EGE AKADEMİK BAKIŞ / *EGE ACADEMIC REVIEW*

Cilt 22 • Sayı 3 • Temmuz 2022
SS. 309/322
Doi: 10.21121/eab.984127
Başvuru Tarihi: 18.08.2021 • Kabul Tarihi: 8.04.2022

The Impact of Economic Growth, Trade Openness and Technological Progress on Renewable Energy Use in Turkey: Fourier EG Cointegration Approach

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ABSTRACT

In 2019, Turkey's total energy imports increased by 287.60%, total GDP increased by 245.44%, and total renewable energy use increased by 774.26%, compared to 1990. Therefore, this study differs investigating the factors affecting the increase in renewable energy use, which is very important for energy importer Turkey in reducing foreign dependency in the field of energy. Unlike other studies, it also reveals that the long-term relationship that does not appear with a traditional test is revealed with current tests. For this, the variables of economic growth, trade openness and technological progress, and renewable energy use are analyzed with annual data for the period 1990-2019. First of all, the stationarity of the variables is investigated with standard ADF and Fourier-ADF tests. Then, the long-term relationship is investigated with cointegration tests. The research findings showed that there was no long-term relationship between the variables according to the traditional Engle-Granger cointegration test but according to the Fourier Engle-Granger and multiple structural break cointegration tests. According to the long-term coefficient estimation results, it has been obtained that economic growth and technological progress are important in increasing the use of renewable energy for Turkey.

Keywords: Economic Growth, Trade Openness, Technological Development, Fourier Engle-Granger Cointegration, Turkey.

JEL Classification Codes: N7, O1, P48, Q55.

INTRODUCTION

Increasing population and industrialization lead to an increase in energy demand. Increasing demand is generally met by fossil fuels. Fossil fuels are cheap, plentiful, easily accessible, and do not require high technology, which makes them more attractive and makes them more preferred especially for developing economies (Shahbaz et al., 2021:1371).

The oil crisis that occurred in 1973 harmed global energy security. This situation has caused all economies to face the fact that fossil fuels are not sustainable and there is a need for alternative energy sources. In addition, abandoning the use of fossil fuels emerges as a necessity, not an option, especially in an environment that started with the global epidemic of COVID-19 and in which the existing threat of a livable world future intensifies. Because the use of fossil fuels causes destructions that are difficult or impossible to compensate for the environmental quality.

Compared to 1990 in 2019, the fact that the world population increased by 45.33% and the energy need for this increasing population will be met mostly from fossil fuels is only an indicator of the magnitude of a livable world threat (World Bank, 2022). Because, while fossil fuel use per capita was 1526.84 (koe) in 1990, this amount increased in 2019 and was realized as 1526.84 (koe) (IEA, 2022). In addition, while the CO_2 emission per capita was 3.9 tons in 1990 as a result of fossil fuel use, this emission increased by 12,82% and increased to 4.4 tons of CO2 emissions per capita in 2019 (IEA, 2022). Increasing CO2 emissions cause global temperature changes and droughts. On the other hand, increasing fossil fuel use seriously threatens the world energy supply security due to the limited amount of fossil reserves in the world and shows the urgency and importance of alternative energy sources (Welsby et al., 2021:231). Renewable energy is a sustainable, reliable, and environmentally friendly energy source for the world. However, it does not seem possible to abandon the use of fossil fuels soon, especially for developing countries. The reason for this is that the initial cost of the renewable energy source is high and it is an energy source that requires high technology. In addition, the fact that the necessary tools and equipment will be imported from developed countries is an important obstacle for developing countries in the short term. On the other hand, since the existing technologies of developing economies are predominantly integrated with fossil fuels, the GDPs of the economies are more dependent on fossil fuels and renewable energy used on a small scale brings high costs. Therefore, the share of green energy consumption in developing countries is well below the desired level and is still at very low levels.

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However, all these negativities for developing economies do not mean that they should reduce the demand for renewable energy. Because, regardless of whether it has renewable energy use or not, it is important to investigate the factors that increase green energy for every economy in a cleaner, healthier, and more livable world.

Countries are classified as developed and developing economies according to the state of their economic levels. These groups, on the other hand, are classified in different ways among themselves. Emerging economies have a special place among developing economies. Emerging economies, on the other hand, are divided into two. The Turkish economy, on the other hand, is an economy that is among the advanced emerging market economies (FTSE, 2015: 2). One of the most important reasons for this is Turkey's high growth rate. While the annual average GDP growth rate in the 1990-2019 period was 4.37% in Turkey, it was 3.01% in the world and 5.14% in 22 emerging economies (World Bank, 2022). Therefore, while the Turkish economy has higher growth rates than the world average in terms of GDP, it has a slower growth rate than the 22 emerging economies[1]. However, the biggest factor behind the high growth rate of these 22 emerging economies being higher than Turkey's is the high growth rate of the Chinese economy. Because, if the Brazilian economy, which has a growth close to or above Turkey's growth rate, is excluded from among 22 emerging economies, the annual average GDP growth rate for 21 emerging economies in the relevant period is 5.45%. Where, it is seen that the effect of the high growth rate of the Chinese economy still continues. Similarly, the annual average GDP growth rate is 5.04% when the Indian economy is excluded, 5.16% when the Indonesian economy is excluded, 5.34% when the Mexican economy is excluded, and 5.66% when the Russian economy is excluded. However, when the Chinese economy is excluded, the rate of increase is 3.15%. Therefore, the annual average growth rate of emerging economies is higher than that of Turkey, due to the high population and high income of the Chinese economy. However, in the absence of a Chinese economy, Turkey's annual average GDP growth rate in the relevant period has a higher GDP growth rate than the average annual growth rate of both the world and 21 emerging economies. Therefore, Turkey is like the wheel of the global economy with its high growth rates. Turkey's high growth rates are related to the high amount of energy used as a result of its economic activities. Turkey is a foreign-dependent country that imports the vast majority of the energy it uses. In the 1990-2019 period, Turkey's annual average energy imports increased by 4.78% and the majority of energy imports are realized as fossil fuels. While the share of fossil fuels in Turkey's total energy use was approximately 81.4% in 1990, this share increased to approximately 83.2% in 2019 (IEA, 2022). However, Turkey is a country that has a high renewable energy potential and is aware of the importance of using renewable energy. While the share of green energy in Turkey's total energy use was 4.77% in 1990, this share increased to 14.53% in 2019. In addition, the annual average increase in fossil fuel use in the 1990-2019 period is 3.75% (3.47% in coal, 2.11% in oil, and 9.24% in natural gas), while the rate of increase in renewable energy use is 7.74% (hydro 4.75% and wind, solar, etc. 12.39%). As a result, it shows that the energy source with the fastest usage rate in Turkey is renewable energy. However, despite the high rate of increase in the use of green energy in the relevant period, Turkey's use of green energy is still below the desired level in the 21st century, despite the technology it has.

