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Regular Article

How effective is financial development in renewable energy investments? Empirical evidence from E−7 countries☆

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ABSTRACT

Today, the world is in the middle of an energy transformation. On the one hand, consumers demand clean energy, and on the other hand, manufacturers are willing to invest in this field. In this context, this study aims to empirically examine the impact of financial development on renewable energy investments in E−7 countries in the 2000–2017 period with the panel threshold regression model developed by Hansen (1999). In addition, the study examined the effects of GDP, patent applications, carbon emissions, inflation, fossil fuel consumption, and the policy index created by the Author as control variables on renewable energy investments. As a result of the analysis, strong evidence was found that the relationship between financial development and renewable energy investments is nonlinear, and there is a single threshold value for financial development (0.3602). However, when looking at the size of the coefficients showing the marginal effects, the positive effect of the increase in financial development on renewable energy investments was found to be above the threshold value (0.8573) and below the threshold value (1.3125). This result shows that the positive marginal effect of financial development on renewable energy investments tends to decrease above the threshold value. This result is thought to be because although the amount of funds in the financial system increased in the later stages of financial development, these funds remained idle and could not be directed to renewable energy investments at the same rate as the level of increase in financial development. In other words, with the development of the financial system, an imbalance may occur among renewable energy investments in the E−7 country group. Kao Panel Cointegration, FMOLS, and DOLS methods were also used in the study to investigate the consistency of the results obtained in the Panel Threshold Regression model. The Panel Threshold Regression analysis concluded that GDP, patent applications, carbon emissions, inflation, and policy index had a significant and positive impact. At the same time, fossil fuel consumption negatively affected renewable energy investments. FMOLS and DOLS results used as alternative models also gave similar results to the panel threshold value model, except for carbon emissions and fossil fuel consumption.

1. Introduction

The energy demand, an indispensable element for human life, has increased daily since ancient times. The continuous increase in the world population and the development of technology are the main reasons for this increase in demand. In particular, the importance of energy as an economic factor has increased with the Industrial Revolution and the spread of mass production. In terms of the production and consumption of energy in demand, fossil fuels are at the forefront of global use. However, the intensive use of fossil energy resources brings some problems. Since these resources are not evenly distributed around the globe, they cause conflicts between supplying and demanding countries and regions. For example, the oil crises in the 1970s caused energy prices to fluctuate, resulting in energy price instability and negatively affecting countries' macroeconomic performance (see Fig. 1).

Fossil fuels are non-renewable energy sources that harm the environment and human health at every production stage. This is because greenhouse gases produced by the production and use of fossil fuels

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cause global warming. Global warming is an environmental event that negatively impacts the Earth in many ways. It affects many sectors in countries, such as agriculture, health care, tourism, construction, logistics, and finance, and causes various environmental, social, health, and economic changes. As a result of all these changes, a transformation process in energy supply has occurred in recent years. As a result, the world's countries have turned their attention to energy production, which contributes to reducing fossil fuel consumption and keeps environmental damage low.

At this point, renewable energy sources are coming to the fore as an excellent alternative to fossil fuels to realize the said energy transition.

Renewable energy sources are energy sources that are inexhaustible and can exist as long as the world exists, although they are consumed. Hydropower, solar, wind, biomass, geothermal, and wave energy are the primary renewable sources. In the report published by the International Renewable Energy Agency (IRENA) in 2021, titled "Global Energy Transformation," it is predicted that the share of renewable energy in energy production will gradually increase, reaching about 55% in 2030, 75% in 2040, and 85% in 2050. Therefore, investment in renewable energy is significant to meet this expectation of renewable energy growth.

Investment in renewable energy has increased dramatically in recent years. According to IRENA, global investment in new renewable energy capacity will reach $303.5 billion in 2020, up 2% from 2019. This increase in investment has seen developing and emerging economies overtake developed countries in renewable energy investment, albeit by a smaller margin than in previous years. Developing countries, particularly China and India, lead the way in renewable energy investment. On the other hand, the most investment in the last ten years has been in solar energy, followed by wind energy when evaluated by technology.

Promoting renewable energy investment depends not only on country energy policies and regulations that directly affect renewable energy penetration but also on various economic policies and strategies, technical and infrastructure factors, financial resources, and market conditions. The International Energy Agency (IEA) has identified several factors, mainly financial and economic, regulatory, institutional, technical, infrastructural and innovative, and environmental, for the growth and development of renewable energy investments.

The main objective of this study is to answer the question: is there a relationship between the level of financial development and investment in renewable energy in the E−7 countries? In the studies conducted at the international and national levels, the relationship in question has been chiefly examined at the level of renewable energy consumption and GDP. Thus, this study differs from other studies in the literature. It is assumed that a country's financial development contributes to raising funds needed for the long-term development of energy-efficient technologies by reducing firms' liquidity risk and facilitating the reallocation of funds from traditional energy with low production efficiency to renewable energy. This case investigates whether financial development's contribution to renewable energy investment in E−7 countries is positive.

In this study, the relationship between renewable energy investment and financial development was analyzed using panel threshold analysis and FMOLS and DOLS estimation methods, with data covering the period 2000–2017 for E−7 countries, and the results were evaluated.

1.1. Literature

In reviewing the energy economics literature, it was found that there are a limited number of studies on the relationship between financial development and renewable energy investment. Most studies in this context focus on determining the factors influencing renewable energy development. The following summarises selected national and international empirical and theoretical studies on the relationship between renewable energy investment and financial development.

1.2. Theoretical studies on renewable energy investments

In their study for Turkey, Kandır and Yakar (2017) investigated the reasons why renewable energy lags behind fossil fuels despite all its positive aspects. As a result of the study, they concluded that financing options should be developed to increase investment in renewable energy, with green bonds being essential in this regard, and that green bonds are necessary for Turkey to achieve its investment targets RE in the coming years.

In their study for China, Liu and Zeng (2017) examined the risks of renewable energy investment using the system dynamics method. The study first examined the technical, political, and market risks practical in RE investment. Secondly, they found that political risk is the main factor affecting RE investment in the early development stage, political risk and technological risk decrease in the future, and market risk is the main uncertainty in the investment development stage.

In their study for the Czech Republic, Dvorak et al. (2017) examined the ability of renewable energy investments to create jobs. As a result of the study, they found that biomass and waste-to-energy companies in the Czech Republic provide the highest employment per MWh, which mainly benefits employment in rural areas of the country.

