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ECONOMIC GROWTH, RENEWABLE ENERGY, AND INFLATION: INTERCONNECTIONS OF A TRIANGLE*

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Abstract

The primary objective of any nation's economy is to achieve economic stability and a high standard of living. This can be attained through sustainable economic growth. However, global economic competition often brings about challenges, one of which is the increasing demand for energy products driven by population growth. Historically, this demand has been predominantly met by fossil fuels, but due to resource depletion and environmental concerns, there has been a growing interest in alternative energy sources. This shift towards renewable energy has become a global trend. The energy sector serves as a key indicator of a nation's prosperity and development, with renewable energy production, transportation, and costs being vital metrics of development. For Turkey, like many developing nations, investing in renewable energy is crucial for sustainable growth. This study explores the relationship between renewable energy, economic growth, and inflation in Turkey from 1975 to 2022. It examines the process of economic growth in the first part, followed by an analysis of energy dynamics and inflation in subsequent sections. The study employs unit root tests such as ADF and PP, along with the Toda-Yamamoto causality test, using available data. The final results are then interpreted.

Keywords: Economic Growth, Renewable energy, Inflation, Toda-Yamamoto

Jel Kodları: F43, K32

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EKONOMİK BÜYÜME, YENİLENEBİLİR ENERJİ VE ENFLASYON: BİR ÜÇGENİN BAĞLANTILAR

Öz

Ülkelerin ekonomilerinin temel hedeflerinden biri de ekonomik istikrarı ve yüksek refah düzeyini sağlamaktır. Bu durum, ekonomik büyümeyi sürdürülebilir hale getirebilmek ve gelişmiş ülkeler arasına girmekle mümkündür. Yıllarca süren ülkeler arası ekonomik rekabet doğal olarak bazı zorlukları beraberinde getirmiştir. Artan nüfus ve buna bağlı enerji talebi bu zorluklardan biridir. Ülkeler, bu talebi yakın tarihe kadar genellikle fosil yakıtlardan karşılamışlardır. Ancak, rezervlerin tükenme tehlikesi ve çevresel etkilerin artması nedeniyle farklı enerji kaynakları arayışı artmıştır. Dünya, bu süreçte yenilenebilir enerjiyle tanışmıştır. Günümüzde refahın ve gelişmişliğin önemli göstergelerinden biri yenilenebilir enerji sektörüdür. Yenilenebilir enerji üretimi, ulaşımı ve maliyetleri gibi kriterler, gelişmişlik düzeyini belirleyen önemli göstergelerdir. Türkiye gibi gelişmekte olan bir ülke için de yenilenebilir enerji önemli bir yer tutmaktadır. Türkiye için yeni sayılabilecek olan yenilenebilir enerji sektörü, ülkeyi daha ileri seviyelere taşıyabilecek adımlardan biridir. Bu çalışma, Türkiye'nin 1975-2022 yıllarına ait yenilenebilir enerji üretimi, kişi başına düşen GSYH ve enflasyona ilişkin verileri kullanarak bu üç değişken arasındaki ilişkiyi incelemektedir. Çalışmanın ilk bölümde ekonomik büyüme süreci incelenmekte, sonraki bölümlerde enerji dinamikleri ve enflasyon analizi yapılmaktadır. Mevcut verilere dayanarak ADF ve PP kök birim testleri uygulanmış ve Toda-Yamamoto nedensellik testi gerçekleştirilmiştir.

Anahtar Kelimeler: Ekonomik Büyüme, Yenilenebilir Enerji, Enflasyon, Toda-Yamamoto.

