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The Relationship between Energy Inflation and Exchange Rate: A Study on Türkiye

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Abstract

Energy is among the indicators that are taken into consideration in increasing the production levels of countries and increasing their welfare. Energy has become an indispensable resource for the industrialization of countries, increasing their industrial production and ensuring their development and growth in this direction. Today, the development and growth of countries have become linked to their energy consumption. However, countries that lack energy resources need to import the energy resources they need in order to realize their development and growth, and their economic activities for this purpose are closely related to other economic indicators, especially the exchange rate, and bring about a series of economic results. This study examines the existence of the relationship between energy inflation and the real exchange rate in Türkiye in light of the fact that Türkiye is heavily dependent on foreign energy consumption. Accordingly, the study utilizes monthly series of energy inflation and real exchange rate variables for the period 2012:M01-2021:M12 for Türkiye. In the study, firstly, the series of the variables are seasonally adjusted with the help of a computer package program, then the variables are logarithmically transformed and the stationarity of the series of the variables is analyzed. According to the results of ADF and PP unit root tests, it is concluded that the series of energy inflation and real exchange rate variables are not stationary at level, but both series become stationary after first differences are taken. In the study, Engle-Granger cointegration analysis was conducted in accordance with the unit root test results. According to the results of cointegration analysis, energy inflation and real exchange rate variables are found to move together in the long run. Finally, Granger causality test analysis was conducted and according to the results of this analysis, the existence of bidirectional causality in the Granger sense between energy inflation and real exchange rate was determined.

Keywords: Energy Inflation, Exchange Rate, Time series, Engle-Granger, Granger.

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Enerji Enflasyonu ve Döviz Kuru İlişkisi: Türkiye Üzerine Bir İnceleme

Mehmet Yunus ÇELİK [1] **Faik DANIŞOĞLU** [2]

Öz

Enerji, ülkelerin üretim düzeylerinin yükseltilmesi, refahlarının arttırılmasında göz önünde bulundurulan göstergeler arasında yer almaktadır. Ülkelerin sanayileşmesi, sanayi üretimlerinin arttırılması ve bu doğrultuda kalkınmalarının ve büyümelerinin sağlanması için enerji vazgeçilmez bir kaynak durumuna gelmiştir. Günümüzde artık ülkelerin kalkınma ve büyümeleri enerji tüketimleri ile bağlantılı bir duruma gelmiştir. Ancak enerji kaynağından yoksun olan ülkelerin, kalkınma ve büyümelerini gerçekleştirmeleri için ihtiyaç duydukları enerji kaynağını ithal etmelerini gerekmekte ve bu amaç doğrultusundaki iktisadi faaliyetleri ise başta döviz kuru olmak üzere diğer ekonomik göstergeler ile sıkı bir ilişki içerisine girmekte ve bir dizi ekonomik sonucu ortaya çıkarmaktadır. Bu çalışmada, Türkiye'nin enerji tüketiminde büyük oranda dışa bağımlı olduğu gerçeğinden yola çıkarak, Türkiye'de enerji enflasyonu ile reel döviz kuru arasındaki ilişkinin varlığını incelenmektedir. Bu doğrultuda çalışmada Türkiye için 2012:M01-2021:M12 dönemi arasındaki, enerji enflasyonu ve reel döviz kuru değişkenlerine ait aylık verilerle elde edilen seriler kullanılmıştır. Çalışmada öncelikle değişkenlere ait seriler, bilgisayar paket programı yardımıyla mevsimsel etkiden arındırılmış, sonrasında değişkenlerin logaritmik dönüşümleri yapılmış ve değişkenlere ait olan serilerin durağan olup olmadıkları analiz edilmiştir. ADF ve PP birim kök testleri analiz sonuçlarına göre, enerji enflasyonu ve reel döviz kuru değişkenlerine ait olan serilerin düzeyde durağan olmadığı, ancak her iki serinin de birinci farkları alınmasıyla durağanlaştığı sonucuna ulaşılmıştır. Çalışmada birim kök test sonuçlarına uygun olarak da Engle-Granger eşbütünleşle analizine geçilmiştir. Eşbütünleşme analiz sonucuna göre, enerji enflasyonu ve reel döviz kuru değişkenlerinin uzun dönemde birlikte hareket ettiği tespit edilmiştir. Çalışmada son olarak, Granger nedensellik test analizi yapılmış ve bu analiz sonucuna göre, enerji enflasyonu ve reel döviz kuru arasında Granger anlamında çift yönlü nedenselliğin varlığı tespit edilmiştir.

