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The Nexus Between Urbanization, Renewable Energy, Financial Development, and Economic Growth: Evidence from Turkey

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Abstract: This study aims to analyze the relationship between renewable energy production and financial development, urbanization, and economic growth in the 1980-2020 period of the Turkish economy, which draws attention to its high growth rate. Methodology: To determine the relationship between financial development, economic growth, urbanization, and renewable Energy, ARDL cointegration analysis, cointegration regression models, and Toda Yamamoto causality analysis will be applied using 1980-2020 period data. Results/Findings: The ARDL boundary test shows a long-run relationship between financial development, economic growth, urbanization, and energy consumption under structural breaks. According to the cointegration regression model results, renewable energy production is determined by financial development and per capita GDP. Toda Yamamoto causality analysis shows the existence of causality running from financial development, per capita GDP, and urbanization variables to renewable energy production. The results reveal that in determining Turkey long-term energy demand projections and strategies of Turkey's, it is necessary to consider both the impact of financial development and economic growth and the supply of energy needs with sustainable resources by minimizing foreign dependency. Originality and Practical Implications: According to the government's estimates, electricity consumption is expected to reach 370 TWh in 2025 and 591 TWh in 2040. These developments reveal the importance of energy consumption in the Turkish economy and make it necessary to investigate the factors affecting energy production.

Keywords: Renewable energy; Financial development, Urbanization, GDP, ARDL cointegration, FMOLS

1. Introduction

The increase in the world's population also increases the need for energy. Global environmental pollution, sources to meet the increasing energy needs, as a result of the use of fossil energy, has become a problem for the whole world. For environmental and sustainable development, environmental damage must be minimized. Renewable energy sources are seen as an essential solution for energy-related environmental problems. Renewable energy sources are natural energy sources such as solar, hydraulics, wind, geothermal, biomass, and marine energies that are less harmful to humans and the environment than fossil energy sources. Renewable energies are clean and inexhaustible sources of energy. They differ from fossil fuels in their diversity, abundance, and potential for use anywhere in the world. Most importantly, they do not harm the environment.

As seen in China and many developed economies, rapid development in a modern economy increases energy and carbon consumption. Emerging markets and economies are expected to influence global trends in all fuels and technologies in the coming decades. It is estimated that oil demand in developing economies will increase by 30%, gas demand by 25%, and coal demand by 4% in 2030 compared to 2020 (IEA, 2021a). Renewable energy is expected to account for two-thirds of new power capacity additions in emerging markets and economies (excluding China) by 2030 (IEA, 2021b). It will be advantageous for emerging markets and developing countries to meet their future energy and development needs from renewable energy sources. The falling costs of clean energy technologies, clean electrification, and renewable energy technologies focusing on efficiency present an excellent opportunity to plan for a lower emission growth path. The Turkish economy is one of the emerging economies, with a growth rate of 11% in 2021 (TUIK, 2022). In Turkey's 11th Development Plan, the main objective is to ensure that the energy supply is continuous, high quality, sustainable, safe, and with bearable costs. For this purpose, it is stated that necessary planning and investments will be made to increase electricity production from renewable energy sources. (SBB, 2022). According to the Turkish Ministry of Energy and Natural Resources, Turkey's total final energy consumption; In 2021, with an increase of 7.7% compared to the previous year, reached 329.6 billion kWh, and electricity generation increased by 8.1% compared to the previous year and reached 331.5 billion kWh. Of Turkey's electricity production, 31.4% is from coal, 32.7% from natural gas, 16.8% from hydraulic energy, 9.4% from wind, 4% from solar, 3.2% 6% was obtained from geothermal energy, and 2.4% from other sources. According to the government's estimates, electricity consumption is expected to reach 370 TWh in 2025 and 591 TWh in 2040. These developments reveal the importance of energy consumption in the Turkish economy and make it necessary to investigate the factors affecting energy production.

Urbanization can determine energy consumption by bringing many structural changes in the economy. Urbanization increases the population and causes the acceleration of economic activities. The increase in economic activities through urbanization increases the energy demand. Therefore, urbanization is among energy consumption's most critical causal factors. According to the data of the Turkish Statistical Institute, the urban population in Turkey, which was 18.5% in 1950, reached 25.2% in 1960, 35.7% in 1970, 53.6% in 1985, and 56.3% in 1990. Between 1990 and 2000, the ratio of the urban population to the general population reached 65%. The proportion of people living in provincial and district centers, 92.8% in 2019, became 93% in 2020 (TUIK, 2022).