Turkey is still not at the desired level in energy-efficient technologies and technological developments in the field of energy. One of the important indicators of this is that the annual average energy losses have an increased rate of 5.37% for the Turkish economy in the 1990-2019 period. It is seen that this high rate of energy loss in Turkey is compared to the annual average GDP growth rate of 4.37% and 3.68% of total energy use in the relevant period, which is a high rate of increase. Therefore, there is a great need for improvement in technological developments as well as energy-efficient technologies for Turkey. As increasing energy-efficient technologies will reduce the amount of energy demanded per unit for the Turkish economy, it will decrease the overall energy demand and lead to higher growth rates by obtaining the same output with less energy or with the same energy. In addition, the increase in the use of clean energy with increasing technological developments will be very important for Turkey. The reason for this is that the increasing use of clean energy not only reduces foreign dependency in the field of energy but also causes less foreign exchange need, less current account deficit, and a less fragile economy. On the other hand, increasing the use of clean energy will be very important for sustainable energy, energy security, and sustainable development. However, the global epidemic of COVID-19, in particular, has led to a greater understanding of the importance of a livable world by world economies. Therefore, since the need for less carbon dioxide emissions, cleaner, healthier, and higher environmental quality for the world has increased, increasing the use of green energy emerges as a necessity for a livable world besides the above-mentioned economic advantages.

Therefore, for the high-growth Turkish economy, higher growth results in more energy demand, more energy loss, more energy need, higher energy imports, higher fossil fuel use, and higher CO2 emissions. In that case, increasing the use of green energy, which will reduce foreign dependency on energy for Turkey, will make significant contributions to sustainable, safe, and environmentally oriented growth.

1 In the IMF's World Economic Report published in 2015, 23 countries, including the Turkish economy, were named as emerging economies. These economies are Argentina, Bangladesh, Brazil, Bulgaria, Chile, China, Colombia, Hungary, India, Indonesia, Malaysia, Mexico, Pakistan, Peru, Philippines, Poland, Romania, Russia, South Africa, Thailand, Turkey, Ukraine, and Venezuela (IMF; WEO, 2015:124).

Third, the long-term relationship between the variables did not emerge when tested with a traditional cointegration test but emerged with current cointegration tests. Finally, the findings to be obtained for an energy importing economy like Turkey will also contain concrete and important information for the developing countries that make up the majority of the world.

In this context, the long-term relationship between economic growth, technological progress, trade openness, and renewable energy use for the Turkish economy for the period of 1990-2019 is investigated. In the next section, similar studies from the related literature are given. In the next section, model and variables to be used in the model are introduced, and methods and findings are presented. Finally, recommendations are presented to policymakers with the help of the results obtained.

LITERATURE REVIEW

Turkey is a developing economy with high growth figures. However, like most developing economies, it is an energy importing economy that cannot meet the energy it needs with its resources. In 2019, Turkey's total GDP increased by 245.44% while total energy imports increased by 287.60% in the same period, compared to 1990. (IEA, 2022). On the other hand, due to its geopolitical position, Turkey has a high potential in the field of green energy, which will increase its independence in energy. Many factors can contribute positively to the realization of this potential. Therefore, it is very important to determine these factors. In recent years, many terms such as economic growth, trade openness, and technological progress with renewable energy have been indirectly discussed and investigated in many studies. However, when we look at the studies investigating the effect of these dynamics on green energy demand in the literature, only the study by Alam and Murad (2020) was found. Alam and Murad (2020) investigated the impact of economic growth, technological progress, and trade openness on green energy demand for 25 OECD countries. Autoregressive Distributed Lag (ARDL) approach, Pooled Mean Group (PMG), Mean Group (MG), and Dynamic Fixed Effects (DFE) methods were used as econometric methods. The findings showed that economic growth, technological growth, and trade openness significantly drive renewable energy demand.

Some studies in the literature indirectly investigate the relationship between economic growth, trade openness, and green energy. However, due to data constraints, there are not many studies investigating the relationship between technological progress and renewable energy. Technological development is represented in different ways in the studies encountered. In some of these studies, R&D expenditures were used as an indicator of technological progress. Aflaki et al. (2014) investigated the importance of innovation processes in the renewable energy industry on economic growth. For the period 1990-2012, different panel estimators such as FE, MG, and CCEMG were used for 15 European Union (EU) countries. Research findings revealed that R&D investments support renewable energy and this has a positive effect on economic growth.

Irandoust (2016) investigated the relationship between clean energy consumption, technological innovation, economic growth, and environmental quality for 4 Scandinavian countries with the Granger Causality test for the period 1975-2012. The findings show that there is a unidirectional causal relationship from technological development to renewable energy and that technological innovation plays an active role in clean energy.