Anahtar Kelimeler: Enerji Enflasyonu, Döviz Kuru, Zaman serileri, Engle-Granger, Granger.

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Introduction

From the past to the present, production and consumption levels are taken as indicators of the economic development level and welfare level of the countries. Accordingly, it is a generally accepted view that producing countries will have more income, while countries with more income can consume more with these incomes and thus reach a higher level of welfare. For the realization of production, especially after the industrial revolution, besides the classical production factors such as labor, capital, natural resources, and entrepreneurs, energy has gained importance as a production factor. Because the most basic input in the industrial sector is energy. The importance of energy as an input in the industrial sector is due to the strong relationship between energy and economic growth (Önder, 2021, p.330).

Energy is a general name given to the power of doing work by any entity (Karagül, 2012, p.37). Economically, energy can be defined as a contemporary production factor that has the capacity to produce external activity directly from a natural resource or through a suitable system, and technological development adds to the three classical production factors in the form of labor, capital, and natural resources (Bayraç, 2020, p.3). According to the use of energy resources—renewable and non-renewable energy sources—and according to their recyclability, they are classified as primary and secondary energy sources (Önder, 2021, p.326). However, fossil energy sources, which are indispensable for production, such as oil, coal, and natural gas, which are both non-renewable and primary energy sources, are unevenly distributed on the earth, and their reserves are being depleted day by day. This situation of primary and non-renewable energy sources creates an important problem of energy supply on a global scale and also causes countries like Türkiye, which are poor in terms of fossil energy resources, to meet a large part of their energy needs through imports (Acaravcı and Yıldız, 2018, p.138).

Besides Türkiye, the European Union (EU), one of the world's most powerful and developed country blocs, is the largest oil and natural gas importer in the world (Erdal and Karakaya, 2012, p.120). On the other hand, following the path of developed countries and adopting the development path by industrializing underdeveloped and developing countries significantly increases the demand for these energy resources on a global scale (Önder, 2021, p.328). This feature of the supply and demand of energy resources has caused the prices of these resources to increase on an international scale (Bayraç, 2020, p.18). While the increase in the price of energy resources creates an increase in the income of energy exporting countries, it creates a decrease in the incomes of energy importing countries. When energy prices fall, the opposite is expected.

However, in order for the positive effect of energy price decreases to occur in energy-importing countries, the exchange rates in these countries must be stable (Aliyu, 2009, p.2). It is expressed as foreign currency, foreign currency, or any other means of payment (Seyidoğlu, 2003, p.290). The exchange rate, on the other hand, can be defined as the price of a currency in terms of a second currency or the local currency per currency unit (Kazar, 2017, p.210). Fluctuations in exchange rates can affect many macroeconomic variables. Depending on the degree of foreign dependency of the country's industries, a fluctuation in exchange rates as a result of a national or international development in the country can lead to continuous inflation within the country. Accordingly, an unexpected fluctuation in the exchange rate is reflected in the prices, i.e., costs, of the inputs used by the country's industry, especially energy, according to the degree of foreign dependency of the country's industry, and this situation disrupts the price stability within the country (Duygulu, 1998, p.109).

In developing countries such as Türkiye, production is highly dependent on imports of energy, raw materials, and intermediates. Therefore, the rise in the exchange rate leads to an increase in the prices of energy, raw materials, and intermediates, which increases costs and disrupts price stability within the country. At the same time, domestic production is negatively affected by the increase in input prices; a decrease in exports occurs, and the decrease in exports worsens the country's balance of payments (Yılmaz and Altay, 2016, p.656).

The exchange rate pass-through effect is explained by the fact that changes in the exchange rate affect domestic prices through imports. As an important economic resource, fluctuations in oil prices also have a significant impact on the stability of an economy through the exchange rate pass-through effect (Qiang, et al. 2019, p.237). The effect of the change in exchange rate on domestic prices through imports is explained by the exchange rate pass-through effect. The changes in the domestic prices of imported energy, raw materials, and intermediate goods caused by the change in the exchange rate are defined as the pass-through effect of the exchange rates. The change in the exchange rate primarily affects the prices of energy, raw materials, and intermediates and then affects domestic costs, which in turn affect domestic prices (Akdemir and Özçelik, 2018, p.36). Accordingly, an increase in the exchange rate will increase the prices of energy, raw materials, and intermediates used in production, so costs will increase, and an increase in costs will increase domestic prices. If the exchange rate falls, this situation will work in the opposite direction.