Arslan and ve Uzun (2017) examined the social acceptance dimension of increasing renewable energy investments. Accordingly, they found that in addition to the importance of the government and companies in increasing renewable energy investment, the attitude of local people in the region where RE investment is to be made can also impact

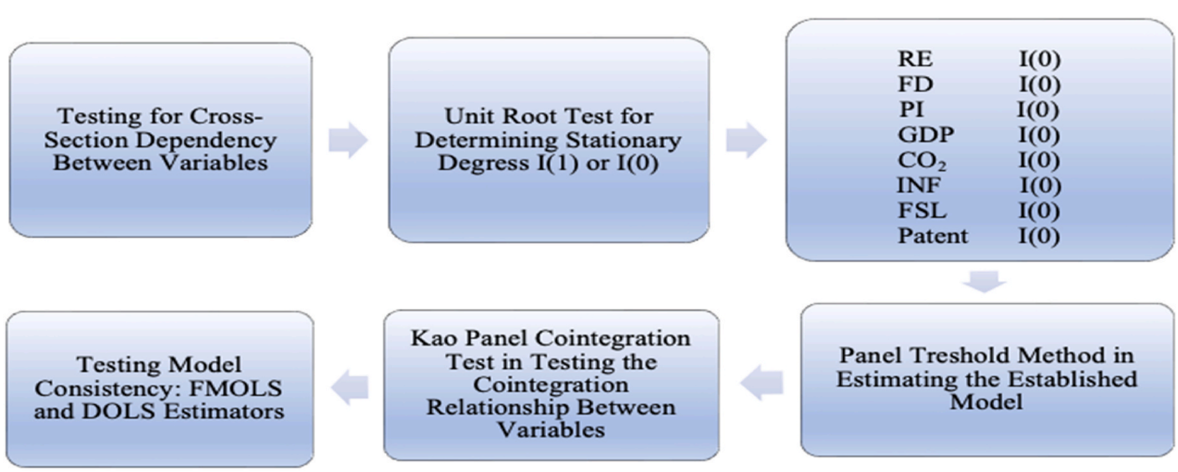

Fig. 1. Stages of analysis of the relationship between financial development and renewable energy investment.

Table 1
Summary of empirical literature examining renewable energy investments.

Author(s)	Methodology	Term	Country	Results
Wang, Zhang, and Li (2023a, 2023b)	Panel Threshold Model	1990–2018	208 Countries	Renewable energy and human capital have heterogeneous impacts on carbon emissions at pre- and post-EKC milestones. In addition, the reducing effect of trade openness on emissions is practical only in high-income countries.
Li, Wang, and Wang (2022)	Panel Threshold Model	1995–2019	120 Countries	As a result of the study, global renewable energy can support economic growth while improving the environment. It has been found that as the urbanization rate increases, the negative effect of renewable energy on the ecological footprint first weakens and then increases, and the positive coefficient on the economy continues its growth trend. Additionally, non-renewable energy has been found to have a more significant positive impact on economic growth but increases the ecological footprint.
Dinçer and Karakuş (2020)	Pedroni and Kao Panel Cointegration	1991–2018	G7	A long-term relationship was found between both variables in the study in which the relationship between RE investments and employment was analyzed.
He et al. (2019)	Panel Threshold Model	2004–2015	150 Medium, Small, and Micro Enterprises in China	The study, which analyses the development of RE investment and the green economy, found the dual threshold effect of green credit on RE investments and the green economy.
Polzin et al. (2015)	Panel Regression Model	2003–2011	OECD Countries	The study investigating the effect of public policy on RE investments found that tariff guarantees are more effective than subsidies in less technologically developed countries. At the same time, RPS is more effective in countries with relatively more advanced technology.
Sisodia and Soares (2015)	Panel Random Effects Model	1995–2011	27 EU Countries	The study investigating the determinants of wind and solar energy investments stated that the perception of solid regulation plays a negative role in solar energy investment, and lower sunlight hours lead to higher wind investment.
Popp et al. (2011)	Panel Fixed Effects Model	1991–2004	26 OECD Countries	In the study, which analyses the factors that are important in determining the investments of 4 different renewable energy sources, namely wind, photovoltaic solar, geothermal, and biomass, it has been found that the information stock represented by the patents mainly increases the investment in wind and biomass energy. In addition, while finding evidence that the ratification of the Kyoto Protocol has a more significant impact than new information on renewable energy investments, they concluded that the main driver of WPP investments is the reduction of carbon emissions and that natural resources and the percentage of energy a country imports are negligible.
Yang et al. (2019)	Threshold analysis	2007–2016	92 renewable energy companies in China	In their study examining the effects of government subsidies on RE investment, they concluded that government subsidies have a positive threshold effect on RE investment.
Jenner et al. (2013)	Panel Fixed Effects Model	1992–2008	26 USA Countries	According to the results of the study in which the effect of the tariff guarantee on wind and solar energy investments was investigated, while the tariff guarantee policies had a positive effect on solar energy investments, no relationship was found with wind energy investments.
Eyraud, Clements, and Wane (2013)	Panel Fixed Effects Model	2000–2010	Developed and Developing 35 countries	They examined the effects of interest rates, tariff guarantees, fossil fuel prices, and carbon pricing policies on green energy investments. The study results directly relate to green investments, high fossil fuel prices, low interest rates, and a sound financial system. In addition, it has been concluded that some policy instruments, such as carbon pricing and the tariff guarantee system, positively and significantly affect green investments. In addition, the study could not determine the relationship between biofuel subsidies and high investment rates.
Yin and Powers (2010)	Panel Fixed Effects Model	1993–2006	USA	The study examining the relationship between RPS and RE investments found that the increase in RPS applications had a positive and significant relationship with RE investments.
Schmid (2012)	Panel Fixed Effects Model	2001–2009	Nine states of India	The study examining the impact of tariff guarantees, private sector participation, and renewable energy policies on RE investments concluded that these policies and practices significantly impact RE investments.

*RE: Renewable Energy *RPS: Renewable Portfolio Standard *WPP: Wind Power Plant.

investment.

Bayraktar and Kaya (2016) theoretically studied the impact of public incentives on renewable energy investment in Turkey. As a result of the study, they concluded that the most commonly used instrument to encourage investment in renewable energy is tariff guarantees.

Gediz-Oral and ve Arpazlı Fazlılar, 2016 studied the importance of public-private partnerships in financing renewable energy investments in Turkey. As a result of this study, they found that renewable energy investments should increase to meet the increasing energy demand in Turkey and that this can be achieved by adopting the law on public-private cooperation, creating effective incentive mechanisms in RE investments, adjusting the timing of off-take guarantees, and promoting the use of RE in the industry.

Ayan, 2013 prioritized RE investments for Turkey using the Analytical Hierarchy Process Approach. By combining different criteria, weighting was calculated. The result determined that investments in hydropower, wind power, biofuels, geothermal energy, and solar energy could be the most suitable in Turkey.

In his study for Turkey, Erdal (2012) theoretically investigated the impact of renewable energy investment on employment. As a result of this research, they found that the increase in investment in renewable energy will help solve the unemployment problem among the country's young population and secure the energy supply.

In their study on the importance of tariff guarantees in renewable energy investment, Couture and Gagnon (2010) found that implementation will contribute to an increase in investment in this sector by increasing the market integration of renewable energy resources for reasons such as fixed price application, which reduces investment risk, and premium pricing policies, which provide incentives for electricity generation.

1.3. *Empirical studies on investments in renewable energies*

Many factors influence investment in renewable energy. Investing in emerging sectors such as renewable energy can pose risks for many investors, but it can also mean higher returns. Investments made in this sector can positively impact countries' macroeconomic indicators. The impact of renewable energy investments on a country's economy and the promotion of investments in this field are studied in the empirical literature. Table 1 provides an overview of the selected literature from studies conducted in this area. Table 1 Summary of empirical literature examining renewable energy investments.