Naimoğlu (2021) investigated the effect of technological innovations in the field of energy on energy consumption with the structural break Gregory-Hansen (1996) cointegration test for Germany in 1990-2019. The research findings show that the overall energy consumption for the German economy is mostly reduced by the technological innovation in the field of green energy, and therefore the technological innovations in the field of green energy increase energy efficiency.

Lee and Min (2015) investigated the effects of technological innovations in the field of green energy on the environment and company performances for Japanese manufacturing companies in the period 2001-2010 using the Minimum Mean Square Linear Estimation method. The findings have obtained that technological developments in the field of green energy increase energy efficiency by increasing the use of green energy and therefore have an effect on increasing environmental quality.

Cho et al. (2013) investigated the relationship between green energy use and R&D expenditures in the field of renewable energy for EU countries in the 1995-2006 period using the Panel SUR method. The findings show that R&D expenditures in the field of green energy have a positive effect on green energy use.

Jin et al. (2017) empirically investigated the effect of technological advances in the energy sector for China in the period 1995-2012 on environmental quality based on Spatial econometrics. Research findings have shown that technological progress increases the use of green energy and has a positive contribution to CO_2 emissions improvement.

Kahouli (2018) investigated the relationship between electricity use, R&D, economic growth, and CO2 emissions for 18 Mediterranean countries during the period 1990-2016 using SUR, 3SLS, and GMM methods. The findings showed that environmental degradation can be controlled by increasing R&D investments and using energy-efficient technologies.

Mensah et al. (2018) investigated the effects of innovation (R&D) on CO2 emissions improvement for 28 OECD countries during the 1990-2014 period using the STIRPAT method. The findings showed that the development in innovation led to an improvement in the energy field and increased environmental quality in most OECD countries.

Some studies in the literature have investigated the possible effects of technological development on the use of renewable energy by using Patent data as an indicator of technological progress. The reason for this is that a higher number of patents will enable more efficient and more effective technologies to increase by increasing the innovation and technological level. Dinda (2011) investigated the effect of production technology on environmental quality for the USA in the period 1963-2007 using the VECM method. In this study, in which the number of patents was used as a technology variable, the findings showed that production technology had a positive effect on renewable energy and only reduced CO2 emissions in the short term.

In some studies, variables that can increase production efficiency are used as technology variables. Lantz and Feng (2006) investigated the relationship between the improvement in technological development and environmental quality for 5 regions of Canada using the Generalized Least Squares (GLS) econometric method. In this study, new equipment was used as an indicator of technological development. This is because new equipment can cause technological innovation or a change in the production structure of the economy. The findings show that increasing technological development will increase the use of alternative energy sources such as green energy, resulting in the use of more efficient technologies and thus less resource use, and thus an increase in environmental quality.

There are many studies in literature investigating the relationship between green energy use and economic growth. However, studies investigating the effect of economic growth on the use of green energy have generally been found in the literature with the conservation hypothesis, namely, one-way causality from economic growth to green energy use. Sadorsky (2009) investigated the relationship between green energy use and economic growth for 18 developing countries over the period 1994-2003. In the study using Panel cointegration, FMOLS, DOLS, and Panel VECM, the findings showed that there is a one-way and significant causal relationship between economic growth and green energy use. Similarly, in the study by Joyeux and Ripple (2011), for 56 developed and developing economies, in the study by Caraiani et al. (2015) for Romania, Poland, and Turkey, and in the study by Alper and Oğuz (2016) were found that the conservation hypothesis is valid for the Czech Republic. In this case, any savings policy that can be applied to reduce energy use in economies where the conservation hypothesis is valid will not harm economic growth. On the other hand, studies in which there is a reciprocal causal relationship between the feedback hypothesis, that is, the use of green energy and economic growth, have also been found in the literature. Apergis and Payne (2010) investigated the relationship between clean energy use and economic growth for 20 OECD countries during the 1985-2005 period. In the study using panel causality, it was found that there is a two-way causal relationship between renewable energy consumption and economic growth. Similarly, In the study by Al-Mulali et al. (2014) for 18 Latin American countries, in the study by Asafu-Adjaye (2000) for 4 Asian countries as India, Indonesia, Thailand, and the Philippines, In the study by Apergis and Payne (2011) for Six Central American countries, In the study by Salim and Rafiq (2012) for emerging economies, in the study by Apergis and Payne (2012), for 80 large country groups, in the study by Pao and Fu (2013) for the Brazilian economy and the study by Shahbaz et al. (2016) found that the feedback hypothesis is valid for the BRICS countries. Therefore, in the case where the feedback hypothesis is valid, that is, there is bidirectional causality between economic growth and clean energy use, any negative impact on economic growth and the use of renewable energy may negatively affect each other. So economies should adopt a stronger energy policy.

On the other hand, when we look at the studies on the energy use of the trade openness, Hossain (2012) investigated the causal relationship between CO2 emissions, energy use, economic growth, trade openness, and urbanization for the Japanese economy in the 1960-2009 period. The findings show that there is a causal relationship between trade openness and energy use for the Japanese economy in the short run. On the other hand, Kohler (2013) investigated the causal relationship between foreign trade, income, environmental recovery, and energy use for the South African country during the period 1960-2009. The findings showed that there is a bidirectional causal relationship between trade openness and energy use. Similarly, Shahbaz et al. (2013) For Indonesia in the period 1975:1-2011:4, Islam et al. (2013) found a mutually causal relationship between trade openness and energy use for Austria over the period 1965-2009.

Therefore, it is seen in the literature that economic growth, technological progress, and trade openness, in general, have a significant impact on energy use, with different effects.

