Eskeland and Harrison, 2002; List and Co, 2000). PHLH posits that FDI has the potential to enhance the environmental performance of domestic enterprises by facilitating knowledge transfer and promoting environmentally sustainable practices (Doytch and Uctum, 2016). As per the hypothesis in question, FDI is more inclined towards employing environmentally friendly technologies and adhering to eco-friendly regulations. Consequently, investment in such projects can significantly reduce pollution levels within the host country (Kisswani and Zaitouni, 2021).

The current study aims to examine how REC is affected by FDI in Türkiye, a country with abundant renewable energy potential. For this purpose, the research is structured in the following way: The subsequent section summarizes the literature reviewed, while the third section elucidates the methodology implemented and the sources from which the data was collected. Our findings, along with a discussion, are given in the fourth section. The last part of a research paper comprises conclusions and recommended policies.

2. LITERATURE REVIEW

The nexus between REC and FDI is a topic of interest in the recent literature. While the results of research differ based on the specific country, time frame, and methodology used, many studies have concluded that FDI and REC cointegrate over time. However, there is yet to be a consensus on whether the relationship is positively or negatively correlated. The findings have been inconsistent, indicating both positive and negative effects. A small yet noteworthy body of literature also suggests no discernible link between REC and FDI.

Sbia et al. (2013) use the Autoregressive Distributed Lag (ARDL) model estimation and Granger causality technique for the United Arab Emirates (UAE) and find that variables are cointegrated, meaning they share a long-run relation. Besides, the causality runs both ways with clean energy (CE) and FDI. As in Sbia et al.'s (2013) study, Samour et al. (2022) report that FDI positively affects REC and that a linkage exists from FDI to REC.

Lee (2013) utilizes panel data analysis for G20 members and notes that FDI does not significantly impact CE, whereas GDP has a positive effect. For 20 emerging market economies applying panel data analysis, Paramati et al. (2016) observe that FDI positively impacts CE and that a relation exists from FDI to CE. A study by Mert and Bölük (2016) employ panel data analysis estimation for 21 Kyoto members and find no causality between FDI and REC. Doytch and Narayan (2016) conduct an analysis of panel data for 74 nations, in which they observe a favorable impact from FDI on REC. The study further concludes that while developed nations exhibit a mutually positive relation between FDI and REC, developing nations and the overall sample of nations demonstrate a positive impact of FDI on REC. Amri (2016) uses panel data analysis for 74 nations and reports that there exists a positive nexus between REC and FDI in developed nations, and FDI exerts a positive influence on REC in developing nations and the whole country sample. Hagert and Malton (2017) utilize panel data analysis for 56 middle-income nations and discover that REC is negatively affected by FDI. Polat and Yazgan (2018) apply panel data analysis for 85 countries, including both developed and developing nations, concluding that FDI positively impacts REC in industrialized nations but has no effect for developing ones. Ghazouani (2018) utilizes the bootstrap ARDL and Granger causality tests on 9 Middle East and North Africa (MENA) members. Empirical evidence shows that when REC is the dependent variable, there is a comovement among the series in Iran, Morocco, and Tunisia for long-run. The causality application also reveals a bidirectional linkage between FDI and REC in Armenia, Iran, Israel, Mauritania, and Morocco. Algeria and Tunisia have a causality from FDI to REC, while Egypt and Türkiye have a causality from REC to FDI. This research also discovers a bidirectional linkage between GDP and REC in Israel, Tunisia, and Türkiye, a causality from REC to GDP in Iran and Algeria, and causality from GDP to REC in Egypt.

Khandker et al. (2018) conduct a study on Bangladesh performing the Johansen approach and Granger causality, which reveal cointegration and bidirectional causality between FDI and REC.

Tasnim (2020) conducts a study similar to that of Khandker et al. (2018) finds that FDI harms REC. Furthermore, the findings of the causality approach note that there is a linkage from FDI to REC and from REC to GDPpc.

