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Frequency Domain Causality Analysis of the Energy- Economic Growth Relationship for Turkey*

Türkiye İçin Enerji- Ekonomik Büyüme İlişkisinin Frekans Alanı Nedensellik Analizi

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Abstract

Energy, which we can show as one of the basic elements of production, is a phenomenon that is emphasized today as it has been in every period of history. Since energy is an indispensable part of the production process, we come across as an important factor in the economic growth of countries, and with this feature, it has been the subject of many studies in the economics literature. The aim of this study is to test the causality relationship between energy and economic growth in Turkey. In this study covering the period between April 2016 and March 2021, the data on the monthly total electricity consumption representing the energy variable and the monthly industrial production index representing the economic growth are analysed with the frequency domain causality analysis method, and whether there is a causal relationship between the variables is examined in the short, medium and long term. According to the results of the analysis, while a unidirectional causality relationship is found from economic growth to energy consumption in the medium and long term, there is no evidence of a causal relationship from energy consumption to economic growth in any term.

Keywords: *Turkey, Industrial Production Index, Electricity Consumption, Frequency Domain Causality Analysis*
JEL Classification: *C13, C22, Q40.*

Öz

Üretimin temel unsurları arasında gösterebileceğimiz enerji, tarihin her döneminde olduğu gibi bugün de üzerinde önemle durulan bir olgudur. Üretim sürecinin vazgeçilmez bir parçası olması nedeniyle enerji, ülkelerin ekonomik büyümelerinde önemli bir etken olarak karşımıza çıkmaktadır ve bu özelliği ile iktisat literatüründe çok sayıda çalışmaya konu olmuştur. Bu çalışmada da amaç enerji ile ekonomik büyüme arasındaki nedenellik ilişkisini Türkiye özelinde test etmektir. Nisan 2016-Mart 2021 dönemini kapsayan bu çalışmada enerji değişkenini temsilen aylık toplam elektrik tüketimine, ekonomik büyümeyi temsilen ise aylık sanayi üretim endeksine dair veriler frekans alanı nedensellik analizi yöntemiyle analiz edilerek, değişkenler arasında bir nedensellik ilişkisi olup olmadığı kısa, orta ve uzun dönemde incelenmiştir. Analiz sonuçlarına göre ekonomik büyümeden enerji tüketimine doğru orta ve uzun dönemde tek yönlü bir nedensellik ilişkisine rastlanırken, enerji tüketiminden ekonomik büyümeye doğru herhangi bir dönemde nedensellik ilişkisi olduğuna dair kanıtlara ulaşılamamıştır.

Anahtar Kelimeler: *Türkiye, Sanayi Üretim Endeksi, Elektrik Tüketimi, Frekans Alanı Nedensellik Analizi*
JEL Sınıflandırması: *C13, C22, Q40.*

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1. Introduction

Energy, which has been a part of production throughout history, has increased its importance especially after the industrialization process and has become one of the indispensable production resources today. In this process, the need for energy has increased day by day with both increasing production and increasing urban life. In this respect, it is obvious that energy consumption is closely related to economic growth, which represents real increases in production. For this reason, this relationship has been discussed by economists for many years and has been the subject of many studies.

Energy is briefly defined as the power that emerges in the form of heat or light in matter. Energy sources are basically classified as renewable and non-renewable energy sources. Today, in energy production, both renewable energy sources such as wind, solar, hydraulic, geothermal energy and non- renewable energy sources such as natural gas, oil, coal or nuclear energy are extensively utilized, and the produced energy is an indispensable element of the production process. Therefore, energy consumption has become an important concept that should be examined together with economic growth in all economies. So much so, that the determination of the relationship between these variables will provide important clues to countries on many issues from growth strategies to energy policies. For this reason, it is quite important to examine the relationships between energy and economic growth, and this importance is the main motivation for this study.

The aim of this study is to determine the causal relationship between economic growth and energy consumption. In this context, whether there is a causal relationship between total electricity consumption, which is used to represent energy consumption, and industrial production, which represents economic growth, is tested with time series methods in Turkey. Unlike other similar studies, this study examines the causal relationships between variables for different terms. The study, together with this introduction, consists of five chapters: literature, data and method, findings and conclusions.