DATA, METHODOLOGY, AND FINDINGS

In this study, which investigates the increase in renewable energy demand for the Turkish economy in the 1990-2019 period, the dependent variable of renewable energy use (lnREN) is taken as the sum (ktoe) of energy from hydro, solar, tides, wind and others.

Figure 1 shows the renewable energy usage trend for the Turkish economy in the 1990-2019 period. The fact that Turkey's renewable energy usage graph has a sensitive and increasing trend shows that renewable energy usage can be affected by many factors.

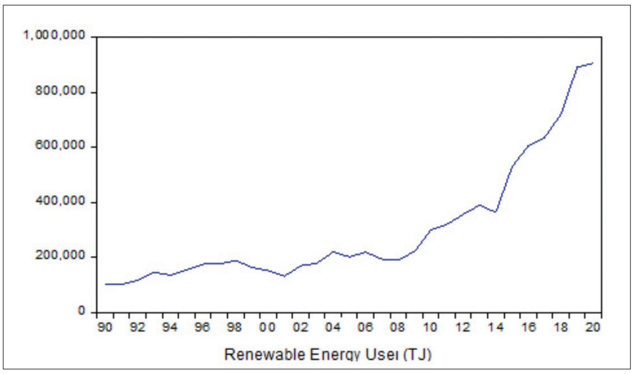

Figure 1: Renewable energy usage graph for Turkey (1990-2021)

Source: International Energy Agency, www.iea.org

High-income economies increase the use of energy-efficient technologies as well as increase the use of green energy. Therefore, the income levels of economies are important. Turkey has higher growth rates than the 21 emerging economies (except for the Chinese economy), which rank high among the world and emerging economies. While these growth rates act as leverage for the global economy, they can cause an increase in investments in the field of energy within the economy.

Figure 2 shows the GDP trends for Turkey, Emerging Economies, and the World for the period 1990-2019.

When Figure 2 is examined, it is seen that Turkey has achieved fluctuating but increasing growth. Turkey achieves these high growth rates with the energy it uses to carry out economic activities. However, Turkey imports the energy it needs from abroad. Therefore, Turkey is an economy dependent on foreign energy in the field of energy. In addition, almost all of the imported energy is realized as fossil fuel and the share of fossil fuels among Turkey's total energy sources is still highly dependent on today's technologies. Low technologies in the field of energy, on the other hand, cause high energy losses.

Figure 3 shows the trends in total energy imports, fossil fuel use, and energy losses for Turkey in the period 1990-2019.

When Figure 3 is examined, energy imports and fossil fuel use have an increasing trend for Turkey in the 1990-2019 period. In addition, the energy losses in the relevant period have an increasing trend. Therefore, a higher growth rate causes an increase in energy imports, fossil fuel use, and energy losses. This shows that higher growth in Turkey will increase energy use, fossil fuel use, energy loss, energy demand, energy imports, foreign

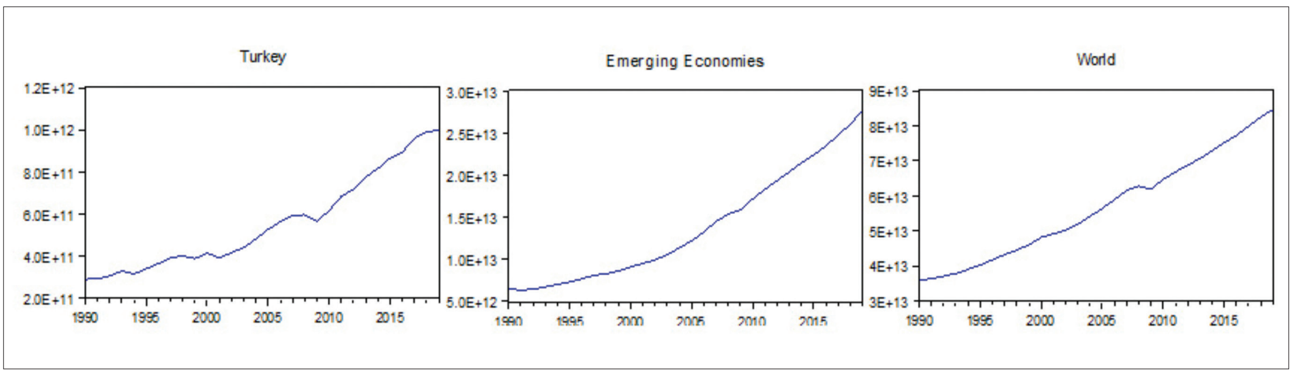

Figure 2: GDP Figures for Turkey, Emerging Economies and the World (1990-2019)

Source: World Data Bank, databank.worldbank.org

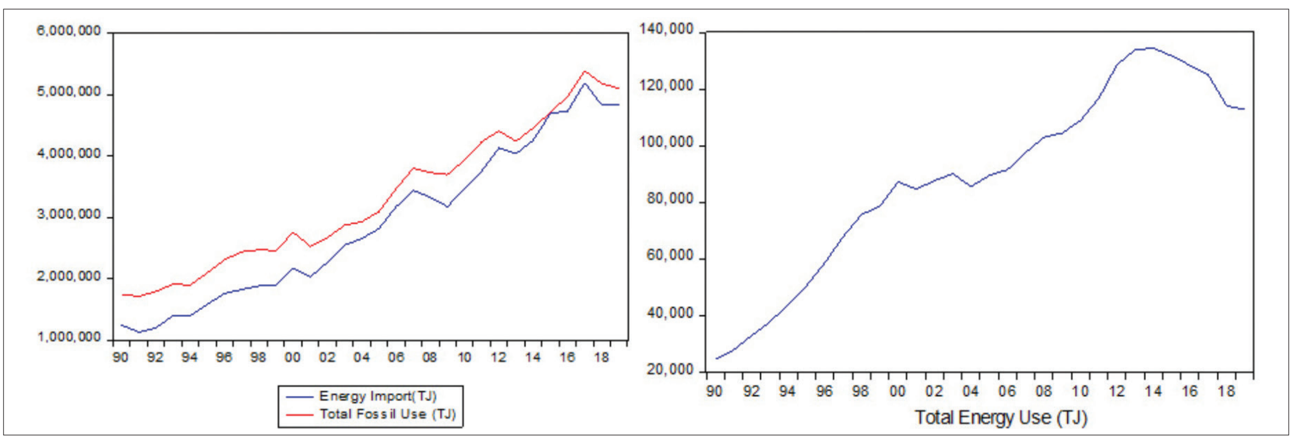

Figure 3: Figures of total energy imports, fossil fuel use, and total energy losses (1990-2019)