Jel Kodları: F43, K32

1. INTRODUCTION

Beyond being the main driving force of modern societies, energy also has a vital role as the carrier of economic and social development. Factors such as rapidly advancing technology, rapid population growth, urbanization, and industrialization have caused the world's energy demand to increase daily. However, the current energy production capacity can only partially meet this increasing demand. For this reason, energy has become one of today's most urgent and critical problems. The solution to the energy problem will be possible by diversifying and increasing energy resources and using existing energy resources most effectively and efficiently. In this context, many factors should be considered, such as the balance of energy production and consumption processes, environmental impacts, economic sustainability and social needs. The increase in world energy needs has caused the review of energy policies and strategies. Steps such as developing sustainable energy resources, increasing energy efficiency and investing in renewable energy technologies can contribute to the solution of the energy problem. Carrying out energy management more effectively and balanced is important for economic growth, environmental protection and social welfare (Serezli, 2022).

After completing their economic growth phase, developed countries have taken steps to combat the environmental pollution problem. In this process, they spent significant economic resources to reduce environmental pollution. With increasing sensitivity to environmental issues over time, efforts to reduce environmental pollution have progressed with technological developments, reducing costs.

Developing countries such as Türkiye are trying to maintain rapidly growing economies with increasing energy consumption. However, it is inevitable that the environmental pollution problem will grow in this process. Increasing awareness of environmental protection on a global scale directs these countries to give more importance to protecting the environment while maintaining economic growth. This reveals the necessity of investing in treatment facilities, recycling systems and sustainable energy sources (Albayrak, 2011).

The aim of this study is to reveal the relationship between renewable energy, economic growth and inflation in Türkiye. The subject of the study is considered necessary due to the recent global inflationary situation and global warming, as governments seriously include renewable energy sources in their programs. The findings are expected to contribute to the literature by making policy inferences. The study is divided as follows: After the introduction, there is a literature review in the second section. In the third chapter, the model and data set used in the study are presented to the reader. The fourth chapter interprets the empirical findings, and the last chapter includes a general evaluation and policy recommendations.

2. LITERATURE REVIEW

This section is divided into two parts: the relationship between renewable energy and economic growth, and the relationship between inflation and economic growth. Empirical studies related to the subject are examined in the chapters.

When looking at the literature, it is evident that in recent years, there has been intensive research on the relationship between renewable energy and economic growth. The central focus of these studies is the causal relationship between energy consumption and economic growth. Some of the prominent hypotheses and related studies in the literature suggest a linear relationship between economic growth and renewable energy. However, some studies have not found a significant relationship between the two variables. Additionally, research conducted in Turkey also indicates the effectiveness of energy policies on economic stability and demonstrates a linear relationship between renewable energy and economic growth.

2.1. The Relationship Between Renewable Energy And Economic Growth

Recently, studies on the relationship between renewable energy and economic growth have attracted attention. Many studies on energy consumption and economic growth wonder in which direction the causal relationship is. There are four possible hypotheses regarding this issue: the growth hypothesis, the conservative hypothesis, the feedback hypothesis, and the neutrality hypothesis. The growth hypothesis explains the unidirectional causal relationship. This indicates that the increase in renewable energy consumption will increase economic growth. The conservative assumption is that economic growth affects energy consumption. The feedback hypothesis states that there is a two-way causality. Fourth, the neutrality assumption indicates that there is no relationship between the two variables.

Sadorsky (2009) examined 18 developing countries. He found that there is a linear relationship between economic growth and renewable energy. Tiwari (2011) conducted a study for India, and the same result was obtained. Inglesi-Lotz (2016) concluded that economic growth is positively affected as energy consumption increases. Rafindadi and Öztürk (2017) reached similar results in their study. Bhattacharya et al. (2017) conducted a study covering 85 countries. As a result of the study, renewable energy triggers economic growth. Kutan et al.