In addition to the studies mentioned in Table 1, another critical study in this field is the work of Wang et al. (2022). In their study, Wang et al. (2022) examined the effect of urbanization on the combination of economic growth and environmental quality by expanding the traditional environmental Kuznets curve (EKC) hypothesis and using the panel threshold value method with the help of 1996–2015 data for 134 countries. As a result of the study, it was found that urbanization strengthens the positive relationship between the economy and carbon emissions and ecological footprint, and the positive effect of economic growth on the ecological footprint is more significant than carbon emissions. In addition, the study found evidence that the positive effect of economic growth on carbon dioxide emissions in high-income countries decreases as urbanization successively exceeds the Threshold. Another critical study is Wang et al., who examined the heterogeneity, asymmetry, and mediation effects of trade openness and trade diversification on carbon emissions for the OECD and G20 countries for the period 1997–2019. (2023)'s work. As a result of the study, it was found that the effect of trade on carbon emissions is heterogeneous: trade openness leads to an increase in carbon emissions, and trade diversification leads to a decrease in carbon emissions. Li, Li, and Wang (2022) investigated, in their study, carbon emissions resulting from transportation sectors in 30 provinces of China with the help of panel threshold value analysis for the period 2005–2019. According to the study, when energy efficiency is below the threshold value of 0.473 million RMB/t, carbon emissions are reduced by 0.818% for every 1% increase in energy efficiency. When the energy efficiency is higher than the threshold value of 0.473 million RMB/t, a 1% increase in energy efficiency reduces carbon emissions by 0.926%. The results also show that urbanization reduces carbon emissions from the transportation sector, but the effect of urbanization is lower than the energy efficiency effect. Additionally, it has been observed that as the level of urbanization increases, the inhibitory effect of urbanization on carbon emissions varies between −0.658 and −0.743. One of the critical studies examining the relationship between energy and carbon emissions is the Li, Wang, Liu, and Jiang (2021) study. The impact of structural changes on per capita carbon emissions from four aspects, energy, trade, society, and the economy, was discussed with the help of FMOLS and the Granger causality test with data from 1990 to 2015 for 147 countries. As a result of the study, it was found that (i) at the global level, economic growth and economic structure are the most significant positive and negative factors, respectively, affecting carbon emissions. (ii) There was a bidirectional Granger causality relationship between global per capita carbon emissions and economic growth and between global per capita carbon emissions and economic structure. (iii) At the income group level, consistent with global results, economic growth, and increased energy intensity supported increased carbon emissions. At the same time, increased renewable energy consumption also helped reduce carbon emissions. (iv) The direction and degree of impact of the remaining three factors vary among different income groups.

2. Model and data sets

This study aims to investigate the impact of financial development on renewable energy investments in the E−7 countries. For this purpose, the following model was created:

$$RE = F\,(FD, PI, GDP, CO2, INF, FSL, Patent) \tag{1}$$

Equation (1) can be rewritten in terms of panel data as follows:

$$RE_{it} = \beta_{0i} + \beta_{1i}\,FD_{it} + \beta_{2i}\,\ln GDP_{it} + \beta_{3i}\,CO2_{it} + \beta_{4i}\,INF_{it} + \beta_{5i}\,FSL_{it} + \beta_{6i}\,\ln patent_{it} + \beta_{7i}\,PI_{it} + \varepsilon_{it.} \tag{2}$$

In equation (2), I represent the panel individual (country), t represents the period, and εit represents the error term with constant variance and zero mean.

Renewable energy investments are just like other types of physical investments. In this regard, supporting renewable energy investments depends not only on energy policies and regulations that directly lead to the further deployment of renewable energy but also on a wide range of economic policies and strategies, technical and infrastructure factors, financing, and market conditions (Barnsley, Blank, & Brown, 2015; Bamati & Raoofi, 2020:446). According to the International Energy Agency (IEA), several factors go into developing and deploying renewable energy investments. These factors Are categorized as Financial and economic, Regulatory and institutional, Technical, infrastructure and innovation, and Environmental factors.

In this context, in the study,

1. As a financial and economic factor, the financial development index, real GDP, inflation, and fossil fuel consumption
2. CO2 emissions per capita as an environmental factor
3. Number of patent applications as a technological factor
4. A policy index expressing government financial support and incentives for renewable energy investment was used as a regulatory factor.

The policy index used in the study was created using the indicators expressing government support and incentives for renewable energy investments in Table 2.

The principal component analysis (PCA) method was applied in the context of selected indicators to determine the relative importance of government financial support and incentives for renewable energy investment and to construct a policy index in the E−7 countries.

The goal to be achieved with principal component analysis is to reduce p variables such as $x_1, x_2, \ldots, x_p$ p p to a smaller number of variables that can represent these variables without causing a significant loss of information and achieve different results to work with reduced new variables (Alpaykut, 2017, p. 378).

The variables in model number 2 and their explanations are listed in Table 3:

This study's period of analysis consists of annual data from 2000 to 2017 and includes China, India, Brazil, Mexico, Indonesia, Russia, and Turkey, referred to as E−7. The E−7 countries are expected to play a leading role in renewable energy generation and consumption in the coming years due to their increasing share of world trade volume, large populations, and the technological breakthroughs they have achieved. For this reason, the E−7 countries were included in the study sample.

In the study examining the relationship between renewable energy investments and financial development, it was deemed appropriate to examine the descriptive statistics of the variables before model estimation.

In this context, descriptive statistics of the variables are expressed in Table 4.

3. Methods and results

This study investigates the nonlinear relationship between financial development and renewable energy investments. For this purpose, the Panel Threshold Value method developed by Hansen (1999) was used as the primary model in the study. This model, an extension of the least squares estimation method, states that individual observations can be divided into classes based on the value of an observed variable, called a threshold variable. As the value of the Threshold variable changes, the relationship between the dependent and independent variables is expected to change non-linearly. For this reason, this method was preferred to determine the nonlinear relationship between financial development and renewable energy investments.

To empirically uncover the relationship between financial development and renewable energy investment, the procedural steps shown in the following figure were followed.

Accordingly, in the first stage, the variables' stationarity degree was determined by examining the cross-sectional dependence between the variables. In the second stage, the presence of a long-run relationship between the variables was examined using the Kao panel cointegration test. In the third stage, the coefficients were determined using the panel threshold regression model that Hansen (1999) developed as the study's base model for parameter estimation. In the final stage, the long-run coefficients were obtained by applying the FMOLS (Full Modified Ordinary Least Square) method developed by Phillips and Moon (1999) and the DOLS (Dynamic Ordinary Least Square) method developed by Kao and Chiang (2001) to examine the consistency of the results obtained with the panel threshold regression model.

3.1. Test of cross-sectional dependence

In the study conducted to analyze the impact of financial development on renewable energy investment, the first step was to test for cross-sectional dependence between series.

When there is cross-sectional dependence between series, the analysis considering this situation affects the reliability and accuracy of the results (Breusch and Pagan, 1980; Pesaran, 2004). In studies where cross-sectional dependence is not taken into account, analysis results become inconsistent and biased. Therefore, testing cross-sectional dependence between series is vital before panel data analysis.

The presence of cross-sectional dependence between series: Using the Breusch-Pagan (1980) LM test, if the time dimension is greater than the cross-sectional dimension (T > N), if the time dimension is equal to the cross-sectional dimension (T = N) Using the Pesaran (2004) CDLM2 test if the time dimension is less than the cross-sectional dimension (T < N) is checked with the Pesaran (2004) CDLM test (Yıldırım et al., 2013, p. 86).