Using panel data analysis for Brazil, South Africa, China, and India, Kutan et al. (2018) detected positive impact of FDI towards REC. Additionally, the research shows a linkage from FDI to REC. A study conducted by Qin and Ozturk (2021) applies a non-linear ARDL model for Brazil, Russia, India, China, and South Africa (BRICS) and indicate that increases in foreign capital inflows exert a favorable impact on REC in India, Brazil, and South Africa, while decreases exerts an unfavorable impact on REC, except for Russia. Additionally, the research reveal that GDP has a long-run favorable effect on REC in Brazil and China. Tan and Uprasen (2022) utilize panel data analysis for BRICS and report that REC is affected by FDI in a non-linear way. Specifically, as the level of environmental regulation strictness surpasses a specific threshold, the influence of FDI on REC shifts from negative to positive. A study by Ergun et al. (2019) apply panel data analysis for 21 African nations and note that FDI positively impacts REC, whereas GDPpc negatively affects it. Moreover, the causality test discloses a bidirectional causal linkage between GDPpc and REC and unidirectional relationship from REC to FDI. Lawal (2023) employs panel data analysis for 6 African countries and concludes that GDP and FDI positively affect REC, similar to Ergun et al. (2019). Consistent with the evidence from the earlier two studies, Dingru et al. (2023), using panel data analysis, find that FDI and GDPpc have a positive effect on REC for sub-Saharan Africa and that there are linkages from FDI to REC and GDPpc.

Naz et al. (2019) use a robust least square estimator and Granger causality approach for Pakistan and note that there is no causality among REC, FDI, and GDPpc. Yahya and Rafiq (2019) employ panel data analysis for 68 countries. The countries are categorized into two groups: low-risk and high-risk. The analysis reveals that brownfield investments positively affect REC in low-risk countries and the overall sample of countries. However, the impact of brownfield investments on REC is insignificant in high-risk states. Meanwhile, greenfield investments have a favorable impact on REC in low-risk economies and the overall sample as well. However, the effect of greenfield investments on REC is negative in high-risk countries. Additionally, GDPpc exerts a favorable impact on REC in high-risk and overall samples, but the impact is insignificant in low-risk economies. Anton and Nucu (2020) use a panel data analysis for 28 European Union (EU) members and report that FDI has a negative effect on REC. A study was conducted by Caglar (2020) applies bootstrap ARDL cointegration and Granger causality methods for 9 nations. The study reports that the cointegration relationship is observed only in a few countries. The causality test results show a negative causality from FDI to REC in Morocco, a favorable causal relationship from FDI to REC in Portugal, and a negative causality from GDPpc to REC in France. For 31 Chinese provinces conducted a study, Fan and Hao (2020) find a relation from REC to FDI in both the short and long period. Ballesta et al. (2022) apply panel data analysis for 28 EU and 176 countries worldwide. The results reveal that for the sample of 176 countries, FDI has a positive impact on REC, whereas for the EU countries, the impact is negative. Furthermore, this research find that the GDPpc has a negative impact on REC for both groups of countries. Ekinci and Ölmez (2021) use the panel bootstrap Granger causality application for G20, Organisation for Economic Co-Operation and Development (OECD), and 43 states and note that there is a bidirectional relation between FDI and REC in G20 countries and 43 countries and a one-way causal linkage from RE to FDI in OECD states. In Kang et al.'s (2021) study, they apply panel data estimation for four South Asian states and note that FDI exerts an unfavorable effect on REC, while GDP has a favorable impact on REC. A study conducted by Gyimah et al. (2022) utilize a mediation model and Granger causality test for Ghana and find that REC exerts a direct and negative relation on both FDI and GDP. Furthermore, the research reveals that there is a bidirectional linkage between REC and GDP but no causality between REC and FDI. Shahbaz et al. (2022) utilize panel data analysis for 39 countries and note that GDPpc positively impacts REC. Furthermore, the analysis demonstrates a U-shaped link between REC and FDI, suggesting that the impact of FDI on REC is non-linear. Akpanke et al. (2023) utilize the panel ARDL technique for 15 West African countries and find that FDI exerts a favorable impact on REC in the long-run. Similarly, Appiah-Otoo et al. (2023) apply panel estimation for 15 West African states and note that FDI exerts a favorable impact on the REC. Moreover, the causality test discloses a bidirectional casual linkage between GDPpc and REC and unidirectional relationship from REC to FDI.