(2018) conducted a study for developing countries. His result is similar to Inglesi-Lotz (2016). Dumitrescu and Hurlin (2012) did not find any relationship between the two variables. The study by Paramati, Apergis and Ummella (2018) shows similar results in the example of G20 economies. Tanrıseven (2018) addressed energy sources in the first section of the study. The utilization status of fossil fuels and renewable energy types in the world and Turkey was analyzed. Kantarmacı (2019) examined the contribution of primary renewable energy production between 2006 and 2016 to economic growth and employment in 28 member countries of the European Union in their study. Hacıimamoğlu (2020) investigated the impact of renewable energy consumption on economic stability in their study conducted in the same year. Özbek (2021) explored the effect of renewable energy production on economic growth in Turkey between 1990 and 2017 in their study. Özgür (2021) aimed to propose economically effective and feasible energy policies by investigating the relationship between economic growth and electricity consumption from renewable energy sources in Turkey. Karademir (2022) examined the impact of renewable energy consumption on economic growth in G20 countries in their study. Aslan (2022) investigated the relationship between renewable energy, financial development, and economic growth in selected BRICS and MINT countries between 2001 and 2019 in their study.

2.2. The Relationship Between Inflation And Economic Growth

Studies in the literature on the subject give different results. While relatively old studies show that inflation contributes to growth, new studies say the opposite (Paudyal, 2011). The direction of the relationship between these two remains a matter of curiosity. There are four possibilities for this relationship: Inflation has no effect, inflation has a positive economic effect, inflation has a negative effect, and finally inflation has an effect within a certain threshold.

Karki et al. (2020) Growth for Nepal is under tremendous support for specific inflation-equal resilience suitable for growth. Adaramola and Dada (2020) found no relationship between economic growth and inflation in Nigeria. A similar result was found by Ekinci (2020) et al., and Boujelbene (2021) also obtained. Fung and Nga (2022) stated that inflation has a long-term positive and significant significance, proving that a 1% increase in inflation improves economic growth by 0.31%. Osei (2023) has found that the optimal inflation level exists for Ghana; inflation above the optimal inflation negatively impacts economic growth, and inflation behind the optimal inflation rate has been proven to increase growth.

3. METHODOLOGY AND DATA

This study examines the causal relationships between economic growth, renewable energy and inflation. In the study, Türkiye's annual energy, per capita income and inflation data covering the period 1975-2022 were used. Table 1 shows descriptions of variables and data sources.

Table 1. Variables, Descriptions and Data Sources

Variable	Description	Source
LNYE	Nat. logarithm of total renewable energy production	TEİAŞ
LNENF	Natural logarithm of consumer price index	World Bank
LNKGYSH	Natural logarithm of GDP per capita	World Bank

Source: Qwn Representation.

In the study, the Toda-Yamamoto (1995) test was applied to find out the causal relationship between the relevant variables. This test differs from the traditional Granger causality test. This difference does not create a problem for the application of the test if the series is stationary and there is cointegration between the variables. At the same time, since non-stationary series are not differentiated in the Toda-Yamamoto test, there is no data loss problem. When applying the Toda-Yamamoto test, first the stationarity of all series is examined to determine their stationary level and the maximum degree of integration (dmax). A Vector Autoregression (VAR) model is also established and the appropriate lag length (k) is determined. Then, by adding the maximum integration degree to the appropriate lag length, VAR is estimated at k + dmax lag length (Yıldız, 2022). The tested VAR model can be represented as follows:

$$y_t = Y_t + \sum_{i=1}^{k+dmax} a_{1i} Y_{t-1} + \sum_{i=1}^{k+dmax} \beta_{1i}\, x_{t-1} + e_{it} \tag{1}$$

$$x_t = Y_t + \sum_{i=1}^{k+dmax} a_{2i} Y_{t-1} + \sum_{i=1}^{k+dmax} \beta_{1i}\, x_{t-1} + e_{2t} \tag{2}$$

Here, the primary hypotheses are as follows: for the first model, X is not the Granger cause of Y, and for the second equation, Y is not the Granger cause. Here, parameter limitations are tested to determine whether there is a causal relationship between the variables.