In this study, the test of Breusch Pagan's (1980) LM was applied, which is used for cases where the time dimension is larger than the cross-sectional dimension (T > N). Table 5 shows the results of cross-sectional dependence between variables. When examining the results of cross-sectional dependence, it can be seen that the probability values of all variables are statistically less than 0.05, and the null hypothesis of "no cross-sectional dependence" is rejected. Consequently, there is cross-sectional dependence among the variables that make up the panel.

Following the cross-sectional dependence results, it was decided to use the unit root test to determine the stationarity levels of the variables used in the analysis.

Accordingly, the second-generation panel unit root test method was used in the next phase of the study, which considers cross-sectional dependence.

3.1.1. Unit root tests

Second-generation panel unit root tests are preferred in determining the degree of stationarity of variables due to cross-sectional dependence between variables. Therefore, the CIPS test, one of the second-generation unit root tests developed by Pesaran in 2007, was used in the study. Pesaran, Cross-Sectionally Enhanced Dickey-Fuller (CADF). The test was applied to the panel regression model given below, and the stationarity properties of the series were analyzed using the calculated t-statistics of the $\widehat{b_i}$ Coefficients estimated in the model (Pesaran, 2007, pp. 267–269).

$$\Delta y_{i,t} = \alpha_i + b_i y_{i,t-1} + c_i \overline{y}_{i,t-1} + d_i \Delta \overline{y}_{i,t-1} + \varepsilon_{it} \tag{3}$$

This method tests the hypothesis "not every cross-section is stationary" against the hypothesis "some cross-sections are stationary."

$H_0 : \widehat{b_i} = 0$ for all cross sections.

$$H_1 : \widehat{b_i} < 0, \mathrm{i} = 1, 2 \ldots N_1, \widehat{b_i} = 0, \mathrm{i} = N_1 + 1, N_2 + 2, N$$

Pesaran defines the arithmetic mean of the CADF test statistics (Cross-sectionally augmented IPS (CIPS)) as the cross-sectionally enhanced IPS test statistic and uses this test to determine the stationarity levels of panel data series.

The CIPS test has a standard normal distribution asymptotically and is calculated as in equation 4

$$CIPS = N^{-1} \sum_{i=1}^{N} CADF_i \tag{4}$$

Table 6 shows the variables' Pesaran (2007) CIPS Test results. According to the table, all variables used in the analysis are stationary at level values in the fixed-trend model.

3.2. Panel threshold regression

The panel threshold regression method, used as the primary model for studying the relationship between financial development and renewable energy investment, determines whether the regression is the same for all observations in the sample or is divided into different classes. Threshold regression analysis, first proposed by Tong, 1983 and further developed by Hansen (1999), has individual-specific effects and observations $\{y_{it}, q_{it}, x_{it}: 1 \le i \le n, 1 \le t \le T\}$ suggests an estimation method for balanced panels. Accordingly, i is the individual effect, time t, y_{it} is the dependent variable, q_{it} is the threshold variable, and x_{it} is a k -k-dimensional vector of exogenous regressors. Threshold regression models indicate that individual observations can be classified according to the value of an observed variable (Altintaş & Koçbulut, 2019, p. 637).

A model with only one possible Threshold:

$$y_{it} = \mu_i + \beta_i' \chi_{it} \mathrm{I}(q_{it} \le \gamma) + \beta_2' \chi_{it} I(q_{it} > \gamma) + \varepsilon_{it} \tag{5}$$

It is expressed as. In equation 5, I(.) represents the indicator function, γ represents the Threshold, and ε_it~(0,σ2) represents the independent and identically distributed (iid) error term. Depending on whether q_{it} is larger or smaller than γ, slope parameters such as β1 and β2 are divided into two separate regimes.

Equation 3.5 can alternatively be rewritten as follows:

$$y_{it} = \begin{matrix} \mu_i + \beta_1 x_{it} + \varepsilon_{it,} q_{it} \le \gamma \\ \mu_i + \beta_2 x_{it} +, \varepsilon_{it,} q_{it} > \gamma \end{matrix} \tag{6}$$

İn addition $x_{it}(\gamma) = \begin{pmatrix} x_{it} I(q_{it} \le \gamma) \\ x_{it} I(q_{it} > \gamma) \end{pmatrix}$ and $\beta = (\beta_1' \beta_2')$ Since it is expressed as, equation (5) can be written as follows (Hansen, 1999, p. 347).

$$y_{it} = \mu_i + \beta_i' \chi_{it}(\gamma) + \varepsilon_{it} \tag{7}$$

Hansen (1999) states that the first way to eliminate personal effects (μ_i) in model estimation is to eliminate individual-specific effects. For this, when equation (5) is averaged over the time index (t),

$$\overline{y}_i = \mu_i + \beta' \overline{x}_i(\gamma) + \overline{\varepsilon}_i \tag{8}$$

Table 2
Variables used to create policy index.

Indicator	Source From
Financial Incentives	IEA Database
Economic Instruments	IEA Database
Regulatory Tools	IEA Database
Grants/Subsidies	IEA Database

Table 3
Variables used in the model and their explanations.

Variables	Descriptions	Source From	Expected Sign
RE	Renewable Energy Investments (Electricity Generation Capacity (MW)	IRENA	
FD	Financial Development Index	IMF	+
PI	Policy Index	The Policy Index was Calculated by the Author using the PCA Method	+
GDP	Real GDP (in US dollars at constant 2010 prices)	World Bank	+
CO_2	Carbon Dioxide Emissions Per Capita	World Bank	+
INF	Inflation (% change calculated as CPI)	World Bank	+/−
FSL	Fossil fuel consumption (% of total consumption)	World Bank	–
Patent	Patent Number of Patent Applications	World Bank	+

It is expressed as. While $\overline{y}_i = \mathrm{T}^{-1}\sum_{t=1}^{T} y_{it}$ ve $\overline{\varepsilon}_i = \mathrm{T}^{-1}\sum_{t=1}^{T}\varepsilon_{it}$ in Equation (8), $\overline{x}_i(\gamma) = \mathrm{T}^{-1}\sum_{t=1}^{T} x_{it}\ (\gamma) = \begin{pmatrix} T^{-1}\sum_{t=1}^{T} x_{it} I(q_{it} \le \gamma) \\ T^{-1}\sum_{t=1}^{T} x_{it} I(q_{it} > \gamma) \end{pmatrix}$.