The annual real GNP per capita calculated with the 1995 prices of the long-term growth of the Turkish economy is shown in Figure 1. As can be seen from the Figure 1 real GNP per capita increased in 1980 and later. With the decisions of January 24, 1980, the import-substituting growth strategy was abandoned in Turkey, an open growth strategy was put into practice, and a significant change was experienced in the economic growth strategy. The adoption of this strategy in the country has increased industrial production and caused an increase in the rate of urbanization.

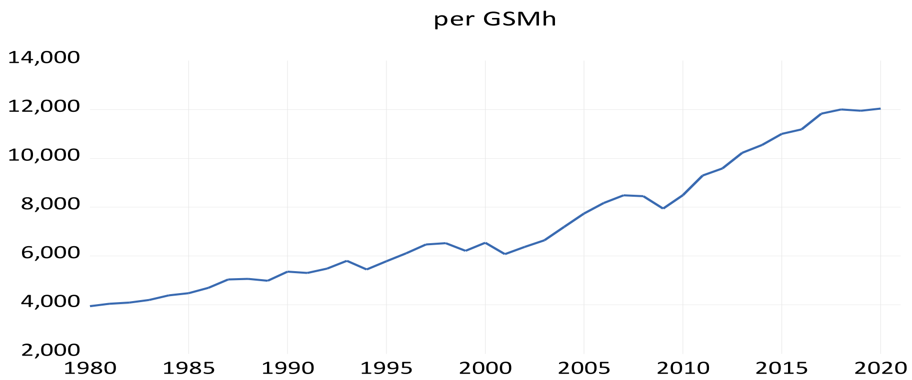

Figure 1. Turkey's economic growth

The study aims to determine the long-term relationship between renewable energy production and financial development, urbanization, and economic growth in the Turkish economy in the 1980-2020 period and to analyze the causal relationship between these variables. After the introduction part of the study, the conceptual framework and literature are given. In the third chapter, information about the method of the study and the data set is presented. After this section, the findings and conclusion sections come.

2. Theoretical Framework and Literature

Energy is the engine of production and economic growth. The relationship between energy consumption and economic growth is a highly studied in the literature. Energy use and energy supply security are of great importance for a sustainable and high economic growth. However, growth needs to be sustainable in a healthy environment. For this reason, countries are turning to projects that will increase renewable energy production. There is a need for an advanced financial system to promote renewable energy.

Financial development is seen as one of the main determinants of renewable energy production and consumption (Ahmed, 2017; Anton & Nucu, 2020; Cetin, 2018; Eren et al., 2019; Ilarslan, 2021; Khatun & Rani, 2021; Ustaoglu, 2022; Wu & Broadstock, 2015; Yilmaz, 2021). It is seen that different variables are also included in the analysis in investigating the relationship between energy consumption and financial development. Economic growth (Assi et al., 2021; Cetin, 2018; Eren et al., 2019; Shahbaz et al., 2021; Yilmaz, 2021) and urbanization (Anwar et al., 2022; Armeanu et al., 2021; Cetin, 2018; Islam et al., 2022; Liu et al., 2021; Zhang, 2019) are among the important determinants affecting energy consumption. Studies conducted in different country groups have found that financial development positively affects renewable Energy (Anton & Nucu, 2020; Belaïd et al., 2021; Shahbaz et al., 2021; Ustaoglu, 2022; Wu & Broadstock, 2015; Yilmaz, 2021). Some studies find bidirectional causality between financial development and renewable Energy (Ahmed, 2017; Eren et al., 2019; Zeren & Karaca, 2021). However, in some studies, the relationship between financial development and renewable energy could not be reached (Assi et al., 2021; Ilarslan, 2021).

One of the variables whose relationship with renewable energy is frequently investigated is the variable of economic growth. Eren et al. (2019) and Yilmaz (2021) found a bidirectional causality relationship between economic growth and renewable energy. Assi et al. (2021) concluded that economic growth affects renewable energy. Cetin (2018) could not find a relationship between renewable energy and economic growth. According to Shahbaz et al. (2021), on the other hand, state that renewable energy negatively affects economic growth.

In studies investigating the relationship between renewable energy and the variable of urbanization, only Anwar et al. (2022) found a bi-directional relationship between urbanization and renewable energy. According to Islam et al. (2022), urbanization negatively affects renewable energy. Cetin (2018) could not find a causal relationship between urbanization and renewable energy, but according to DOLS results, he concluded that urbanization is a determinant of renewable energy consumption.