4. FINDINGS

In the Toda-Yamamoto test, the stationarity of the series must first be examined and the maximum degree of integration must be determined. For this purpose, the stationarity of the series was tested with the Improved Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. The Dickey-Fuller unit root test is the most widely used and validated unit root testing method. This method was developed to eliminate error autocorrelation in the tests. Lagged values of the dependent variable are added to the regression as explanatory variables. Akaike and Schwarz criteria determine the lag value mentioned (Awokuse, 2003). Although ADF is insufficient, it is an improved root unit test. The Dickey-Fuller method may sometimes be insufficient in finding unit roots. While the Dickey-Fuller method is a parametric method, it is based on the assumption that error terms in PP tests may be interrelated and heterogeneous. Thus, there is no need to determine the lag length in the Phillips-Perron test. It is also robust to heteroscedasticity in error terms (Phillips, Perron, 1988). ADF and PP unit root test results are shown in Table 2.

Table 2: Unit Root Test Results

	ADF		*PP*	
	t stat.	**p-value**	**t stat.**	**p-value**
LNENF	-1.412052	0.5685	-1.428796	0.5603
ΔLNENF	-7.176366	0.0000*	-7.180936	0.0000*
LNYE	-1.234107	0.6519	-1.122864	0.6992
ΔLNYE	-8.752440	0.0000*	-10.53999	0.0000*
LNKGSYH	-1.000920	0.7456	-1.000894	0.7456
ΔLNKGSYH	-7.126151	0.0000*	-7.125511	0.0000*

Note: Probability values are shown in parentheses. * indicates the 1% significance level.

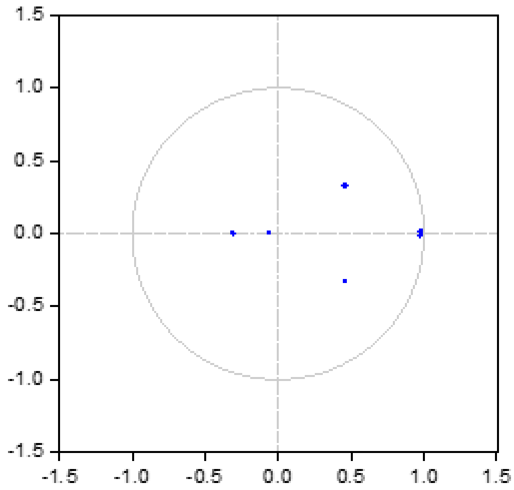
Based on the information in Table 2, it can be said that all variables are stationary at the first difference, as a common result of both tests. In this case, the maximum degree of integration (dmax) is taken as 1.

Table 3: Lag Lenght

Lag	**LogL**	**LR**	**FE**	**AIC**	**SC**	**HQ**
0	-1123.130	NA	3.41e+18	51.18773	51.30937	51.23284
1	-1000.067	223.7515*	1.91e+16*	46.00303*	46.48963*	46.18348*
2	-991.9660	13.62379	2.01e+16	46.04391	46.89545	46.35970
3	-986.0769	9.101316	2.35e+16	46.18531	47.40181	46.63645
4	-979.9713	8.603402	2.76e+16	46.31688	47.89832	46.90335

According to the information in Table 3, the appropriate lag length (k) is determined as 1. At this stage, the VAR model is estimated by adding the maximum integration degree (d_{max} = 1) to the lag length (k = 1) (k + d_{max} = 2). Here, various diagnostic tests must be performed to determine the validity of the VAR model. For this purpose, first the inverse roots of AR characteristic polynomials are examined.

Graph 1: Inverse Roots of AR Characteristic Polynomial



When the inverse roots of AR characteristic polynomials are examined, it is understood that all roots are within the unit circle. Accordingly, it can be said that the variables do not have unit roots and the model is stationary. Table 4 shows the LM test results conducted to determine whether the model has an autocorrelation problem.

Table 4: Autocorrelation LM Test

Lag	**LM-Stat**	**p-value**
1	9.291678	0.4108
2	14.75822	0.0978
3	7.187874	0.6176

According to the LM test results, there is no autocorrelation problem in the model. Table 5 shows the results of the White test conducted to determine whether the model has a heteroscedasticity problem. According to the results of this test, there is no heteroscedasticity problem in the model. After determining the suitability of the VAR model, the VAR model was estimated with $k + d_{max} = 2$ lag length and the Toda-Yamamoto causality test was conducted. The results of the causality test are summarized in Table 6.