The equation obtained again by taking the differences between Equations (7) and (8) is as follows:

$$y_{it}^{*} = \beta' x_{it}^{*}(\gamma) + \varepsilon_{it}^{*} \tag{9}$$

Equation number 9 represented $y_{it}^{*} = y_{it}$- $\overline{y}_i$, $x_{it}^{*}(\gamma) = \chi_{it}(\gamma)$- $\overline{x}_i(\gamma)$ ve $\varepsilon_{it}^{*} = \varepsilon_{it} - \overline{\varepsilon}_i$'. Using this notation, equation (9) becomes equal to equation (10).

$$Y^{*} = X^{*}(\gamma)\beta + \varepsilon^{*} \tag{10}$$

For any value (γ), β, which represents the slope coefficient, is estimated by the ordinary least squares method (OLS) as in equation (11):

$$\widehat{\beta}(\gamma)(X^{*}(\gamma)'X^{*}(\gamma))^{-1}X^{*}(\gamma)'Y^{*} \tag{11}$$

According to Chan (1993) and Hansen (1999), the threshold value (γ) can be estimated more easily with the help of equation (12) by minimizing the sum of squares of error.

$$S_1(\gamma) = \widehat{\varepsilon}^{*}(\gamma)'\widehat{\varepsilon}^{*}(\gamma) = Y^{*'}\left(I - X^{*}(\gamma)'(X^{*}(\gamma)'X^{*}(\gamma))^{-1}X^{*}(\gamma)'\right)Y^{*} \tag{12}$$

$$\widehat{\gamma} = argmin_{\gamma} S_1(\gamma) \tag{13}$$

First, $\widehat{\gamma}$ is calculated, and the slope coefficient is estimated as $\widehat{\beta} = \widehat{\beta}(\gamma)$ The residual vector $\widehat{\varepsilon}^{*}(\gamma)'\widehat{\varepsilon}^{*}(\gamma)$ And the residual variance is estimated by equation (14) below (Hansen, 1999, p. 349).

$$\widehat{\sigma}^2 = (\eta(\mathrm{T}-1))^{-1}\widehat{\varepsilon}^{*'}\widehat{\varepsilon}^{*} = (\eta(T-1))^{-1}S_1(\widehat{\gamma}) \tag{14}$$

In the method Hansen (1999) developed, equality 5 has a single threshold value. While the null hypothesis of $H_0 : \beta_1 = \beta_2$, established to test the significance of the threshold value, states that there is no threshold effect, that is, the model is linear, and the alternative hypothesis $H_1 : \beta_1 \neq \beta_2$ indicates the existence of a threshold effect. This shows that the model is not linear. The validity of the hypotheses is determined according to the F statistic, and the F statistic is formed as in the equation numbered 15. Under the H_0 hypothesis, the threshold value cannot be determined, and F_1 has an asymptotic distribution outside the standard. The significance of the threshold effect is tested using bootstrap on the critical values of the F statistic. S_0 represents the sum of squares of error of the linear model (Wang, 2015:123; Altintaş & Koçbulut, 2019, p. 639).

$$F_1 = \frac{(S_0 - S_1(\widehat{\gamma}))\widehat{\gamma}))S_0 - S_1}{\widehat{\sigma}^2} \tag{15}$$

According to Hansen (1999), the best way to establish a confidence interval for the threshold value is to create an acceptance region using probability ratios for tests performed above (γ).

Accordingly, while F_1, tests the hypothesis $H_0 : \beta_1 = \beta_2, LR_1(\gamma_0)$ tests the hypothesis $H_0 : \gamma = \gamma_0$. Equation (16) below shows the probability ratio statistic.

$$LR_1(\gamma) = \frac{S_1(\gamma) - S_2(\widehat{\gamma})}{\widehat{\sigma}^2} \tag{16}$$

To test the hypothesis $H_0 : \gamma = \gamma_0$, the likelihood ratio test rejects large values of $LR_1(\gamma_0)$. Sometimes, testing two or more threshold models in studies may be necessary. Accordingly, the existence of more than one threshold value is tested as in equation (17).

$$y_{it} = \mu_i + \beta_1' \chi_{it} \mathrm{I}(q_{it} \le \gamma_1) + \beta_2' \chi_{it} I(\gamma_1 < q_{it} \le \gamma_2) + \beta_3' \chi_{it} I(\gamma_2 < q_{it}) + \varepsilon_{it} \tag{17}$$

In equation (17), the threshold values should be $(\gamma_1, \gamma_2)\gamma_1 < \gamma_2$ According to Hansen (1999), higher-order threshold models can be easily derived from the two-threshold models. Since the slope coefficients $(\beta_1, \beta_2, \beta_3)$ of the threshold values in the equation numbered 17 are linear, the OLS estimation is convenient, and the sum of squares of the error $S(\gamma_{1,}\gamma_2)$ can be easily calculated, as in the single-threshold model (Hansen, 1999).: 353). When the multiple threshold model is evaluated, the hypotheses are $H_0 : \beta_1 = \beta_2 \mathrm{and} H_1 : \beta_1 \neq \beta_2$ and the rejection of the null hypothesis indicates at least one threshold value (Sekmen & Topuz, 2019, p. 262).

Table 5
Cross-section dependency test results.

Variables	LM Test Statistics values
lnRE	358.002 (0.00) ***
FD	138.787 (0.00) ***
PI	341.31 (0.00) ***
lnGDP	350.185 (0.00) ***
CO_2	209.823 (0.00) ***
Inf	58.386 (0.00) ***
Fossil	188.791 (0.00) ***
lnpatent	260.250 (0.00) ***
Model	63.183 (0.00) ***

Note: () shows probability values. In addition, * 0.10, **0.05, and *** 0.01 indicate significance levels.

Table 4
Descriptive statistics of variables.

Variables	lnRE	FD	PI	lnGDP	CO_2	INF	FSL	lnPatent
Mean	10.4512	0.44907	−8.62E-09	27.9828	0.73008	0.07777	0.755128	8.53801
Median	10.7055	0.43536	−0.619929	1.24E+12	0.57025	0.06290	0.77430	8.36065
Maximum	13.3388	0.64540	8.08308	29.9519	1.65552	0.54915	0.92142	14.0352
Minimum	8.44556	0.27945	−1.653031	26.8400	0.17000	−0.007320	0.51318	5.05624
Std. Dev.	1.14617	0.09079	1.92844	0.68612	0.45218	0.07980	0.14027	2.10725
Observations	126	126	126	126	126	126	126	126

The empirical model used in analyzing the relationship between financial development and renewable energy investment is as follows:

$$y_{it} = u_i + \beta_1 \widetilde{\pi}_{it} \mathrm{I}(\widetilde{\pi}_{it} \leq \gamma_1) + \beta_2 \widetilde{\pi}_{it} I(\gamma_1 < \widetilde{\pi}_{it} \leq \gamma_2) + \beta_3 \widetilde{\pi}_{it} I(\gamma_2 < \widetilde{\pi}_{it} \leq \gamma_3) + \beta_3 \widetilde{\pi}_{it} I(\gamma_2 < \widetilde{\pi}_{it}) + \delta X_{it} + \varepsilon_{it} \tag{18}$$

The model in equation number 18 represents the triple threshold model. y_{it} denotes the dependent variable, the country i's renewable energy investment in period t, ε_{it} Denotes the error term, u_i, denotes the country fixed effects, $\widetilde{\pi}_{it}$ Denotes the financial development with exogenous threshold variable, and I denote the indicator function. In addition, γ_1, γ_2, γ_3 represent the threshold parameters for financial development in the multi-threshold model while X_{it} is the vector consisting of control variables.

To determine the number of thresholds to determine the relationship between financial development and renewable energy investment, model number 18 is estimated using the least squares method in a form that includes three thresholds.