Looking at the studies in the literature, it is seen that the relationship between energy consumption and economic growth and financial development and economic growth is generally emphasized, and the relationship between energy production and financial development has been researched relatively less. Another issue that attracts attention while scanning the literature is the scarcity of studies examining financial development, economic growth, urbanization, and energy consumption. It is also noteworthy that analysis methods that do not take structural breaks into account are used in the studies. When we look at the studies in the literature, most of the empirical evidence shows that the level of financial development positively affects renewable energy production. In addition, few studies investigate the relationship between renewable energy and financial development in the Turkish sample. For this reason, it is planned that the study will contribute to the literature.

The hypotheses developed in line with these inferences are given below.

H1: There is a positive relationship between economic growth and renewable energy production.

H2: There is a positive relationship between the level of financial development and renewable energy production.

H3: There is a negative relationship between urbanization and renewable energy production.

3. Empirical Research

3.1 Data

In the analysis, real income per capita (at constant prices, 2015 USD) as a measure of economic growth, urbanization rate as an indicator of urbanization (the share of the urban population in the total population), financial development index as a measure of financial development, and the share of renewable energy in total energy were analyzed. Data on these variables were obtained from the World Bank, International Renewable Energy Agency (IRENA), and the International Monetary Fund (IMF). All variables were seasonally adjusted and included in the analysis using their logarithms. Abbreviations for the variables are listed in Table 1.

Table 1. Definitions of variables

Variables	Definitions	Source
Real Income Per Capita	GDP	www.worldbank.org
Urbanization Rate	URP	www.worldbank.org
Financial Development Index	FD	www.imf.org
Renewable Energy	RE	www.irena.org

The change graphs of the variables in the relevant period are presented in Figure 2. When the graphs in Figure 2 are examined, it is seen that FD has increased by gaining significant momentum, especially after 2000 in Turkey. In the same period, there was a rapid upward trend in GDP, but after the 2008 global economic crisis, a decrease was observed. It is observed that the RE variable entered an upward trend after the government decided to encourage renewable energy investments in 2005.

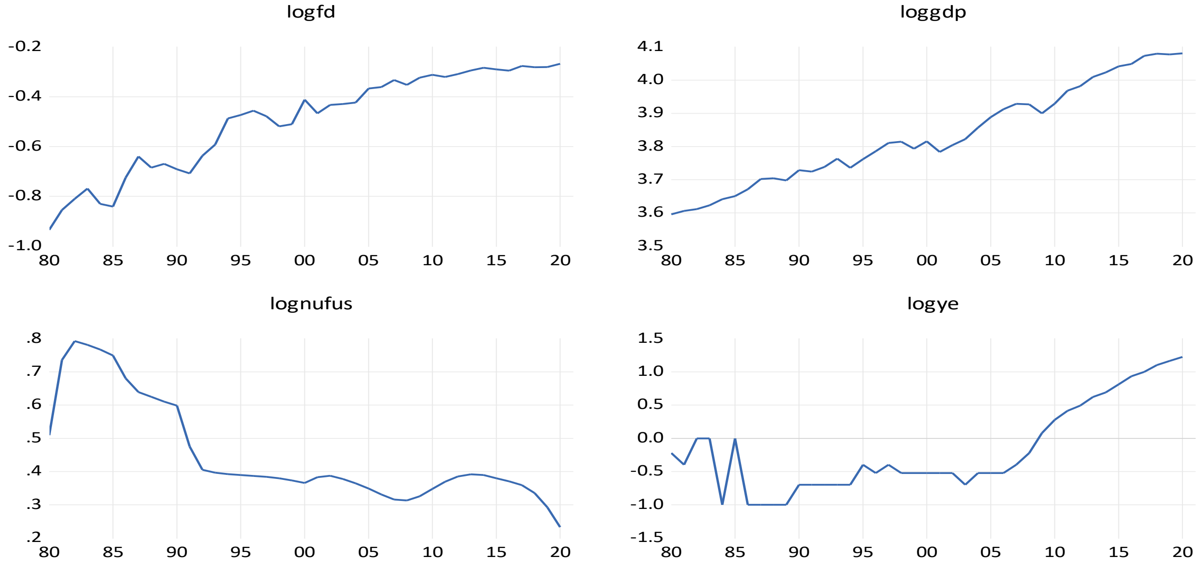

Figure 2. Graphs showing the change of variables over time

Descriptive statistics are statistical values that provide summary information about the data used in studies and summarize them. Descriptive statistical information about the variables used in the study is presented in Table 2.