On the other hand, with a change in the exchange rate, the price of imported energy, raw materials, and intermediates may change. Changes in energy, raw material, and intermediate prices can also affect the economic indicators of countries through the channel of the exchange rate. Energy, raw materials, and intermediate prices, as well as income transfer from countries that import energy, raw materials, and intermediate products to countries that export them, are realized through trade, and exchange rates are determined in this way (Şit and Alancıoğlu, 2019, p.23). Namely, with the increase in the prices of energy, raw materials, and intermediates, there will be more foreign exchange outflow from the countries that import energy, raw materials, and intermediates, and this will decrease the amount of foreign exchange in that country, leading to a further increase in the exchange rate, that is, the depreciation of the national currency. Considering the supply and demand characteristics in the energy, raw material, and intermediate markets, the demand for energy and raw materials will constantly increase in countries such as Türkiye that have insufficient energy and raw material resources, have an increasing population, and want to achieve economic growth. This situation will cause the demand for energy and raw materials to always be above the supply and will ensure that the prices of energy and raw materials are on a constant upward trend (Alıcı and Kızıltan, 2023, p.13).

In line with the theoretical explanations, the following conclusion can be reached: A fluctuation in energy and raw material prices affects the exchange rates of countries that are dependent on foreign energy and raw materials. On the other hand, a fluctuation in exchange rates causes fluctuations in energy and raw material prices in energy and raw material importing countries through the exchange rate pass-through effect.

The aim of this study is to reveal the existence of a long-run relationship between the real exchange rate variable and the energy inflation variable representing energy and raw material prices in Türkiye, which is dependent on foreign energy and raw materials. In line with this objective, the next section of the study first presents the studies on energy prices and exchange rate, the following section presents the theoretical background of the methodology used in the study and the next section presents the results of the analysis. In the study, Engle-Granger cointegration analysis method and Granger causality analysis method were applied in line with the characteristics of the series formed with the data of energy prices and real exchange rate variables. According to these analysis methods, it is concluded that the series move together in the long run and there is a bidirectional causality relationship between the variables in the short run. Although there are many studies in the literature on the relationship between energy prices and exchange rates, studies on Türkiye are limited. Especially as the inflation problem in Türkiye has reached serious dimensions in recent years, it is important to reveal the source of this problem. This importance constitutes the starting point of the study and considering the characteristics of the series used in the study, the use of an alternative method that reveals the relationship between the variables has increased the originality of the study and it is aimed to contribute to the literature with the most up-to-date data on the subject.

Literature

In the economics literature, there are many studies, both national and international, to test the relationship between energy resources and macroeconomic variables in different dimensions. This literature is still growing because energy is a strategic resource for national industrial production in a country and for the economic growth of all countries in the world, and given that foreign exchange is used in international energy trade, this literature is still growing (Aloui and Jammazi, 2013, p.63). In this section of the study, different empirical studies that aim to analyze the relationship between the exchange rate and the variables related to energy resources in different periods, as well as the relationship between these variables and different macroeconomic variables, are presented chronologically.

Chaudhuri and Daniel (1998) analyzed the relationship between real bilateral exchange rates and real oil prices for 16 OECD countries with monthly data for the period 1973-1996. According to the results of the study, it is concluded that real exchange rates and real oil prices of countries are cointegrated in the long run.

Amano and Norden (1998) tested the relationship between the real exchange rate and oil prices for the period 1972–1993 using the Johansen cointegration analysis method and Granger causality analysis. According to the results of the cointegration analysis in the study, it was concluded that oil prices and exchange rates act together. On the other hand, according to Granger causality analysis, it was concluded that the real exchange rate is the cause of oil prices in the Granger sense, but the reverse is not true.

Chen and Chen (2007) examined the long-run relationship between real oil prices and real exchange rates using panel data analysis with monthly data for the period 1992-2005 for G7 countries. According to the findings of the study, real exchange rates and real oil prices variables are cointegrated in the long run and there is a strong relationship between them.

Öztürk, Feridun, and Kalyoncu (2008) examined the relationship between oil prices and exchange rates for Türkiye between 1986 and 2006 using Johansen cointegration analysis and Granger causality analysis. According to the results of the study, it was concluded that oil prices and exchange rate variables are cointegrated. According to the results of the Granger causality analysis, a one-way causality relationship was determined in the sense of Granger from oil prices to the dollar rate.

Aliyu (2009) examined the relationship between oil price and exchange rate fluctuations and GDP for Nigeria between 1986 and 2007 using Granger causality analysis and Johansen cointegration analysis. According to Granger causality analysis in the study, he found that oil price and exchange rate variables in Nigeria are the cause of GDP in the Granger sense. According to the Johansen cointegration analysis, it was found that there is a long-term relationship between the variables, and a 10% increase in oil prices causes a 7.72% increase in GDP. He concluded that a 10% increase in the real exchange rate creates a 0.35% increase in GDP.