In this context, the findings of the multi-threshold model are presented in Table 7, $\gamma_{1,}\gamma_{2,} ve \gamma_3$ represent the first, second, and third threshold values estimated in the model. In addition, the F statistical values of the estimated threshold parameters in Table 7 and the bootstrap probability values of these values are included.

Accordingly, while the F statistical value of the first threshold parameter is greater than the critical values of 1%, 5%, and 10%, the F statistical values of the second and third threshold parameters are not more diminutive and more significant than all three critical values. Therefore, there is only one threshold value in the estimated model, which was found to be 0.3602.

The panel threshold regression model estimates for the relationship between financial development and renewable energy investment are presented in Table 8. The results in Table 8 represent the results of the single-threshold model. Accordingly, the table shows no linear relationship between financial development and renewable energy investment. β_1 and β_2 The coefficients show the regime-dependent effect of financial development on renewable energy investment. Although both β_1 and β_2 coefficients are positive; they are statistically significant at the 1% level.

According to these results, financial development both below the Threshold (FD $\leq$ 0.3602) and above the Threshold (FD $>$ 0.3602) has a positive effect on renewable energy investment in the group of countries studied. However, let's examine the magnitude of the coefficients indicating the marginal effects. The positive effect of the increase in financial development on renewable energy investment above the Threshold is minor. This result can be evaluated as the positive marginal effect of financial development on renewable energy investment above the Threshold tends to decrease. This result can be evaluated such that the positive marginal effect of financial development on renewable energy investment above the Threshold tends to decrease. The results obtained by Raza et al. (2020), Anton and Nucu (2020), Eren et al. (2019), and Raza et al. (2020) are also compatible. The studies mentioned found a positive effect of financial development on renewable energy. In addition, the study findings are not in line with Burakov and Freidin (2017. The study contains results indicating that financial development does not affect renewable energy.

Finally, the estimated model controls for the effects of variables identified in the literature reviewed that impact renewable energy investment. Accordingly, a 1% increase in the Policy Index increases renewable energy investment by 0.06. These results are also compatible with the studies of Yilmaz and Hotunluoğlu (2015), Kaya and Bayraktar (2019), Crago and ve Chernyakhovskiy (2014) and Berksoy and Akdoğan (2018). In these studies, as the incentives the state gives to renewable energy investments increase, renewable energy investments are positively affected. As the trend towards renewable energy increases globally, many countries allocate resources to this field as a government policy and offer various fiscal and financial incentives. In this context, countries encourage renewable energy investments to ensure energy security, save the climate and nature from the impact of fossil fuels, and ensure economic development.

In addition, there is a 1% increase in real GDP and a 0.36% increase in renewable energy investment. It can be said that GDP, as an economic development indicator, significantly encourages renewable energy investments. These results are based on Wang and Wang (2020), Lin and Moubarak (2014), Koçak and Şarkgüneşi (2017), Özşahin et al. (2016) is also compatible with. In these studies, results indicated a positive effect between renewable energy and GDP. Higher income levels are essential in covering the costs to encourage renewable energy investments. The fact that renewable energy technologies are generally higher than fossil fuel costs also increases the cost of replacing infrastructures based on fossil energy resources with other renewable-based ones. In this context, higher income levels will allow the possibility of accessing or developing new technologies essential for the increased production and use of renewable energy. On the other hand, the findings obtained in the study do not agree with Payne (2009) and Kesbiç and ve Er (2017). In their studies, Payne (2009) and Kesbiç and ve Er (2017) did not find a significant relationship between renewable energy and GDP.

The other variable examined in the study is carbon emissions. A 1% increase in carbon emissions increases renewable energy investments by 0.13%. The results obtained are also consistent with Omri and Nguyen (2014), Nguyen and Kakinaka (2019), and Bamati and Raoofi (2020). In these studies, carbon emissions positively affect renewable energy. The increase in carbon emissions worsens environmental conditions, and therefore, political pressure is exerted on developing clean energy sources for a cleaner environment. Thus, the increasing demand for a cleaner environment encourages renewable energy investments.

The other control variable whose effect on renewable energy investments was examined in the study is inflation. 1% increase in inflation, increase renewable energy investment by 0.64%. Accordingly, the results obtained are similar to those of Malik et al. (2014) is similar. But on the other hand, the results obtained do not coincide with the studies of Yahya and Rafiq (2019). Accordingly, there is no clear consensus in the literature on the effect of inflation on renewable energy investments. For this reason, it can be evaluated that inflation can affect renewable energy investments positively and negatively.

In the study results, looking at the number of patent applications, it is seen that a 1% increase in patent applications increases RE investments by 0.22. These results are similar to those obtained by Geng and Ji (2016), with which Popp et al. (2011) are compatible. In these studies, it was found that the number of patents representing technological innovation positively affected renewable energy investments in the long term. Technological advances and innovation reduce investment costs and contribute to the increase in renewable energy investments in most countries. On the other hand, the study results do not coincide with Gan and Smith (2011). In their study of OECD countries, Gan and Smith (2011) did not find a significant effect of technology and innovation on renewable energy.

The last control variable that is thought to affect renewable energy investments in the study is fossil fuel consumption. A 1% increase in fossil fuel consumption increases RE investments by 0.30. These results

Table 6
Pesaran (2007) CIPS test results of variables.

Variable Name	CIPS Test Statistic
lnRE	−3.039 (0.00)***
FD	−4.280 (0.00)***
PI	−2.974 (0.00)***
lnGDP	−2.974 (0.00)***
CO_2	−3.08 (0.00)***
Inf	−1.304 (0.09)*
Fossil	−7.03 (0.00)***
lnpatent	−6.87 (0.00)***

Note: () shows probability values. * 0.10, **0.05 and *** indicate 0.01 significance levels.

were obtained from Marques et al. It is also compatible with (2010). Marques et al. (2010) obtained results in their study that fossil energy sources limit renewable energy. Fossil resources and renewable energy sources are considered substitutes for each other. The increase in renewable energy investments, due to cost reductions and the emergence of social awareness on this issue, presents these resources as suitable alternatives to fossil fuels. For this reason, there is expected to be a negative relationship between fossil fuel consumption and renewable energy investments. In this context, the increase in fossil fuel use negatively affects renewable energy investments.

3.3. Kao panel cointegration test

The Kao Panel Cointegration Test was used in the study to examine the relationship between variables. The panel cointegration test developed by Kao (1999) is based on DF and ADF tests for error residuals (εit.), which indicates that the null hypothesis has no cointegrated relationship between the series. Unlike Pedroni's (1999) test, this test, which is a specific test for homogeneous and discrete coefficients, is expressed using the following panel regression model (Lau, Chye, & Choong, 2011: 148; Akıncı, Akıncı, & Yılmaz, 2014: 88):

$$y_{it} = x_{it}^{'}\beta + z_{it}^{'}\gamma + \varepsilon_{it} \tag{19}$$

It is assumed that y_{it} and x_{it}^{i} Equation (19) is stationary in the first order, at the I(1) level, and a cointegrated relationship does not occur. Kao (1999) advocates equality such $z_{it} = \{\mu_i\}$, εit. Based on the series' ADF and DF unit root tests, he investigated the cointegration relationship between the series. Of the DF series $\hat{\varepsilon}_{it} = \rho\hat{\varepsilon}_{i,t-1} + v_{it}$_it and of the ADF series $\hat{\varepsilon}_{it} = \rho\hat{\varepsilon}_{i,j-1} + \sum_{j=1}^{p}\theta_j\Delta\hat{\varepsilon}_{i,t-j} + v_{itp}$, It is expressed as and in the patterns it is calculated with the help of $\hat{\varepsilon}_{it} = \hat{Y}_{it} - \hat{X}_{it}\hat{\beta}$ and $\hat{Y} = Y_{it} - \hat{Y}_i$ Equations. Based on these patterns, the OLS estimates of the ρ and t statistics,

$$\rho = \frac{\sum_{j=1}^{N}\sum_{t=2}^{T}\hat{\varepsilon}_{it}\hat{\varepsilon}_{i,t-1}}{\sum_{j=1}^{N}\sum_{t=2}^{T}\hat{\varepsilon}_{it}^{2}} Vet_p = \frac{(\hat{\rho}-1)\sqrt{\sum_{j=1}^{N}\sum_{t=2}^{T}\hat{\varepsilon}_{i,t-1}^{2}}}{S_e} \tag{20}$$