2. Literature

When the literature is examined, it is seen that studies on the relations between energy and economic growth, especially on the USA, have a large place in the literature. Kraft and Kraft (1978), which examines the relationship between these studies for the USA, is the work that comes to the fore in the related literature. In the study in which the 1947-1974 period was analyzed, it was determined that there was a unidirectional causality relationship from growth to energy consumption. On the other hand, studies conducted by Akarca and Long (1980), Hamilton (1983) and Stern (1993) with the Granger causality analysis method in the literature stand out as other studies examining the energy-growth relationship for the USA. While Akarca and Long (1980) could not find a significant causal relationship between variables, Hamilton (1983) and Stern (1993) concluded that there is a unidirectional relationship from energy to growth. In the other two studies conducted for the USA, Stern (2000) concluded that there is a cointegration relationship between economic growth and energy consumption and Payne (2009) concluded that there is no significant causal relationship between these variables similar to Akarca and Long (1980). In other studies conducted for the USA, Yıldırım et al. (2012) found a one- way causality relationship from renewable energy consumption to GDP, while Arora and Shi (2016) found that the causality relationship between GDP and energy consumption in the USA for the 1990s was bidirectional. However, in the 2000s, they concluded that this relationship was unidirectional from GDP to energy consumption.

Similarly, many studies in which the relationship between these variables are made for different countries and country groups stand out in the literature. Yu and Choi (1985), one of these studies and making a comparative analysis for the Philippines and Korea, concluded that there is one-way causality is from energy to growth for the Philippines and there is one- way causality from growth to energy for Korea. In another study, Erol and Yu (1987) did not find a significant causal relationship between energy

and growth in their study on 6 industrialized countries. In other studies focusing on different countries, Cheng and Lai (1997) and Aqeel and Butt (2001) respectively found unidirectional causality from economic growth to energy consumption for Taiwan and Pakistan, while Paul and Bhattacharya (2004) found bidirectional causality for India. In another study, Narayan and Smyth (2008) revealed the existence of a unidirectional causality relationship from energy consumption to real GDP for G7 countries. Ouedraogo (2013), who analyzed 15 African countries, concluded in his study that there is a causal relationship from GDP to energy in the short run while from energy to GDP in the long run. In a study in which 75 countries were analyzed using panel data techniques, Esen and Bayrak (2017) concluded that there are statistically significant relationships between energy consumption and economic growth in the long run.

On the other hand, studies examining the relations between these variables in Turkey are also frequently encountered in the literature, and differences are observed between the findings of the relevant studies. For example, Soytaş and Sarı (2003), Ertuğrul (2011), Yenilmez and Erdem (2018) found a causality relationship from energy to growth, while Özata (2010), Savaş and Durğun (2016) determined the direction of causality from growth to energy consumption. In the other two studies, Erdal et al. (2008) and Korkmaz and Develi (2012) concluded in their studies that there is a bidirectional causality relationship between the variables. In another study, Altınay and Karagöl (2005) could not find any evidence for a causal relationship between energy and growth for Turkey. On the other hand, Erbaykal (2008), who is among the studies examining the relationship in question periodically, emphasized that energy consumption has a positive effect on growth in the short term. But they concluded that electricity consumption has a negative effect while oil consumption has a positive effect on growth in the long term. In another study examining the related relationship periodically, Aydın (2020) determined a unidirectional causality relationship from energy consumption to growth in the long run.

As a result, to summarize the relevant literature in a few sentences, first of all, it is seen that a common conclusion could not be reached in studies examining the relations between related variables. In some of the related studies, a unidirectional causality relationship from energy to economic growth or from economic growth to energy is determined, while in some studies, a bidirectional causality relationship is encountered. It is also possible to come across studies in the literature in which no causal relationship could be determined between the relevant variables.

3. Data and Method

In the study, the causality relationship between energy consumption and economic growth is examined in the short, medium and long term and it is investigated whether there is a causal relationship in these periods. In the study carried out with monthly observations for the period of April 2016 and March 2021, the variables representing energy consumption and economic growth are shown in Table 1 with their explanations and data sources.