Selmi, Bouoiyour and Ayachi (2012) tested the relationship between oil price variability and exchange rate for Morocco and Tunisia using the GARCH method with quarterly data for the period 1972-2010 and found significant results for both countries.

Benhmad (2012) analyzed the causality relationship between the real US dollar effective exchange rate and US real oil prices using monthly data for the period between 1970 and 2010. According to the results of the study, there is a bidirectional causality relationship between the real US effective exchange rate and US real oil prices.

Wang and Wu (2012) analyzed the relationship between energy prices (crude oil, gasoline, heating oil, and natural gas prices) and exchange rate variables for the USA for the period 2003–2011 using linear and non-linear causality analysis methods. Analyzed in two periods, before and after. Accordingly, a weak non-linear causality from the exchange rate before the 2007 global financial crisis to natural gas prices and a linear causality from oil prices to the exchange rate were found. After the global financial crisis, both linear and non-linear bidirectional causality between exchange rates and oil prices and a one-way linear causality from gasoline and heating oil prices to exchange rates were detected; however, nonlinear causality between these variables is bidirectional.

Aloui, Aissa and Nguyen (2013) analyzed the dependence between crude oil prices and exchange rates using the GARCH approach for the period 2000-2011 and found a significant dependence relationship between crude oil prices and exchange rates.

Reboredo, Rivera, and Zebende (2013) examined the relationship between oil prices and exchange rate variables in the period 2000–2012 using the cross-correlation analysis method. In the study, the relationship between oil prices and exchange rates was examined in two different periods: before and after the 2008 global financial crisis. Before the 2008 global financial crisis, a weak and negative relationship was found between oil prices and exchange rates. After the 2008 global financial crisis, although the relationship between oil prices and the exchange rate was negative, it was concluded that the strength of the relationship increased.

Kargı (2014) tested the existence of the relationship between oil prices, inflation, and GDP variables for Türkiye between 1988 and 2013 by using Engle-Grangar and Johansen cointegration analyses and Granger causality analysis. According to the results of the study, a cointegration relationship was determined between the variables in the period under consideration. In addition, according to the result of the Granger causality analysis, a Granger causality relationship was determined from GDP to oil prices and from oil prices to inflation.

Shafi et al. (2015) analyzed the effect of oil prices and exchange rates on GDP for France between 1971 and 2012 using the Engle-Granger cointegration analysis method. According to the results of the study, it has been determined that the exchange rate and oil prices are positively related to GDP. Again, Shafi, Hua, and Idrees (2015) investigated the existence of the relationship between GDP, oil prices, and real exchange rates for Germany between 1971 and 2012 using the Engle-Granger cointegration analysis method. According to the results of the study, they determined that there is a positive relationship between GDP, oil prices, and the real exchange rate.

Kisswani (2015), using panel cointegration and Toda-Yamamoto analysis method with quarterly data for selected ASEAN countries for the period 1973-2013, found that oil prices and real exchange rate variables are cointegrated in the long run and there is a bidirectional causality relationship between the variables.

Tiwari and Albulescu (2016) examined the relationship between oil price and exchange rate variables using multi-horizon Granger causality analysis for India between 1980 and 2016. According to the results of the study, they concluded that the exchange rate is the cause of oil prices in the long run, while the opposite situation occurs in the short run.

Yılmaz and Altay (2016) examined the relationship between exchange rate and oil price variables for Türkiye between 1985 and 2015 using the ARDL cointegration analysis method and the causality in variance method. According to the results of the study, they determined the existence of a cointegration relationship between oil prices and exchange rate variables. They also concluded that there is a causal relationship between oil prices and exchange rates.

Sun et al. (2019) examined the relationship between the variables using Granger causality analysis, variance decomposition, and network analysis methods using crude oil prices and the sub-indices of the producer price index (PPI) for the Chinese economy for the period 1999–2018. According to the results of the study, it has been concluded that crude oil prices are the cause of PPI values belonging to different industry branches, and it has been determined that the degrees of effect of crude oil prices on PPI values belonging to different industry branches are also different. In the study, the relationships between PPI values belonging to different industry branches were also revealed.