Table 2. Descriptive statistics

	RE	FD	GDP	URP
Mean	2.301	0.348	7199	3015
Median	0.300	0.349	6470	2429
Maximum	16.805	5.539	12038	6201
Minimum	000	0.116	3941	13.588
Std. Dev.	4.252	0.136	2530	15.626
Skewness	2.176	-0.157	0.623	1.420
Kurtosis	6.684	1.629	2.160	3.598
Jarque-Bera	55.567	3.377	3.858	3.000
Probability	0.926	0.747	0.145	0.107
Observations	41	41	41	41

Table 2 shows the mean, median, most prominent and smallest values of the series and their standard deviations for the dependent and independent variables. In addition, the values of kurtosis and skewness coefficient, which help us to have information about the distribution of the series, and the results of the Jarque-Bera test, which tests their conformity to the normal distribution, are also seen. Jarque-Bera test results show that the series are normally distributed.

To determine the relationship between financial development, economic growth, urbanization, and renewable Energy, ARDL cointegration analysis, cointegration regression models, and Toda Yamamoto causality analysis will be applied using 1980-2020 period data. With the ARDL model, cointegration relationships and short and long run relationships will be revealed. Cointegration regressions (FMOLS, DOLS, CCR) allow the determination of long-term estimation parameters for variables with a cointegrating relationship. Toda Yamamoto causality analysis to determine the direction of the relationship between the variables will be performed.

3.2 Method and Analysis

In econometric analysis, first, it is necessary to determine the stationarity levels of the variables. For this purpose, unit root tests were applied to the variables used in the study. Many methods have been developed for the determination of stationarity. Stationarity can also be determined by visual inspection of the series or using the colegram. Today, unit root tests developed for this purpose are used to determine stationarity. The ADF test assumes that the error terms are statistically independent and have constant variance. Therefore, when using the ADF test, it is necessary to ensure that there is no correlation between the error terms and that they have constant variance. Phillips & Perron (1988) (PP) proposed a non-parametric test method that considers serial correlation and varying variance in error terms as an alternative to the ADF tests. In the study, the stationarity of the data was examined with Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests. Whether there are deterministic components (interruption and /or trend) in the model to be used in unit root testing was determined by a hierarchical process. According to this, in the variables of financial development (FD) and urbanization rate (urban population (URP) as a percentage of the total population), it was determined that the cut-off and trend-free model was appropriate. The cut and trend model were found to be appropriate for the GDP per capita (GDP) and renewable energy (RE) variables. Secondly, the number of lead-lag that should be added to the model to determine whether the residues are clean sequences was selected by AIC and SIC information criteria. The unit root test results are presented in Table 3.

Table 3. Unit roots test

Variables	ADF	PP
FD_t	-3.296 (0.022)**	-3.770 (0.006)***
GDP_t	-2.578 (0.291)	-2,628 (0.270)
ΔGDP_t	--6.660 (0.000)***	-6.753 (0.000)***
URP_t	-2.669 (0.088)*	-0.814662 (0.804)
ΔURP_t	-4.912 (0.000)***	-7.075 (0.000)***
RE_t	-0.616 (0.970)	-2.192 (0.480)
ΔRE_t	-7.020 (0.000)***	-12.489 (0.000)***

Note: Values in parentheses indicate probability values. ***, ** and * indicate 1%, 5% and 10% significance levels, respectively. Latency lengths were determined automatically according to the Akaike Information Criteria in the ADF test and the Newey-West bandwidth in the PP test.

When Table 3 is examined, the financial development (FD_t) variable is stationary at the level. The variables of GDP per capita (GDP_t), Renewable Energy (RE_t), and urbanization rate (URP_t); It is seen to be non-stationary according to ADF and PP unit root tests. When the first-order differences of these series are taken, they become stationary. One of the reasons why non-stationary variables are non-stationary is that the shocks that occur can cause the data generation process of the series to change. In other words, if the structural break is ignored, the series will tend to be non-stationary. Since ADF and PP unit root tests do not consider a structural break, the results obtained from these tests will be insufficient. Therefore, the unit root test was applied to the non-stationary GDP_t, URP_t, and RE_t series at this stage.

The structural break unit root test in Table 4 is the Perron (1997) test. When the results obtained from the Perron (1997) test are examined, it is concluded that the variables of renewable energy, national income per capita, and urbanization rate are non-stationary due to structural break. In other words, the series is non-stationary because of a structural break. It is seen that all three series are stationary, considering the structural break.

Table 4. Unit root test with structural break

Variables	Perron
GDP_t	-7.16173**** (2009)
URP_t	-11.32917 (1991)***
RE_t	-15.96778*** (1984)

Note: Values in parentheses indicate probability values. ***, ** and * indicate 1%, 5% and 10% significance levels, respectively.