Source: International Energy Agency, www.iea.org exchange need, current account deficit, and vulnerability. On the other hand, although the technological advances are not at the desired level for Turkey with high growth rates, the technology also causes an increase in the diversity of energy sources. One of the important effects of this is that Turkey is a country with high export figures. However, since the actual export is usually made with imported goods, it also increases the imports in parallel with the increased exports. While Turkey's exports have an average growth rate of 7.75% in the 1990-2019 period, its imports have an average growth rate of 6.42%.

Figure 4 shows the total export and import trends for Turkey in the period 1990-2019.

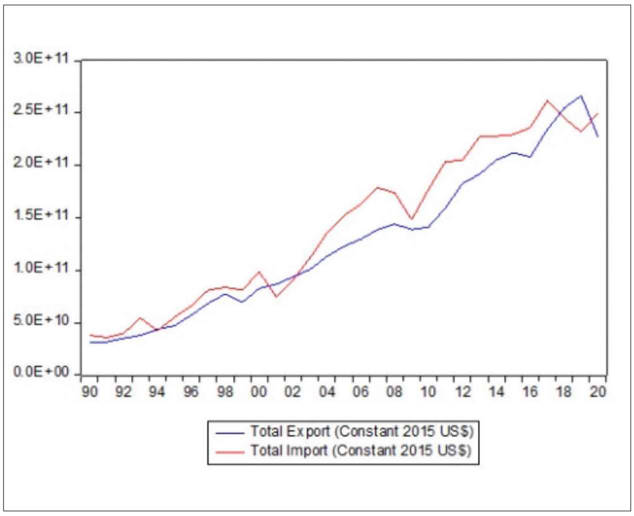

Figure 4: Export and Import graphs (1990-2019)

Source: World Data Bank, databank.worldbank.org

When Figure 4 is examined, Turkey's export and import figures for the period 1990-2019 have an increasing trend. In addition, export and import figures move together. While import values were higher than exports in 1990, it was the opposite in 2019. Therefore, Turkey has to increase its imports to increase its exports. This increasing export is provided by the energy it uses. In production, energy costs are among the most important costs. Increasing growth in Turkey brings with it increasing exports, increasing technological development, and alternative energy source diversity. It is shaped according to the superiority of any one of the negative effects of energy waste as a result of the gains arising from technological efficiency and the overproduction brought by the export ambition.

Model, and Data

In this section, the relationship between green energy use (lnREN) and economic growth (lnGDP), trade openness (lnTRD), and technological progress (lnTECH), which will reduce foreign dependence on energy for the Turkish economy, will be examined for the equation

$$\ln REN_t = \beta_1 + \beta_2 \ln GDP_t + \beta_3 \ln TRD_t + \beta_4 \ln TECH_t + u_t$$

Where renewable energy use (lnREN) is the sum of energy from Hydro, Solar, Wind, and others (ktoe), economic growth (lnGDP) (GDP per capita (2010 base year US$)) technological development (lnTECH), technological innovation (i.e. technological development) number of patents) and trade openness (index value) as a proxy measure. The economic growth, technological innovation, and trade openness series are taken from the World Bank, and the total renewable energy usage series is from the IEA. Natural logarithms of all variables were used.

Methodology, and Empirical Findings

In this part of the study, a stationarity test will be performed for each variable before the long-term relationship between the variables. Stationarity will be tested with standard ADF unit root test and Fourier ADF tests. For the long-term relationship, first, the traditional Engle-Granger (1987) cointegration test will be used. Then, with the inclusion of trigonometric functions in the model, the current Fourier Engle-Granger cointegration test and Maki (2012) cointegration tests, which allow multiple structural breaks, will be used for the long-term relationship. Finally, the direction and magnitude of the effect of the explanatory variables on the dependent variable will be investigated with the Fully Modified Ordinary Least Squares (FMOLS) and Canonical Cointegrated Regression (CCR) long-term coefficient estimators.

Standart ADF ve Fourier ADF Unit Roots Tests

When the stationarity of the variables is tested with the standard ADF unit root test, the structural changes that can be found in the series are ignored. Therefore, when the stationarity of the series is investigated with the standard ADF test, the stationarity degree can be determined incorrectly for a series with structural change, and this may cause the subsequent analysis stages to be selected incorrectly. Therefore, the use of stability tests, in which structural changes are taken into account, together with the standard ADF test, will increase the reliability of the test results.

Different stability tests followed different methods to take into account the structural changes. In the stationarity test that Enders and Lee (2012) brought to the literature, problems such as the time and number of structural breaks that can be found in the variables can be caught by adding the low-frequency sine and cosine trigonometric functions to the standard ADF model. However, Enders and Lee (2012) stated that the important thing in this test is to determine the frequency.