The research on the link between REC and FDI in Türkiye is limited. While several studies have been conducted with varying results based on methodology, variables used, and periods, most have found no significant relationship between REC and FDI. Er et al. (2018) use the ARDL cointegration test and find that REC is negatively affected by FDI. Arı (2021) utilize the Johansen methodology and Hacker-Hatemi (2006) bootstrap causality tests. In contrast to Er et al.'s (2018) findings, Arı's findings indicate no long-run relations among the variables, and no causality between them is observed. Çeştepe and Tatar (2023) apply RALS-EG and RALS-EG2 cointegration tests. Like Arı's (2021) study, they find no cointegration between the series.

3. DATA AND METHODOLOGY

In this research, the role of FDI on RECs is explored through the use of time series analysis. The variables employed in the model consist of annual series from 1973 to 2022. The relevant official institution has published data on the REC variable annually since 1973. The last data announced for this variable is for 2022. For this reason, annual data from 1973 to 2022 were selected as the dataset for the study. As in many studies in the literature, the GDP series was added to the model as an explanatory variable. Among the variables, REC and GDP were included in the model in logarithmic form, and FDI was added in the estimation as a ratio to GDP. The empirical model employed to explore the influence of FDI on RECs can be presented as follows.

$$REC_t=\beta_0+\beta_1 FDI_t+\beta_2 GDP_t+u_t \quad (1)$$

Table 1 sets out the descriptions of the series contained for analysis, their units and the databases from which they were obtained.

3.1. Unit Root Analysis

If the characteristic structure of a time series changes over time, or if it cannot return to the characteristic feature it lost in the face of a shock, it is thought to have a non-stationary structure, in other words, to contain a unit root. In its most general definition, stationarity is when the characteristic values of a time series, like mean, variance, and covariance, do not change over period. A variable is considered to be absolutely stationary if all moments of the probability distribution, rather than just two moments such as mean and variance, have a time-invariant structure (Gujarati, 2003). Since analyses involving non-stationary series can generate spurious regression problems, stationarity tests are performed first in time series analysis. The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) applications are among the traditional approaches that allow the detection of stationarity. The estimation equations of the ADF test, which is an upgraded type of the Dickey and Fuller (1979) approach, can be presented as follows (Enders, 2010).

$$\Delta y_t = \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \gamma y_{t-1} + u_t \quad (2)$$

$$\Delta y_t = \beta_0 + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \gamma y_{t-1} + u_t \quad (3)$$

$$\Delta y_t = \beta_0 + \beta_1 trend + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \gamma y_{t-1} + u_t \quad (4)$$

Equations (2), (3), and (4) refer to pure, intercept, and intercept-trend models, respectively. In these equations, β is the constant term, y is the variable tested for stationarity, and p denotes optimal lag length. The null hypothesis (H_0) used by all three models to investigate the stationarity is as follows.

H_0: γ=0

A decision about H_0 is made by comparing the t-statistic obtained by estimating all three models employing the ordinary least squares (OLS) procedure with the critical value stated across the relevant table. If the estimated t-statistic is smaller than the critical value in the table, H_0 is rejected and the series is considered stationary. Otherwise, the series is assumed to exhibit the unit root and to be non-stationary.

If structural breaks are ignored during data generation, traditional unit root approaches lose their power. The weaknesses of these unit root procedures can be strengthened by using dummy variables to capture the shift in level and trend when the break date is certain. In addition to these tests, new tests have been developed that allow for one or two structural breaks. However, these new tests lose their power in cases where the dates of structural breaks are not well known or there are many breaks (Enders and Lee, 2012). By adding the Fourier function to the stationary process, Enders and Lee (2012) developed an alternative procedure that solves the above issues. According to this test, also known in the literature as Fourier ADF (FADF), the Fourier term to be added to the unit root equation is as follows (Enders and Lee, 2012).

$$d(t) = \alpha_0 + \sum_{k=1}^{m} \alpha_k \sin\left(\frac{2\pi kt}{T}\right) + \sum_{k=1}^{m} \beta_k \cos\left(\frac{2\pi kt}{T}\right); \; T/2 \geq m \quad (5)$$

m in equation (5) is the count of cumulative frequencies included in the approximation, T is the number of observations, and k indicates the specific frequency. If a single frequency component is to be used, the Fourier term is as follows.

$$d(t) = \alpha_0 + \alpha_1 \sin\left(\frac{2\pi kt}{T}\right) + \beta_1 \cos\left(\frac{2\pi kt}{T}\right) \quad (6)$$