It is calculated using the equations. Table 9 shows the Kao Panel Cointegration results. According to the results of the Kao Panel Cointegration test, it was determined that there is a long-term relationship between the variables.

3.4. Panel FMOLS and DOLS estimators

Suppose it is determined that there is a long-run cointegration relationship between variables. In that case, cointegrated panel regression models are estimated to determine the direction and degree of the relationship (Recepoğlu & Değer, 2016, p. 12). To estimate the relationship between cointegrated panel data variables, the Full Modified Ordinary Least Squares (FMOLS) method developed by Phillips and Moon (1999) and the dynamic least squares method developed by Kao and Chiang (2001) (Dynamic Ordinary Least Squares DOLS) are commonly used in the literature.

The FMOLS and DOLS methods are developed after the OLS method due to biased results in estimating the series between which a long-term relationship exists. While the FMOLS method corrects the internality and autocorrelation problem with a nonparametric approach, the DOLS method corrects the autocorrelation by taking the variables with their lagged values and estimating in this way (Vergil & Ayaş, 2009, p. 105; Üçler & Kızılkaya, 2014, p. 36).

One of these methods, the FMOLS method, allows for considerable heterogeneity between sections. It also considers the correlations between the constant term, the error term, and the differences between the independent variables (Kok & Şimşek, 2006). The FMOLS method developed by Pedroni (2001) and Phillips and Moon (1999) is based on the following panel regression model;

$$y_{it} = \alpha_i + \beta x_{it} + \mu_{it} \tag{21}$$

$$x_{it} = x_{it-1} + \varepsilon_{it} \tag{22}$$

In equation 3.21, y_{it} represents the dependent variable, x_{it} represents the independent variables and α_i Represents the fixed effects. In equation (21), the error terms are included as a stationary process. For this reason, there is a long run cointegration relationship between y_{it} and x_{it} when y_{it} it is first-order integrated. This way, β shows the long-run cointegration vector that must be estimated. To obtain the cointegration vector for the panel using the FMOLS panel estimator, the model in equation (21) is first estimated using the FMOLS estimator for each cross-section. Then, the cointegration vector for the panel is calculated by taking the average of the cointegration coefficients from the FMOLS estimator for each cross-section (Nazlıoğlu, 2010, p. 99; Gulmez, 2015: 24). On the other hand, the DOLS method requires the estimation of the regression model in equation (23) (Taasim & Daud, 2020: 26):

$$y_{it} = \alpha_i + \beta x_{it} + \sum_{k=-K_i}^{K_i} + \mu_{it}^{*} \tag{23}$$

In this regression model, -Ki and Ki denote the number of precursors and lags. The panel cointegration coefficient obtained with the help of the above equation is calculated as follows:

$$\hat{\beta}_{GD}^{*} = N^{-1}\left(\sum_{i=1}^{N} Z_{it}Z_{it}^{'}\right)^{-1}\left(\sum_{i=1}^{N} Z_{it}Y_{it}^{*}\right) \tag{24}$$

Here, $\hat{\beta}_{GD}^{*}$ is the cointegration coefficient obtained from the DOLS estimation for each cross-section, while Z is the ($Z_{it} = (X_{it} - X_i^{-}, \Delta X_{i,t-k}, \ldots$

Table 7
Threshold test results.

Test for Only One Threshold	
γ_1	0,3602
F-Statistic	24,76
p-value	0,000
(%10, %5 ve %1 critical values)	(10,52), (12,84), (16,72)
Test for two Threshold	
$\gamma_{2.}$	0,4319
F-Statistic	8,18
p-value	0,20
(%10, %5 ve %1 critical values)	(10,75), (12,40), (16,68)
Test for three Threshold	
$\gamma_{3.}$	0,4295
F-Statistic	5,38
p-value	0,42
(%10, %5 ve %1 critical values)	(12,05), (16,10), (22,89)

Note: 500 bootstrap replications were used in the model.

Table 8
Financial development threshold value and renewable energy investments model forecast results.

Dependent Variable Renewable Energy Investments (RE)	
Threshold Parameter (γ_1)	0.3602
the p-value for Threshold Parameter Significance	0.0000***
Impact of Financial Development on RE Investments (FD Regime Coefficients)	
β_1	1.3125(0.000)***
β_2	0.8573(0.000)***
Control variables	
PI	0.0604(0.000)***
lnGDP	0.3603(0.000)***
CO_2	0.1363(0.078)**
Inf	0.6458(0.000)***
Fossil	−0.3055(0.056)*
lnpatent	0.2247(0.000)***

, $\Delta X_{i,t+k}$)) 2(K+1) × 1 dimensional vector. Table 10 includes the Panel FMOLS and DOLS Estimation results.

Accordingly, FMOLS estimates show that a 1% increase in financial development increases RE investment by 0.88, a 1% increase in government financial support for RE investment increases RE investment by 0.05, a 1% increase in real GDP increases RE investment by 0.44, a 1% increase in carbon emissions increases RE investment by 0.24, a 1% increase in inflation increases RE investment by 0.77, a 1% increase in the number of patent applications increases RE investment by 0.24. On the other hand, a 1% increase in fossil fuel consumption reduces RE investment by 0.48 percent.

Using estimates from DOLS, which are similar to FMOLS estimates, a 1% increase in financial development increases RE investment by 0.74, a 1% increase in government financial support for RE investment increases RE investment by 0.06, a 1% increase in real GDP increases RE investment by 0,36, a 1 % increase in the inflation rate increases RE investment by 0.56, a 1 % increase in the number of patent applications increases RE investment by 0.22, In addition, the variables of fossil fuel consumption and carbon emissions were found to be statistically insignificant. Generally, it can be said that the estimation results of FMOLS and DOLS are similar.

4. Conclusions, policy implications and limitations

The economic and political measures implemented in the past, the technological progress, and the population growth have led to the fact that consumers cannot be controlled. Parallel to the increase in consumption, the energy demand has increased daily. Meeting the increasing energy demand, mainly from fossil energy resources, has raised some problems. Fossil energy resources, which have been used as an essential factor of production since the Industrial Revolution, are not evenly distributed as they are collected in some areas of the world. For this reason, many political, social, and economic problems often arise among the countries that produce and consume these resources. In particular, countries that meet their energy needs through imports experience macroeconomic problems such as inflation, current account deficits, and low growth rates. In addition, political vulnerabilities may arise between energy-importing and energy-consuming countries.