The standard ADF equation is as follows.

$$\Delta y_t = p y_{t-1} + \beta_1 + \beta_2 trendu_t \quad (3)$$

Table 1: Standart ADF and Fourier ADF Unit Root Test Results

	Level					
Variable	Frequency	MİNSSR	Lag	FADF	ADF	F-Test
lnREN	5	0.0774	6	3.629	0.879	5.382
lnGDP	4	0.0086	1	0.085	1.741	3.611
lnTECH	1	0.0715	2	1.046	-0.873	11.361***
lnTRD	5	0.0360	7	0.818	-1.907	6.937*
	First Difference					
Variable	Frequency	MİNSSR	Lag	FADF	ADF	F-Test
lnREN	1	0.0764	7	-4.372**	-5.266	12.395***
lnGDP	4	0.0077	1	-3.990	-5.429***	3.738
lnTECH	1	0.06667	1	-5.562***	-4.554	10.769***
lnTRD	5	0.0434	6	-9.052***	-4.885	8.073**

Note: Fourier F test critical values 1%=10.35%, 5%=7.58, 10%=6.35%, Fourier ADF k=1 critical values 1%=-4.42%, 5%=-3.81, 10%=-3.49%, Fourier ADF k =5 critical values 1%=-3.58%, 5%=-2.93%, 10%=-2.60, ADF critical values 1%=-3.753, 5%=-2.998, 10%=-2.639. *(10%), **(5%) and ***(1%) are levels of significance.

Enders and Lee (2012) added sine and cosine functions to this model and obtained the model as

$$\Delta y_t = p y_{t-1} + \beta_1 + \beta_2 trend + \beta_3 \sin\left(\frac{2\pi k t}{T}\right) + \beta_4 \cos\left(\frac{2\pi k t}{T}\right) + u_t \quad (4)$$

Where k is the frequency value, t is the trend and T is the time. Here, the k frequency value represents the frequency value with the value at which the residual sum of squares is the minimum (MinSSR). In that case, the frequency value corresponding to the MinSSR value will be used.

For all series to be used in the model, stationarity tests were performed with standard ADF and Fourier ADF tests, and the results are given in Table 1.

When Table 1 is examined, technological progress (lnTECH) and commercial openness (lnTRD) series have unit roots in their level values according to the Fourier ADF test. Other variables are unit rooted in their level values according to the standard ADF test. Renewable energy use (lnREN), trade openness (lnTRD) and technological progress (lnTECH) variables become stationary at I(1) to the Fourier ADF test. On the other hand, economic growth (lnGDP) is stationary at I(1) according to the standard ADF test. Therefore, all variables become stationary at I(1).

Cointegration Tests

According to the standard ADF and Fourier ADF stationarity test results, all variables were found to be I(1) and the long-term relationship was investigated considering that there might be a cointegration relationship between the series. The long-run relationship between the variables will first be tested with Engle-Granger (1987) test. All variables must be I(1) to use this test. Two stages are followed while applying this test. As the first step, the stationarity of the series is tested and if the series have the same degree of stationarity, the following model is used.

$$y_t = \beta x_t + e_t \quad (5)$$

For this model, an EKK estimator is used and residuals are obtained. Then, DF or ADF stability tests are applied to these residues. The stationarity of the residuals will indicate the existence of a long-run relationship between the variables.

For Turkey, the long-term relationship between green energy use (lnREN) and economic growth (lnGDP), trade openness (lnTRD), and technological progress (lnTECH) was tested with the standard Engle-Granger (1987) test and the results are given in Table 2.

If Table 2 is observed, the ADF test was applied to the residues obtained as a result of the model run. Since the test statistical value obtained is smaller than the critical values, it shows that there is no long-term relationship between the variables.

For the Fourier Engle-Granger cointegration test, which was brought to the literature by Yılancı (2019), trigonometric functions were added to the standard Engle-Granger cointegration test as follows.

$$y_t = a_0 + \gamma_1 \sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 \cos\left(\frac{2\pi kt}{T}\right) + \beta' y_{2t} + u_t \quad (6)$$

Where, $k=1,\ldots,5$ denotes frequency values that can take values. Models are run for these values and k frequency value with MinSSR value is determined. In the Fourier Engle-Granger cointegration test, the model in which the sine and cosine trigonometric functions are added is

Table 2: Cointegration Test Results

Dependent Variable	Independent Variables	ADF Test Statistic	Critical Values
lnREN	lnGDP, lnTECH, lnTRD	-2.78	%1=4.84, %5=4.11, %10=3.73

Table 3: Cointegration Test Results

Dependent Variable	Independent Variables	Frequency	MİNSSR	Cointegration Test Statistic
lnREN	lnGDP, lnTECH, lnTRD	1	0.057256	-4.822***

Note: Critical values for Fourier EG cointegration are 1%=-4.805, 5%=-4.122, 10%=-3.767, and *(10%), **(5%) and ***(1%) are levels of significance.

estimated with the EKK and the residuals are obtained. As in the standard Engle-Granger cointegration test, the stability of the residues is tested with DF or ADF tests. However, the test statistics of the residue to be obtained here are compared with the critical values obtained by Yılancı (2019) and included in his article.

The relationship between renewable energy use (lnREN) and economic growth (lnGDP), trade openness (lnTRD), and technological progress (lnTECH) for Turkey has been tested with the Fourier Engle-Granger test and the results are given in Table 3.

If we pay attention to Table 3, models were run in the Fourier Engle-Granger test and the most appropriate frequency value for MinSSR was obtained as 3. The test statistics obtained for the appropriate frequency, on the other hand, show that there is a long-term relationship between the variables at the 1% significance level since it is greater than the critical values.