As a result, the FADF equation created using a single frequency equation is as follows.

$$\Delta y_t = \alpha_0 + \gamma y_{t-1} + \alpha_1 \sin\left(\frac{2\pi kt}{T}\right) + \beta_1 \cos\left(\frac{2\pi kt}{T}\right) + \sum_{i=1}^{p} \delta_i \Delta y_{t-i} + u_t \quad (7)$$

3.2. Cointegration Analysis

The literature contains many tests to determine cointegration, which means that variables comovement in the long-term. The Engle-Granger (1987) approach, which is considered the basis of traditional cointegration tests, only examines cointegration between two variables and is carried out under the condition that both the regressor and explained variable are first difference stationary [I(1)]. Another of the traditional tests, the Johansen and Juselius (1990) and Johansen (1991) tests, allows the examination of cointegration relationships between several variables and also reveals the condition that the variables are I(1). Unlike the other tests mentioned above, Pesaran et al. (2001) technique allows investigating the presence of cointegration without considering if the series are level stationary [I(0)] or I(1). According to this test, the unconstrained model in which the existence of cointegration is examined can be presented as follows (McNown et al., 2018):

Table 1: Explanation of series

Variable	Unit	Acronym	Source
Renewable Energy Consumption	Thousand toe	REC	ETKB
Foreign Direct Investment	Net inflows, % of GDP	FDI	World Development Indicators (WDI)
Gross Domestic Product	Constant $2015	GDP	WDI

Table 2: Basic descriptive statistics of the series

	REC	FDI	GDP
Mean	8.938	0.866	26.678
Min.	8.641 (2014)	0.019 (1976)	25.637 (1973)
Max.	9.172 (2021)	3.623 (2006)	27.808 (2022)
SD	0.097	0.855	0.628
Kurtosis	3.833	4.341	1.860
Skewness	−0.535	1.309	0.131
Jarque-Bera	3.839	2.963	2.849
Prob.	0.146	0.227	0.240
Observations	50	50	50

Table 3: Results of traditional stationarity tests

Series	ADF		PP		KPSS	
	C	C&T	C	C&T	C	C&T
REC	−3.135 (3)**	−3.059 (3)	−2.658	−2.630	0.102***	0.103**
ΔREC	−8.252 (0)***	−8.151 (0)***	−8.174***	−8.089***	0.124	0.111
FDI	−2.127 (0)	−3.193 (0)	−1.982	−3.063	0.403***	0.080***
ΔFDI	−6.639 (0)***	−6.565 (0)***	−13.258***	−13.052***	0.034	0.034
GDP	0.340 (0)	−2.472 (0)	0.475	−2.472	6.489***	0.139***
ΔGDP	−6.748 (0)***	−6.730 (0)***	−6.802***	−6.989***	0.068	0.032

Δ designates the first lag of the variable. The values in brackets refer to the optimum lag length. ** and *** signify significance at 5% and 1%, respectively

$$\Delta y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 x_{t-1} + \sum_{i=1}^{p} \delta_i \Delta y_{t-i} + \sum_{i=0}^{q} \theta_i \Delta x_{t-i} + \mu_t \quad (8)$$

Equation (8) is used to test for the presence of cointegration using F-statistic or t-statistic. The possibility of cointegration can be tested in comparison of the F-statistic calculated by estimating equation (8) with the critical value in the corresponding table. When the computed F-value passes the upper bound, it is decided that these variables are cointegrated; when the computed F-value drops under the lower bound, it is determined that these series is not cointegrated. If the F-statistic is within the upper and lower bounds of the table, a decision regarding cointegration cannot be made. This uncertainty situation in the ARDL approach was eliminated thanks to the cointegration procedure devised by McNown et al. (2018). Thus, the detection of long run comovement can be decided by testing the following three hypotheses (McNown et al., 2018).