3.2.1 Cointegration analysis

In the ARDL bounds test approach developed by Pesaran et al. (2001), the cointegration relationship between the variables can be tested I(0), I(1), or a combination. The ARDL bounds test was used as a cointegration test in the study. The ARDL approach has several advantages, such as allowing the investigation of the cointegration relationship, applying to small samples, using optimal lag lengths, and not needing pre-tests in case the stationarity level is different between the variables (Nazlioglu & Soytas, 2011; Pesaran et al., 2001). An unconstrained error correction model should be established first to determine whether there is cointegration between the variables with the ARDL method (Polat & Gemici, 2017; Simsir et al., 2015). The equation based on the Error Correction Model used in this study is as follows:

$$\Delta Y_t = \psi_0 + \sum_{i=1}^{m} \psi_{1i}\, \Delta Y_{t-i} + \sum_{i=0}^{m} \psi_{2i}\, X_{t-i} + \psi_3 Y_{t-1} + \psi_4 X_{t-1} + \varepsilon_t \tag{1}$$

In the equation Δ, it represents the first difference of the series, and m represents the lag length. After determining the degree of stationarity of the variables in ARDL analysis, the optimal lag lengths of the variables can be found using Akaike Information Criteria (AIC) and Schwarz Information Criteria (SIC). The length that makes the Information Criteria value the smallest is determined as the lag length of the model. In the next step, the cointegration relationship between the variables is investigated with the Bounds Test. In the related test:

$H_0 = \psi_3 = \psi_4 = 0$ (No cointegration);

$H_1 = \psi_3 \neq \psi_4 \neq 0$ (There is cointegration).

Under the null hypothesis, "No cointegration," the hypotheses are tested by calculating the overall F statistics and comparing them with the critical values. We can accept or reject the null hypothesis depending on the evaluation of the calculated F statistic. After determining the cointegration relationship between the variables, the long-term coefficients are determined within the framework of the equation given below.

$$Y_t = \psi_0 + \sum_{i=1}^{m} \psi_{1i}\, Y_{t-i} + \sum_{i=0}^{n} \psi_{2i}\, X_{t-i} + \varepsilon_t \tag{2}$$

In the next step of the ARDL approach, the short-term relationship between the variables is determined by the Error Correction Model shown below.

$$\Delta Y_t = \psi_0 + \sum_{i=1}^{m} \psi_{1i} \Delta\, Y_{t-i} + \sum_{i=0}^{n} \psi_{2i} \Delta\, X_{t-i} + \lambda ECM_{t-1} + \varepsilon_t \tag{3}$$

The ECM represents the error correction term calculated from the estimated equilibrium relationship established in Eq. (1). In the ARDL method, first of all, whether there is a long-term relationship between the variables should be tested. An appropriate lag number is selected according to the Akaike information criterion (AIC) to perform the ARDL test. It was determined that the most appropriate ARDL (4,4,2,0) model was according to the AIC information criterion. Table 5 presents the most appropriate ARDL (4,4,2,0) model and diagnostic tests to detect the presence of cointegration.

Table 5. ARDL prediction model and diagnostic tests

Panel A: ARDL (4.4,2.0) Model Prediction Results				
Variable	**Coefficient**	**Std. Error**	**t-statistic**	**Prob.**
RE(-1)	0.124	0.130	0.952	0.350
RE(-2)	0.697	0.134	5.188	0.000
RE(-3)	0.175	0.123	1,417	0.169
RE(-4)	-0,403	0,139	-2.882	0.008
URP	0.574	1.456	0.394	0.696
URP(-1)	2.086	2.676	0.779	0.443
URP(-2)	-1.742	2.693	-0.646	0524
URP(-3)	-3.983	2.259	-1.762	0.091
URP(-4)	3.057	0.936	3.265	0.003
GDP	2.357	1.898	1.241	0.226
GDP(-1)	-1.990	2.037	-0.976	0.025
FD	-1.991	0.987	-2.018	0.055
c	-17.195	4.174	-4.119	0.000
R^2 =0.96		Adj.R^2=0.95	F =56.210(0.000)	
Panel B: Diagnostic Tests				
Test		Statistic	Prob.	
Jarque-Bera Normalik testi		0.182	0.402	
Breusch-Godfrey LM testi		0.411	0.525	
Breusch-Pagan-Godfrey testi		12.150	0.102	
Ramsey Reset testi		0.262	0.794	

According to the diagnostic test results stated in Panel B, it was determined that the error term had a normal distribution, no autocorrelation or changing variance problem in the model, and no model-building error. In the study, the Bounds test was applied to determine whether there is a cointegrated relationship between the dependent variable renewable energy production, and the independent variables, real GDP per capita, financial development index, and urbanization rate. In this context, the Boundary test results are presented in Table 6 below.