In the Gregory-Hansen (1996) cointegration test, the break is taken into account with the assumption of 1 structural break in the model, while in the Hatemi-J (2008) cointegration test, the break is taken into account with the assumption of 2 structural breaks in the model, and the break dates are determined pre-intuitively. However, in Maki's (2012) cointegration test, break dates and break numbers are determined internally in the model, not pre-intuitively. Therefore, the Maki (2012) cointegration test is considered more extended than the Gregory-Hansen (1996) and Hatemi-J (2008) cointegration tests. For Maki's (2012) cointegration test, 4 basic models are discussed as follows and the cointegration relationship is tested for each model.

$$Model\,0:\ y_t = \mu + \sum_{i=1}^{k} \mu_i D_{i,t} + \beta x_t + u_t$$

$$Model\,1:\ y_t = \mu + \sum_{i=1}^{k} \mu_i D_{i,t} + \beta x_t + \sum_{i=1}^{k} \beta_i x_i D_{i,t} + u_t$$

$$Model\,2:\ y_t = \mu + \sum_{i=1}^{k} \mu_i D_{i,t} + \gamma t + \beta x_t + \sum_{i=1}^{k} \beta_i x_i D_{i,t} + u_t$$

$$Model\,3:\ y_t = \mu + \sum_{i=1}^{k} \mu_i D_{i,t} + \gamma t + \sum_{i=1}^{k} \gamma_i t D_{i,t} + \beta x_t \sum_{i=1}^{k} \beta_i x_i D_{i,t} + u_t$$

Where, Model 0 denotes the model with no trend break, Model 1 the no trend level and break in slope, Model 3 the trended level and break in slope, and Model 4 the model with the break-in level, slope, and trend. D represents the dummy variable. In the Maki (2012) cointegration test, as in the Kapetanios (2005) stationarity test, the break dates are determined internally and a similar process is followed. First, by choosing any of the above 4 models, the model is run for each possible structural break, and the stability test statistics applied to the residues are obtained. The first break obtained in this way is the value at which the residual sum of squares is minimum among the selected models. Then, the first break obtained is added to the model and similarly, the second break is obtained with the logic of residual sum of squares. This process continues until the maximum number of breaks are taken. The basic hypothesis for Maki's (2012) cointegration test is "There is no cointegration relationship between series under structural breaks". The cointegration relationship between dependent and independent variables was tested with the Maki (2012) cointegration test and the results are given in Table 3.

Looking at Table 4, it is seen that there is a cointegration relationship between the variables in all models except for Model 3. Therefore, the series move together in the relevant period. According to Maki's (2012) cointegration test results, foreign capital outflows were experienced due to the decrease in investor confidence in many developing economies, including Turkey, with the Asian crisis that emerged on the 1997 breakout date. Therefore, the series move together in the relevant period. According to Maki's (2012) cointegration test results, Foreign Direct Investments (FDI) were experienced due to the decrease in investor confidence in many developing economies, including Turkey, with the Asian crisis that emerged on the 1997 breakout date. As FDI provides capital and technology transfer to the host country, it has also significantly affected the use of technology and renewable energy, which requires capital (Göçer and Bulut, 2015: 736). In addition, FDI, which decreased by 57% due to the effect of the 2008 global economic crisis, decreased to 8.4 billion dollars in 2009 (Göçer and Peker, 2014: 110). On the other hand, the policy changes made in the field of energy after the 2002 elections, when the new government came to power, showed their effect in 2003 and later. In addition, Turkey's coup attempt in 2016 showed its effect in the field of energy as well as in all other fields.

Table 4: Cointegration Test Results

Model	Test Statistic	Critic Values	Break Dates
Model 0	-11.715***	%1=-6.229, %5=-5.704, %10=-5.427	1997, 1999, 2014, 2017
Model 1	-6.972**	%1=-6.472, %5=-5.957, %10=-5.682	1997, 2009, 2012, 2016
Model 2	-6.960*	%1=-7.767, %5=-7.155, %10=6.868	1997, 2010
Model 3	-7.723	%1=-8.331, %5=-7.743, %10=-7.749	1995, 2003, 2009

Note: Critical values are taken from the Maki (2012) study. *(10%), **(5%) and ***(1%) are levels of significance.

Table 5: FMOLS, and CCR Long-Term Coefficient Estimation Results

lnREN	lnGDP	lnTECH	lnTRD	C
FMOLS	1.341***	0.307***	0.165	-2.783***
	(0.252)	(0.060)	(0.116)	(0.822)
CCR	1.131**	0.355***	0.140	-2.035*
	(0.317)	(0.073)	(0.131)	(1.018)

Note: *(10%), **(5%) and ***(1%) are levels of significance.

Estimation of Cointegration Coefficients

According to the standard Engle-Granger cointegration test, no long-term relationship was found between the variables. But, according to the current cointegration test of Fourier Engle-Granger and Maki (2012), it has been found that there is cointegration relationship between the variables in the relevant period. Therefore, the long-term coefficient estimation will be made to see how the explanatory variables affect the dependent variable. For this, FMOLS was brought to the literature by Philips and Hansen (1990) and where structural changes are included as dummy variables in the model, and CCR estimators developed by Park (1992) will be used.

The coefficient estimation results made to see the effect of the explanatory variables on the dependent variable are given in Table 4.

If we pay attention to Table 4, both estimation results showed similar results. According to both estimators, the variables of economic growth (lnGDP), trade openness (lnTRD), and technological progress (lnTECH) positively affect green energy consumption (lnREN). According to both estimators, it was found that economic growth (lnGDP) increased renewable energy use (lnREN) the most, while trade openness (lnTRD) increased the least. However, trade openness (InTRD) was statistically insignificant.

The short-term coefficient estimation results are given in Table 5.

Paying attention to Table 5, the ECT coefficient was negative and statistically significant at the 1% significance level for FMOLS and 5% for CCR. Therefore, the existence of a cointegration relationship between green energy consumption and explanatory variables in the relevant period is confirmed. The ECT denotes the rate of correction in the long run and indicates that for FMOLS (-0.718)/ CCR (-0.911) approximately 0.72%/ 0.91% of a variant at period t-1 will return to equilibrium at period t.