On the other hand, fossil energy resources are limited by reserves. The possibility that these resources may be depleted leads to the search for new energy sources. In addition, fossil fuels cause global warming and lead to a deterioration of the ecological balance. Most greenhouse gas emissions that cause global warming come from energy use. The intensive use of fossil fuels such as coal, oil, and natural gas to meet energy needs triggers global warming by releasing carbon dioxide. As a result of all these problems, renewable energy sources have emerged as an excellent alternative to fossil fuels.

In this context, this article serves as the primary model to comprehensively analyze the impact of financial development and the policy index, real GDP, carbon emissions, inflation, fossil fuel consumption, and patent application numbers on renewable energy investments for E−7 countries in the period 2000–2017 with using the threshold method. In addition, Kao cointegration, FMOLS, and DOLS methods were used to investigate the accuracy of the main model results. The findings from the study are listed below:

1. The panel threshold value method developed by Hansen (1999) provides strong evidence that the relationship between financial development and renewable energy investments is nonlinear, and there is a single threshold value (0.3602) for financial development. According to the analysis findings, both financial development below the threshold value (FD $\leq$ 0.3602) and above the threshold value (FD $>$ 0.3602) positively affects renewable energy investments in the E−7 country group. However, when looking at the size of the coefficients showing the marginal effects, the positive effect of the increase in financial development on renewable energy investments was found to be above the threshold value (0.8573) and below the threshold value (1.3125). This result shows that the positive marginal effect of financial development on renewable energy investments tends to decrease above the threshold value. This result is thought to be because although the amount of funds in the financial system increased in the later stages of financial development, these funds remained idle and could not be directed to renewable energy investments at the same rate as the increase in financial development. In other words, with the development of the financial system, an imbalance may occur among renewable energy investments in the country group in the analysis sample. FMOLS and DOLS estimation results used to test the robustness of the model yielded similar results to the basic model.
2. The second important finding obtained in the study is that the policy index, which represents the financial support provided by the state to renewable energy, has a positive effect on renewable energy investments in both the basic model and the FMOLS and DOLS models. As the trend towards renewable energy increases globally, many countries allocate resources to this field as a government policy and offer various fiscal and financial incentives. In this context, countries encourage renewable energy investments to ensure energy security, save the climate and nature from the effects of fossil fuels, and ensure economic development.
3. GDP positively affects renewable energy investments in both the basic model and the FMOLS and DOLS models, and the results are statistically significant in all three models. The fact that renewable energy technologies are generally higher than fossil fuel costs also increases the cost of replacing infrastructures based on fossil energy resources with other renewable-based ones. In this context, higher income levels will allow the possibility of accessing or developing new technologies essential for the increased production and use of renewable energy.
4. While the coefficient of carbon emissions was found to positively affect renewable energy investments in the basic model and the FMOLS model, and the coefficients were statistically significant, in the DOLS model, the coefficient of the variable was still positive, and the result was found to be statistically insignificant. The increase in carbon emissions worsens environmental conditions, resulting in a

Table 9
Kao panel cointegration results.

Kao Panel Cointegration Test	T statistic	Probability value
ADF	−2.7395	0.0031*

Note: The * sign in the table indicates that the relevant test statistic is statistically significant at the 1% significance level.

Table 10
Panel FMOLS and DOLS estimation results.

Dependent Variable: Renewable Energy Investments (RE)				
Variables	coefficient	Standard error	T statistic	probability value
FMOLS				
FD	0.8881	0.3169	2.8022	0.0066***
PI	0.0520	0.0167	3.1059	0.0024***
lnGDP	0.4400	0.1495	2.9433	0.0040***
CO2	0.2438	0.1155	2.1099	0.0372**
Inf	0.7720	0.2205	3.4998	0.0007***
Fossil	−0.4813	0.2332	−2.0639	0.0415**
lnpatent	0.2414	0.0411	5.8736	0.0000***
DOLS				
FD	0.7421	0.3281	2.2616	0.0256**
PI	0.0620	0.0177	3.4911	0.0007***
lnGDP	0.3611	0.1517	2.3805	0.0190***
CO2	0.1275	0.1247	1.0221	0.3089
Inf	0.5631	0.2092	2.6912	0.0082***
Fossil	−0.2709	0.2538	−1.0673	0.2881
lnpatent	0.2290	0.0425	5.3870	0.0000***

cleaner environment. Political pressure is exerted on the development of clean energy sources. Thus, the increasing demand for a cleaner environment encourages renewable energy investments.

5. While inflation positively affects renewable energy investments in all three estimated models, the results obtained in all three models were found to be statistically significant. In the literature, there is no clear consensus on the effect of inflation on renewable energy investments. For this reason, it can be evaluated that inflation can affect renewable energy investments positively and negatively.
6. While fossil fuel consumption negatively affects renewable energy investments both in the panel threshold regression model and the FMOLS and DOLS models, the coefficients obtained were statistically significant in the Panel threshold regression and FMOLS model. Still, they were found to be insignificant in the DOLS model. Fossil resources and renewable energy sources are considered substitutes for each other. The increase in renewable energy investments, due to cost reductions and the emergence of social awareness on this issue, presents these resources as suitable alternatives to fossil fuels. For this reason, there is expected to be a negative relationship between fossil fuel consumption and renewable energy investments.
7. Finally, patent applications were found to positively affect RE investments in both the primary and FMOLS and DOLS models and were statistically significant. Technological advances and innovation reduce investment costs and contribute to the increase in renewable energy investments in most countries.

Based on the findings from this article, the following policy recommendations can guide policymakers:

1. Considering that renewable energy investments are similar to other types of physical investments, the following policy suggestions based on the findings from this article can guide policymakers:
2. Ensuring capital depth and expanding financial instruments are recommended to increase renewable energy investments.
3. Expanding the range of renewable energy-based instruments of institutions and vehicles in the capital market is necessary to ensure capital depth.
4. By increasing the transaction volume and amount of capital for renewable energy resources in the capital market, the capital market can be transformed into a fully efficient market.
5. To spread renewable energy investments to the public, financial inclusion can be achieved by providing microcredit opportunities suitable for every income group. In this way, capital efficiency will be achieved, and the efficiency of renewable energy investments will increase as access to the financial system will be easier.

Although this study has made particular contributions to the existing literature, it still has certain limitations. The first limitation of the study is the difficulties related to the accessibility of data on renewable energy investments. A limitation of this study is that the data included in the analysis were available until 2017. In future studies, other dimensions of renewable energy investments can be examined using different methods. For example, a comparative analysis of countries/country groups with different development levels can be made. In addition, by adding additional variables in future studies, more diverse panel data models can be created, and new studies on the subject can be conducted.

CRediT authorship contribution statement

Basak Ozarslan Dogan: Conceptualization, Methodology, Data curation, Writing – original draft, Visualization, Validation, Formal analysis, Investigation, Resources. **Muharrem Afsar:** Writing – review & editing, Supervision.

Declaration of competing interest

There is no conflict of interest in this article between the authors.

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