Table 6. Bounds F-test for cointegration

Dependent Variables (k)	F Statistic	I(0)	I(1)
3	4.540	2.79	3.67**

When the Table 6 is examined, it is seen that the calculated F statistic is greater than the critical value. Therefore, the H_0 hypothesis expressed as "There is no cointegration relationship between the variables" is rejected, and it is accepted that there is a cointegration relationship between the variables. According to these results, it has been determined that there is a long-term cointegration relationship between renewable energy production, per capita GDP, urbanization rate, and financial development.

According to the long-term estimation results given in Table 7, the variables that have a statistically significant effect on the dependent variable, renewable energy production (RE), are GDP per capita (GDP) and financial development level (FD). While per capita GDP and financial development level positively affect renewable energy production, the effect of the urbanization rate on renewable energy production is negative. Although the rate of urbanization harms renewable energy production, this finding is not statistically significant.

Table 7. Long-Term forecast results

Variables	Coefficient	Std. Error	t-statistic	Prob.
URP	-0.017	1.827	-0.009	0.992
GDP	10.439	2.645	3.945	(0.000)***
FD	4.909	3.008	1.631	(0.009)*
c	-42.378	10.869	-3898	(0.000)***

The estimated error correction term was negative and significant, as expected. Seen Table 8 the value of the relevant coefficient was -0.40, and the cointegrated relationship between the variables was confirmed. Therefore, this means that 40% of the short-term imbalance between renewable energy production and per capita GDP, financial development, and urbanization rate is corrected in the next period, and this improvement repeats every year. At this stage of the study, CUSUM and CUSUM-Q tests, which are structural stability tests of the parameters, were applied to test the robustness of the models.

Since the CUSUM and CUSUMSQ graphs in Figure 3 are at the 5% significance level, and the test statistics are between the critical limits drawn, it can be said that the coefficients in the error correction model are stable.

Table 8. ARDL short-run and error correction model forecast results

ARDL (4,4,2,0) Model Forecast Results				
Variable	**Coefficient**	**Std. Error**	**t-statistic**	**Prob.**
ΔRE(-1)	-0.469***	0.098	-4.778	0.000
ΔRE(-2)	0.227*	0.114	1.988	0.058
ΔRE(-3)	0.403***	0.099	4.043	0.000
ΔURP	0.574	1.138	0.504	0.618
ΔURP(-1)	2.668*	1.382	1.930	0.066
ΔURP(-2)	0.925	1.350	0.685	0.499
ΔURP(-3)	-3.057***	0.675	-4.524	0.000
ΔGDP	2.357*	1.236	1.906	0.069
ΔGDP(-1)	-3.869***	1.370	-2.823	0.009
CointEq(-1)	-0.405***	0.078	-5.162	0.000

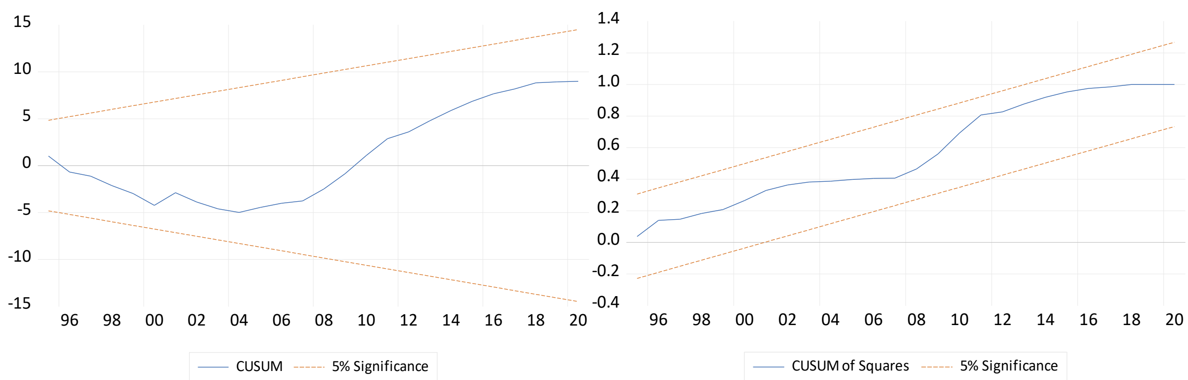

Figure 3. Cusum and Cusum Q Test

3.2.2 Cointegration regression models (FMOLS, DOLS, CCR)

When the variables are cointegrated, the relationship between the explanatory variables and error terms creates an internal problem. Three regression models have been developed that eliminate the internality problem in traditional cointegration methods (Münevvere, 2020). These models are FMOLS (Fully Modified Ordinary Least Square) developed by Phillips & Hansen (1990). CCR (Canonical Cointegrating Regression) was developed by Park (1992), and DOLS (Dynamic Ordinary Least Square) was developed by Stock & Watson (1993). FMOLS, CCR, and DOLS cointegration regression methods are based on the condition that the series used are stationary in difference, just like traditional cointegration methods. However, the fact that the obtained coefficients can be interpreted offers a significant advantage. The FMOLS estimator uses a semi-parametric correction method to avoid estimation problems caused by the long-term correlation between the cointegrated equation and stochastic shocks (Grima et al., 2021; Yildiz & Ozdemir, 2019).