Table 1. Energy and Economic Growth Variables

Variable	Explanation	Source
Energy	Monthly % change in total electricity consumption	Turkish Statistical Institute
Growth	Monthly % change in industrial production index	Turkish Statistical Institute

In the study, the causal relationship between energy consumption and growth is examined in the short, medium and long term. For this purpose, the causality relationship between these variables is examined with the help of the frequency domain causality approach. In the study, this method is preferred in order to determine whether the causal relationships between the variables differ in the short, medium or long term.

Frequency domain approach was first introduced by Granger (1969) and has been developed with different approaches over time. Breitung and Candelon's (2006) approach is one of them. In this method,

the causality relationship can be examined in the short, medium and long term by separating the test statistics into different frequencies within the specified period.

The analysis of Breitung and Candelon (2006), which allows the determination of causality at any frequency by imposing linear restrictions on the VAR model, is basically based on the work of Geweke (1982). The measurement causality developed by Geweke (1982) can be written as:

$$M_{X \Rightarrow Y}(\omega) = log\left[1 + \frac{\left|\psi_{12}(e^{-i\omega})\right|^2}{\left|\psi_{11}(e^{-i\omega})\right|^2}\right]$$

Here, at $\psi_{12}(e^{-i\omega})$=0, $M_{X \Rightarrow Y}$ (ω) = 0 and it is expressed as Y is not the Granger cause of X at ω frequency. In Breitung and Candelon (2006) approach, the following linear restrictions are imposed on the null hypothesis in order to suggest that there is no Granger causality at ω frequency:

$$\sum_{j=1}^{p} \theta_{12,j}\ cos(j\omega) = 0$$

$$\sum_{j=1}^{p} \theta_{12,j}\ sin(j\omega) = 0$$

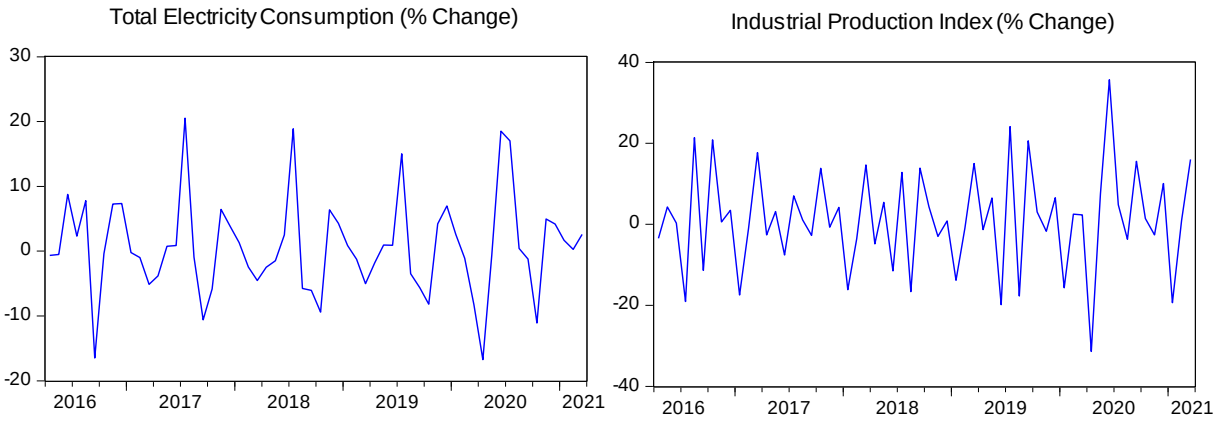
Here, the null hypothesis can be tested with the F test under linear constraints

4. Findings

In the first stage of time series analysis, it is important to investigate the stationarity of the series. So much so that working with non-stationary series may give erroneous results depending on the method applied. The frequency domain causality test is based on the VAR model. Thus, series to be used in the analysis must be stationary. Therefore, before proceeding to the causality analysis, we need to test whether the series are stationary.

Here, before unit root tests, we can see the change of both variables over time with the help of Figure 1. In the left panel of Figure 1, the monthly % change in total electricity consumption representing the energy variable, and the monthly % change in the industrial production index representing the economic growth variable in the right panel.