H_{0A}: $\alpha_1=\alpha_2=0$ (all regressors-F test)
H_{0B}: $\alpha_1=0$ (the lag of dependent variable-t test)
H_{0C}: $\alpha_2=0$ (the lag of independent variable- t test)

Yilanci et al. (2020) added the Fourier term to the ARDL equation to explore the possibility of cointegration in cases where the date of structural breaks is unclear or there is multiple. Accordingly, the cointegration model to be estimated in this paper can be stated as follows.

$$\Delta REC_t = \alpha_0 + \sum_{i=1}^{p} \alpha_1 \Delta REC_{t-i} + \sum_{i=0}^{q} \alpha_2 \Delta FDI_{t-i} + \sum_{i=0}^{m} \alpha_3 \Delta GDP_{t-i} + \beta_1 REC_{t-1} + \beta_2 FDI_{t-1} + \beta_3 GDP_{t-1} + \beta_4 \sin\left(\frac{2\pi kt}{T}\right) + \beta_5 \cos\left(\frac{2\pi kt}{T}\right) + u_t \quad (9)$$

Finally, if all the test statistics calculated for all three null hypotheses are above the bootstrap critical value in absolute value, the variables are considered to be cointegrated.

4. EMPIRICAL RESULTS

Presented in Table 2 are the basic statistical measures for the analysed series in this paper. The table displays the main statistics for REC, FDI, and GDP and the years in which the extreme values of the respective series occurred. Accordingly, means REC, FDI and GDP 8.93, 0.86, and 26.67, respectively. Upon inspecting the standard deviations, it is clear that the REC variable has the smallest deviation compared to FDI and GDP variables, indicating that REC data is more closely distributed around the mean. The minimum and maximum levels for REC series were recorded in 2014 and 2021, respectively, while FDI variable recorded its minimum value in 2006 and maximum value in 2021. The GDP variable recorded its minimum value in 1973 and maximum value in 2022. Finally, the Jarque-Bera scores point to a normal distribution for all series.

Table 4: Results of Fourier ADF stationarity tests

Series	Frequency	Min. SSR	FADF test stat.	F test stat.
REC	3	0.314	−3.427 (0)**	10.997***
FDI	1	15.044	−4.287 (1)**	32.468***
GDP	1	7.944	−0.434 (1)	33.820***

The values in brackets refer to the optimum lag length. ** and *** signify significance at 5% and 1%, respectively

In conducting the analysis, the study utilizes logarithmic form for the REC and GDP variables, with FDI being considered as a ratio. In order to ensure accurate forecasting of long-run trends and to avoid spurious regressions, unit root analysis is essential as a preliminary step in assessing the stationarity of series. For that purpose, the current study employed the ADF, PP, and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) stationarity tests to identify any unit roots within the time series. The output presented in Table 3 reveals that almost all variables were found to be I(1) for both constant (C) and constant-trend (C&T) models, according to both the ADF and PP approaches. Only for the ADF test is the REC stationary at the 5% significance level in the constant model. According to the KPSS test, H_0, which claims that the series is stationary, was rejected at the level of the series but not at the first difference. Consequently, the variables were identified as I(1) in the KPSS test, as in the ADF and PP results.

The evidence of the Fourier ADF approach, which takes into account the possibility that the dates of the structural breaks are not known exactly or that there are many breaks, are shown in Table 4. Considering the outputs of this unit root procedure, the FADF test statistics of REC and FDI appear to be statistically significant at the 5% significance level. However, it is not statistically significant at the FADF value level of the GDP variable. In other words, while the REC and FDI are stationary at the level, the GDP variable is difference stationary. Since the series are stationary at different orders, the long-run linkage between them has been examined according to the ARDL approach, which allows the analysis to be performed without taking into account whether the series is I (0) or I (1).

Table 5: Results of Fourier bootstrap ARDL approach

Model	k	AIC	Lags	Test	Test Statistic	Bootstrap Critical Value		
						0.90	0.95	0.99
REC=f (FDI, GDP)	4.7	−3.040	4-4-4	H_{0A}	6.775***	3.862	4.966	6.742
				H_{0B}	−3.807**	−2.934	−3.351	−4.019
				H_{0C}	5.668**	3.411	4.936	7.849

Amount of bootstrap replications 1000. $\hat{\mathbf{k}}$ denotes number of frequency. ** and *** signify significance at 5% and %1 level, respectively

Table 6: Results of long-run estimation

Series	Coef.	t-Stat.	Prob.
FDI	−0.138**	−2.246	0.032
GDP	0.146	1.870	0.071
Constant	5.324**	2.655	0.012
Model validation tests			
x^2_{SC} : 1.379 (Prob=0.118)			
x^2_{NOR} : 0.062 (Prob=0.969)			
x^2_{HET} : 1.802 (Prob=0.115)			
x^2_{RR} : 1.192 (Prob=0.243)			
CUSUM and CUSUMSQ: Stable			