$$RE = \beta_0 + \beta_1 FD + \beta_2 GDP + \beta_3 URP + \mathcal{E} \tag{4}$$

As a result of FMOLS, DOLS, and CCR regression models, the variables and effect sizes that are effective on renewable energy production were tried to be determined. Table 9 shows the coefficients of the independent variables in the model as a result of the analysis and the test statistics results regarding the coefficients' significance.

Table 9. FMOLS, DOLS, and CCR regression model results

Variable	FMOLS		DOLS		CCR	
	Coefficient	t- statistic	Coefficient	t- statistic	Coefficient	t- statistic
URP	0.471	0.482	-0.362	-0.258	0.944	1.302
GDP	8.669	1.260***	10.095	5.127***	8.748	7.485***
FD	3.836	2.787***	5.279	2.160**	3.184	2.989***
C	-37.633	-7.154***	-41.248	-5.026***	-35.676	-7.320***
	R^2=0.735		R^2=0.889		R^2 =0.753	
	Adj.R^2=0.713		Adj.R^2=0.836		Adj.R^2=0.733	

In the models established in the study, R^2, which expresses how much of the dependent variable is explained by the independent variable, was calculated as 73% for FMOLS, 88% for DOLS, and 75% for CCR. When the results of the FMOLS regression model were examined, it was determined that the GDP per capita and financial development variables affected renewable energy production at the level of 1% significance. A one-unit increase in the per capita GDP variable causes 8,669 units of renewable energy production, and a unit increase in financial development causes an increase of 3,836 units in renewable energy production. As a result of the DOLS regression model, it was determined that the GDP per capita was at the 1% significance level, and the financial development variables affected the renewable energy production at the 5% significance level. According to the DOLS regression model, a one-unit increase in per capita GDP variable causes an increase of 10,095 units. A unit increase in financial development causes an increase of 5.279 units in renewable energy production. As a result of the CCR regression model, it was found that the GDP per capita and financial development variables affected renewable energy production at the level of 1% significance. According to the CCR regression model, a one-unit increase in GDP per capita increases renewable energy production by 8,748, and a one-unit increase in the financial development variable increases renewable energy production by 3,184 units. The urbanization rate has no statistically significant effect on renewable energy in all three models. It is seen that the results obtained from FMOLS, DOLS, and CCR regression models support each other.

3.2.3 Toda Yamamoto causality test

The Toda Yamamoto causality test does not require the same level of stationarity between the series or a cointegration relationship between the variables. In the Toda Yamamoto causality approach, firstly, the Vector Autoregressive (VAR) model should be established, and the lag length (p) should be determined. Second, the highest degree of integration, d-max, is added to the lag length p. The test model can be written as follows:

$$Y_{t=\varphi+} \sum_{i=1}^{p+dmax} \alpha_{1i} Y_{t-1} + \sum_{i=1}^{p+dmax} \alpha_{2i} X_{t-1} + \mu_{1t} \tag{5}$$

$$X_{t=\varphi+} \sum_{i=1}^{p+dmax} \beta_{1i} X_{t-1} + \sum_{i=1}^{p+dmax} \beta_{2i} Y_{t-1} + \mu_{1t} \tag{6}$$

While questioning causality in the Toda Yamamoto test, it is tested that the base coefficients are zero and different from zero. In the Toda Yamamoto causality test, firstly, the standard VAR model was created, and the Akaike (AIC), Schwarz Bayesian (SBC), and Hannan and Quinn (HQC) information criteria were taken into account in the selection of the VAR model lag length. In the model, p gives the optimal lead-lag, and d-max gives the maximum integration number of the variables used.

For all models created according to the information criteria, the optimal lag number p is 2. ADF and PP Unit Root tests determined the maximum integration level (d-max) among the variables. After determining the number of lags of the VAR model, a causality analysis was carried out within the framework of the 3rd-degree VAR model by adding 1, which is the maximum degree of integration of the variables entering the model, to this lag number (2). The causality analysis results of the variables are given in Table 10.