CONCLUSION AND POLICY IMPLICATIONS

The Turkish economy, which is among the advanced emerging market economies, has an annual growth rate that is higher than the average GDP growth rate of the world and emerging economies. Energy use is among

Table 6: FMOLS, and CCR Short-Term Coefficient Estimation Results

ΔlnREN	ECT_{t-1}	ΔlnGDP	ΔlnTECH	ΔlnTRD	C
FMOLS	-0.718***	1.968***	-0.222	-0.248	0.025*
	(0.213)	(0.483)	(0.141)	(0.190)	(0.014)
CCR	-0.911**	2.516**	-0.344	-0.304	0.026
	(0.385)	(1.068)	(0.213)	(0.271)	(0.018)

Note: *(10%), **(5%) and ***(1%) are levels of significance.

the most important inputs of this growth. Turkey is a country where most of its energy demand cannot be met with its own resources and is an importer in the field of energy. Therefore, the use of clean energy is of vital importance for the Turkish economy. The share of fossil use in the total energy used by the Turkish economy in 2019 is as high as 83.18%, which is a very high rate. On the other hand, despite today's technologies, the share of green energy in 2019 is still not at the desired level, as 14.62%. Therefore, this situation shows that the Turkish economy, which is an energy importer, needs to increase its share of renewable energy more for its sustainable growth. Renewable energy is an important alternative energy source for Turkey. The fact that the renewable energy graph of the Turkey has sensitive fluctuations and an increasing trend in the relevant period shows that many factors affect the clean energy demand sensitively.

In this study, the long-term relationship between economic growth, trade openness, and technological innovation variables, which are thought to affect the use of green energy in the 1990-2019 for the Turkish economy, and the use of green energy is investigated. This study has important contributions to the literature. First of all, it is the research of the renewable energy demand for the Turkish economy, which is among the developing countries that make up the majority of the world. The second is that the Turkish economy will act as a lever for global economic growth with its high growth rates, and it will contribute more and more sustainably to global economic growth by increasing the renewable energy demand for Turkey. The third is that this study will make positive contributions to the increase in environmental quality, as Turkey's high use of fossil fuels causes the environmental quality of Turkey and the world to be negatively affected. Finally, it is an empirical investigation of the question of how to increase the clean energy demand with current methods.

In this study, which investigates the factors that will affect the green energy demand for Turkey in the 1990-2019 -, no long-term relationship has emerged the Engle-Granger (1987) test. However, with the Fourier Engle-Granger test developed by Yılancı (2019) and the current cointegration tests with multiple structural breaks introduced to the literature by Maki (2012), it has been observed that there is a long-term relationship between the variables. For this purpose, conventional ADF and Fourier ADF stationarity tests were used and it was found that the series was stationary after taking the first difference. Then, the cointeration relationship between the variables was investigated and the long-term relationship was found. Finally, FMOLS and CCR long-term coefficient estimators are used. Research findings have shown that economic growth and technological improvement increase the use of green energy in Turkey. The trade openness coefficient was positive but statistically insignificant. The increase in economic growth leads to an increase in energy-efficient technologies. In addition, increasing income leads to an increase in green energy investments by reducing energy imports, which bring the highest cost in production and one of the biggest obstacles to sustainable development. It is considered that higher technological development will have a positive impact on the field of green energy and the necessary tools and equipment will be produced within the country and contribute positively to employment and growth. The change in foreign trade has different results. While the increase in foreign trade causes gains due to technological efficiency in some economies, it is shaped according to one of the negative effects of excessive use of fossil fuels and more energy waste and energy loss as a result of excessive production with export ambition in some economies.

As a result, economic growth, technological development, and trade openness significantly affect the use of clean energy. The findings obtained in this study coincide with the technological development results of the studies conducted by Lee and Min (2015) for Japan and Lantz and Feng (2006) for the Canadian economy. It also coincides with the results of economic growth in the studies of Sadorsky (2009) for 18 developing countries and Tiwari (2011) for India. Similarly, studies by Hossain (2012) for the Japanese economy and Alam and Murad (2020) for the 25 OECD countries coincide with the results that trade openness affects renewable energy use.

According to the research findings obtained, policymakers have important duties for the Turkish economy, which is among the advanced emerging market economy. First of all, the fact that economic growth increases the use of clean energy in Turkey can be associated with technological developments and an increase in energy source diversity. Therefore, it is vital to increase investments in the field of green energy and to produce domestically the equipment to be used in the field of green energy for economic growth to be sustainable, which can positively affect the increase in the use of green energy, which reduces foreign dependency in energy. The positive effect of the increase in technological innovation on the use of clean energy can be associated with the transformations in the energy field, which brings the highest cost in production. Therefore, it is considered that increasing technological innovation will lead to the development of energy-efficient technologies and the abandonment of fossil fuels, which imposes a heavy burden. If the effect of trade openness on green energy use is the gains arising from technological efficiency, it is expected that the use of clean energy, which will reduce foreign dependency on energy, will increase. In other words, higher trade openness for economies leads to the development of efficient production techniques with technological innovations, leading to the widespread use of green energy, which has a significant positive effect on the efficient use of energy.

As a suggestion for the limitations of the study and future studies, it is thought that the literature related to this study has recently developed, and therefore, it is thought that researching this subject with different country groups and current period data will make important contributions. In this study, researching the renewable energy demand at the general economy-level gives general information. However, researching the sectoral renewable energy demand will also contain important and detailed information. In addition, in this study, renewable energy demand is investigated only with economic variables. It is evaluated that the multidimensional research of the subject, such as social, political, demographic, and structural, as well as economic variables, will provide detailed and important information to policymakers.

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