** shows the coefficients are significant at 5% level. x^2_{SC}; Breusch-Godfrey serial correlation LM test, x^2_{NOR}; Jarque–Bera normality test, x^2_{HET}; Breusch-Pagan-Godfrey heteroscedasticity test, and x^2_{RR}; Ramsey-RESET model error test

The evidence of the cointegration analysis are presented in Table 5. To detect the cointegration using the Fourier bootstrap ARDL test, the computed test statistics for each hypothesis must exceed their corresponding critical values. In other words, rejecting all three null hypotheses (H_{0A}, H_{0B}, and H_{0C}) is necessary. As Table 5 shows, H_{0A} was rejected at the 1% significance level, while H_{0B} and H_{0C} were also rejected at the 5% level. This evidence suggests that the alternative hypotheses, which propose a cointegrated relationship, can be accepted instead of the null hypotheses. Thus, the series is cointegrated, which means there are long-run relations among the series. In other sayings, REC, FDI, and GDP have a comovement in the long-run.

Table 6 lists the long-run coefficients of the analysis, which investigates the impact of FDI and GDP on REC. According to the evidence, FDI has a negative impact on REC and a 1% increase in FDI decreases REC by 0.13%. GDP has a positive but statistically insignificant effect on REC. The diagnostic test results show no problem of heteroscedasticity, serial correlation and normality in the residuals. Beside, based on the outputs of the CUSUM and CUSUMSQ tests, the coefficients in the ARDL model are stable.

5. CONCLUSION

Energy's role in economic growth is crucial for developed and developing countries. However, over-reliance on fossil fuels accelerates climate change by increasing GHG emissions and hinders the realization of sustainable growth targets. As a result, countries have explored alternative energy sources, with renewable energy sources gaining traction due to their potential to meet energy needs sustainably. Despite their potential, the high cost of investments in renewable energy sources necessitates private sector investments, particularly in developing countries. FDI can play an essential part in enhancing economic growth through potential benefits such as human capital formation, capital accumulation, productivity enhancement, employment growth, and technology transfer. In turn, this can indirectly promote the growth of renewable energy. In addition to their contributions to production, employment and balance of payments financing, FDIs also affect the environment in terms of the methods they follow in the production process and the technology they use. FDIs can affect environmental degradation and therefore REC, due to the technical and scale effects they create. FDIs coming to the country can promote the use of renewable energy by developing the technological infrastructure in the production process and attaching importance to sustainability. In such a case, while the country's income level will increase, REC will increase, and environmental quality will improve. On the other hand, FDI may not lead to the development of more advanced and new technological possibilities and may reduce RECs and, thus, environmental degradation. In other words, while these investments positively contribute to the country's economy, they may ignore environmentally friendly production. The fact that FDIs coming to the country do not develop the technological infrastructure and follow the traditional production structure based on intense fossil fuel consumption, citing the increase in production costs, may cause a decrease in RECs. Thus, although the income level in the economy increases, REC may decrease and environmental degradation may progress. For all these reasons, it is of great importance to reveal the effects of FDIs on REC, one of the most important indicators of environmental improvement and sustainability.

Despite being home to only limited fossil fuel reserves, Türkiye has significant potential for renewable energy. Moreover, due to its high potential for attracting FDI, it is essential to examine the country's linkage among FDI and REC. While a large part of the studies in the literature have been analysing the effects of FDIs on production, employment and balance of payments financing, the number of studies analysing the effects of FDIs on RECs is quite limited. For this purpose, the study investigates the long-run impact of FDI on RECs in Türkiye for the period 1973-2022 using the bootstrap Fourier ARDL technique. The empirical evidence from this study shows that FDI leads to a reduction in RECs, which also implies an increase in non-renewable energy consumption. This evidence is in line with those of Hagert and Malton (2017), Tasnim (2020), Anton and Nucu (2020), and Kang et al. (2021). This result also raises concerns about environmental sustainability and underlines the need for policy interventions. To address this challenge, a range of policy measures could be implemented, including the diversification of FDI composition, introduction of tax incentives and provide subsidies to encourage REC. These measures could help to bolster REC and mitigate the environmental consequences associated with FDI in Türkiye.

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