Table 10. Toda Yamamoto causality test result

Variable	F statistic	Prob.	Direction of Causality
RE- FD	0.474	0.924	FD→RE
FD- RE	9.472**	0.023	
RE-GDP	2.976	0.395	GDP→RE
GDP -RE	19.704***	0.002	
RE-URP	5.690	0.127	URP→RE
URP-RE	14.768***	0.002	

These results found a one-way causality relationship between financial development and renewable energy at the 5% significance level. The direction of the relationship is from financial development to renewable energy. This shows that more resources can be used for renewable energy production as financial development increases. This result is in Anwar et al. (2022), Belaïd et al. (2021), Cetin (2018), Shahbaz et al. (2021), Ustaoglu (2022), and Wu & Broadstock (2015) in the same direction as the findings obtained in the sample of different countries. Ahmed (2017), Armeanu et al. (2021), Eren et al. (2019), and Zeren & Karaca (2021), on the other hand, indicate that there is bidirectional causality between the two variables. On the other hand, Assi et al. (2021) did not find any causal relationship between financial development and renewable energy consumption. The unidirectional causality relationship was determined from per capita income and urbanization rate, another economic growth indicator variable, to renewable energy at the 1% significance level. The relationship between economic growth and renewable energy Assi et al. (2021), while Cetin (2018) could not find any causality finding between economic growth and renewable energy in his study. Shahbaz et al. (2021), on the other hand, concluded that economic growth negatively affects renewable energy. On the other hand, Eren et al. (2019) and Yilmaz (2021) found a bi-directional causality relationship between economic growth and renewable energy. The causality relationship between urbanization and renewable energy is seen in the literature (Zhang, 2019) study. Armeanu et al. (2021) also found a bidirectional causality relationship between urbanization and renewable energy. Anwar et al. (2022) and Islam et al. (2022) concluded that the effect of urbanization is negative, while Cetin (2018) and Liu et al. (2021) concluded that there is no causal relationship between urbanization and renewable energy.

4. Discussion and Conclusions

The fact that the Turkish economy is a developing economy reveals the importance of investigating the factors affecting energy production, as the energy demand will continue to increase today and in the future. In this study, the relationship between financial development and energy consumption is investigated by considering structural breaks in the sample of Turkey in the 1980-2020 time period. Economic growth and urbanization variables are also included in the analysis. The structural break unit root test carried out the stationarity analysis of the variables, Perron (1997), and the classical unit root tests, such as ADF and PP. The long-term relationship between the variables was analyzed with the ARDL bound test. The long-term estimates of the variables were examined with the help of FMOLS cointegration regression models. The causality relationships between the variables were investigated with the Toda-Yamamoto causality approach.

GDP per capita (GDPt), Renewable energy (REt), and urbanization rate (Pt) variables; It is seen to be non-stationary according to the ADF and PP unit root tests. Perron's unit root test with structural break was detected in 1984 in the RE series, in 1991 in the URP series, and in 2009 in the GDP series (Perron, 1997). ARDL bounds test shows that there is a cointegration relationship between variables. ARDL long-term estimation results have a statistically significant and positive effect on per capita GDP (GDP) and financial development level (FD) variables on renewable energy production (RE). The effect of the urbanization rate on renewable energy production is negative. In all of the cointegration regression models (FMOLS, DOLS, and CCR), economic growth (GDP) and financial development (FD) variables were found to have a statistically significant and positive relationship.

In contrast, the urbanization rate (URP) variable negatively affected all three models but was statistically insignificant. On the other hand, the Toda Yamamoto causality test shows a unidirectional causality relationship between economic growth (GDP), financial development (FD), and the Urbanization rate of renewable energy.

This situation can be interpreted as the economic development providing the necessary funds for investment in renewable resources because it is a developing country. However, although there is a unidirectional causality relationship between the rate of urbanization and renewable energy, the cointegration regressions show that it has a negative effect.

As Turkey is a developing country, its energy demand is constantly increasing. However, this energy need must be met with resources that are not harmful to the environment in the long term. Turkey has demonstrated its environmental awareness with the Paris Climate Agreement it signed in 2021. In determining Turkey's long-term energy demand projections and strategies by policymakers, both the impact of financial development and economic growth should be considered while minimizing foreign dependency and providing energy with sustainable resources. More incentives and support should be given to renewable energy generation, bearing in mind that well-developed financial systems tend to encourage renewable energy generation through more accessible access to finance. The use of a single developing country sample in the study constitutes the limitation of the study. In future studies, analysis can be developed by using not only urbanization but also different socio-economic variables.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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