Figure 1. Monthly % Changes in Total Electricity Consumption and Industrial Production Index



The graphs in Figure 1 give an idea that the variables may be stationary. However, in order to decide on this, stationarity should be determined by unit root tests. For this purpose, ADF and PP tests are applied to both series and the results are summarized in Table 2.

Table 2. Unit Root Tests

			None	Intercept	Trend & Intercept
Energy	**ADF**	**I(0)**	-8.890271 (0.0000)	-8.999250 (0.0000)	-8.918670 (0.0000)
	PP	**I(0)**	-7.588547 (0.0000)	-9.010746 (0.0000)	-8.848638 (0.0000)
Growth	**ADF**	**I(0)**	-11.25698 (0.0000)	-11.25698 (0.0000)	-11.24114 (0.0000)
	PP	**I(0)**	-13.89846 (0.0000)	-18.01638 (0.0000)	-18.48947 (0.0000)

Probability values are shown in parentheses.

According to results of the unit root tests, both series are stationary at I(0). Therefore, the level values of the variables can be used in the causality test. The results of the Breitung and Candelon (2006) frequency domain causality test are summarized in Table 3.

Table 3. Frequency Domain Causality Analysis

	Long- run		**Medium- run**		**Short- run**	
	ω = 0.01	**ω = 0.05**	**ω = 1.00**	**ω = 1.50**	**ω = 2.00**	**ω = 2.00**
Energy→Growth	1.3305	1.3313	3.1739	4.2063	2.8769	2.8907
Growth→Energy	6.3091*	6.3175*	8.6997*	0.0731	2.2678	3.9861

*indicates a statistically significant causal relationship at the 5% level.
The lag length for the VAR model is determined with the help of Schwarz Information Criterion.

Values expressed as ω = 0.01 and ω = 0.05 in the table represent long-run frequencies, ω =1.00 and ω = 1.50 represent medium-run frequencies, and ω = 2.00 and ω = 2.50 represent short-run frequencies. When the table is examined, it is concluded that there is a causal relationship from growth to energy consumption, mostly at low frequencies (ω =0.01, ω = 0.05 and ω =1.00), in other words, in the medium and long term. However, no causality relationship has been reached from energy to growth in short, medium or long run.

5. Conclusion

Production, which is the basis of economic growth, necessitates the use of certain energy sources as well as various factors that we call factors of production. Energy obtained from renewable or non-renewable sources is one of the basic elements of production for all economies that are industrialized or in the process of industrialization. On the other hand, it is seen that the demand for energy increases with production due to some reasons such as rapid growth of developing countries and the increasing urban population. As a result, these interrelationships between energy consumption and production suggest that there may be a causal relationship between the variables.

Although there are many studies in the literature examining the relationship between these variables, there is no consensus on the direction of the relationship. Many empirical studies on this subject imply that the relevant relationship may differ according to time and place. In this study, it is aimed to determine whether there is a causal relationship between the variables by examining the causality relationship in Turkey in the short, medium and long-term for the April 2016 – March 2021 period. At the same time, if there is a relationship, determining the direction of this relationship is among the objectives of this study.

In the study, in which frequency domain causality analysis is used, it is determined that there is a causal relationship from economic growth to energy consumption at low frequencies, while no causality relationship is found from energy consumption to growth at all frequencies. In other words, in the study, while economic growth is seen as a cause of energy consumption in the medium and long term

for Turkey in the period under study, sufficient evidence is not found that energy consumption is the cause of growth in the short, medium or long term. It can be said that the research findings are similar to the results of some studies mentioned in the literature such as Özata (2010), Savaş and Durğun (2016). However, no distinction is made between the terms in these studies. Therefore, this study differs from other studies in the literature at this point.

The determination the energy-economic growth relationship and the direction of this relationship are important in terms of both determining growth strategies and implementing energy policies, especially in developing countries that are dependent on foreign energy. For a rapidly developing economy like Turkey, these results obtained in the study provide important clues both for energy policies that are currently in practice and planned for the future. However, in terms of guiding the studies planned to be done on the subject here, it may be important to emphasize that the analyses are carried out specifically for electricity consumption in the study, and different results can be obtained if different variables representing energy consumption are used.

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