Table 6: Toda-Yamamoto Causality Test Results

	Stat.	**Prob.**
Energy-> Growth	0.760465	0.6837
Growth-> Energy	8.520148	0.0141*
Energy-> Inflation	5.475269	0.0647

Inflation-> Energy	0.204650	0.9027
Inflation-> Growth	1.408299	0.4945
Growth-> Inflation	7.798494	0.0203*

Note: Probability values are shown in parentheses. * indicates the 1% significance level. The appropriate lag length for the VAR model was determined according to the Schwarz Information Criterion.

According to the Toda-Yamamoto test result, while there is no causality relationship from energy to growth, there is a one-way causality relationship from growth to energy. In addition, while a causality relationship from energy to inflation was observed at a 10% significance level, no causality from inflation to energy could be determined. On the other hand, according to the test results, it is possible to talk about a one-way causality relationship between growth and inflation. There is no causality relationship from inflation to growth.

5. CONCLUSION AND POLICY RECOMMENDATIONS

Economic growth is a complex concept that expresses the development process in countries. This process involves structural changes in the economy and generally includes elements such as increasing per capita income, increasing labor productivity, and progress in social, political, and intellectual fields. Economic growth is the cornerstone of developed country policies. Some of the factors that fuel economic growth are capital accumulation, increase in production, increase in investments, increase in employment and technological changes. When the effects of these factors come together, economic growth occurs and the level of welfare increases throughout the country. By managing these factors, developed countries encourage economic growth and try to achieve sustainable progress.

Energy creates a wide range of impacts, from meeting people's basic vital needs at the individual level to helping businesses operate efficiently and countries achieve their development goals. However, energy emerges as an issue that needs to be addressed for economic growth and development and broader perspectives such as environment, sustainability, security, and international relations. Energy is in constant demand despite price fluctuations. Today, energy, which has a vital role in ensuring stability, prosperity, and security, appears to be a complex field that needs to be managed in detail in terms of both its resources and effects.

This study was conducted to understand the long-term relationship between renewable energy, economic growth and inflation in Türkiye. Within the scope of the research, renewable energy production, gross domestic product (GDP), and inflation data from 1975-

2022 were examined. The analysis made in this study examines Türkiye's energy policies and aims better to understand the impact of transformation on economic performance. The impact of renewable energy investments on economic growth and inflation has been tried to be revealed through analysis of long-term data.

The study evaluates the impact of Turkey's energy policies on economic stability. Consequently, a concrete assessment based on empirical data regarding the effectiveness of energy policies can be conducted. The findings can guide the identification of policies and strategies necessary for Turkey to achieve its sustainable development goals. This enables the optimization of energy policies towards sustainability and economic efficiency. Moreover, the study can assist Turkey in utilizing its energy resources more efficiently. This, in turn, can enhance energy security by balancing economic growth with energy demand, thereby reducing dependence on external sources. By aiding our understanding of the impact of energy policies on economic stability, the study can contribute to preventing economic crises and sustaining economic growth. This could lead to tangible economic benefits such as reducing unemployment rates and ensuring a more equitable distribution of income.

Based on these data and information, several policies can be implemented. Firstly, increasing investment in renewable energy would be beneficial. Studies indicate a linear relationship between economic growth and renewable energy, emphasizing the importance of enhancing investments in renewable energy to achieve Turkey's economic growth objectives and meet its energy needs. Therefore, facilitating access to renewable energy sources through state incentives can be effective. Another policy could involve diversifying renewable energy sources, which can enhance energy security and meet energy demand. While taking these steps, environmental and social considerations should be taken into account. Finally, technological advancements should be pursued. Turkey's investment in innovative technologies and support for R&D activities can provide a competitive advantage in the energy sector.

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