Econometric Analysis

Data Set

In this study, time series generated with monthly data on real exchange rate and energy inflation variables between 2012:M1-2021:M12 in Türkiye are analyzed with a computer package program. The data on the variables subject to the study were obtained from the Electronic Data Distribution System (EDDS) of the Central Bank of the Republic of Türkiye. Before starting the analysis, real exchange rate and energy inflation variables are seasonally adjusted by multiplicative decomposition method and logarithmic transformations of the seasonally adjusted variables are made. In this study, the real exchange rate variable (lnk) and the energy inflation variable (lnee) are symbolized by (lnk) and (lnee), respectively.

Engle-Grangar time series analysis and Granger causality analysis techniques were utilized to test the existence of a relationship between the real exchange rate and energy inflation variables for Türkiye.

ADF Unit Root Analysis

The long-term feature of the time series is revealed by determining the value of the variable in the previous periods and how it affects this period. In this direction, in order to understand what kind of process the series comes from, the value of the series in each period should be regressed with the values it took in the previous periods (Tarı, 2010, p.387). In this direction, it is important whether the time series created with the data belonging to the variables, in terms of their properties, contain a unit root, that is, whether the series are stationary or not. Because, in the later stage of the time series analysis, the most appropriate time series analysis method should be preferred according to the unit root test results of the series (Mert and Çağlar, 2019, p.97). Dickey and Fuller (1979) developed the ADF (Augmented Dickey Fuller) unit root test derived from the DF (Dickey Fuller) model in the analysis of the stationarity of time series in their study. The lagged values of the variable explained in order to eliminate the autocorrelation problem in the equations created for the ADF unit root test are located on the right side of the equation as the explanatory variable (Dickey and Fuller, 1979, p.428). The following ADF equations (1), (2), and (3) have been created. Equation (1) is without constant and trend, equation (2) with constant and without trend, and equation (3) with constant and trend ADF equation models.

$$\Delta Y_t = \delta Y_{t-1} + \sum_{i=1}^{p} \beta_i \, \Delta Y_{t-i} + \epsilon_t \qquad (1)$$

$$\Delta Y_t = \mu + \delta Y_{t-1} + \sum_{i=1}^{p} \beta_i \, \Delta Y_{t-i} + \epsilon_t \qquad (2)$$

$$\Delta Y_t = \mu + \beta_t + \delta Y_{t-1} + \sum_{i=1}^{p} \beta_i \, \Delta Y_{t-i} + \epsilon_t \qquad (3)$$

In the ADF equations, Y_t represents the series considered, the constant μ, the lags included in the equation, β the trend and Є the error term. When the test statistic calculated in the given equations is less than the critical value, the null hypothesis expressing the existence of a unit root is rejected and it is decided that the series are stationary (Mert and Çağlar, 2019, p.100). The unit root test is instructive about which cointegration method will be used.

Phillips-Perron Unit Root Analysis

In the Dickey Fuller unit root test, it is assumed that the distribution of random errors is statistically independent and has constant variance (Sevüktekin and Çınar, 2017, p.378). However, Phillips-Perron (PP) develops a new non-parametric method for unit root analysis, estimates the DF equations and rearranges the t_δ test statistic, ensuring that the asymptotic distribution is not affected by serial correlation (Mert and Çağlar, 2019, p.101). The equation (4) PP is given below.

$$\ddot{t}_\delta = t_\delta \left(\frac{\gamma_0}{f_0}\right)^{1/2} - \frac{T(f_0 - \gamma_0) s_{\tilde{\delta}}}{2 f_0^{1/2} s} \qquad (4)$$

Here, $\tilde{\delta}$ estimator, t_δ standard DF test statistic, $s_{\tilde{\delta}}$ standard error, s standard error of test regression, γ_0 is a consistent estimator of error variance, and f_0 is zero frequency residual spectrum estimator. In the PP test, as in the standard ADF test, when the calculated test statistic is less than the critical value, the null hypothesis expressing the existence of a unit root is rejected, that is, it is decided that the series are stationary.

Engle-Granger Cointegration Analysis

In the Engle-Grangar cointegration approach, while investigating a long-term relationship between two variables, it is assumed that the series of the variables studied are integrated to the same degree. After the series examined in this approach are subjected to unit root test analysis, according to the result of this analysis, it is necessary to reach the conclusion that the series are integrated in the first order, that is, they are I(1). Otherwise, the Engle Grangar approach cannot be used (Sevüktekin and Çınar, 2017, p.562). In the Engle-Granger approach, the series belonging to the X and Y variables, which are primarily considered, are estimated according to the least squares method in the equations (5) and (6) given below, and error terms are obtained.

$$Y_t = \beta_0 + \beta_1 X_t + \epsilon_{1,t} \qquad (5)$$

$$X_t = \alpha_0 + \alpha_1 Y_t + \epsilon_{2,t} \qquad (6)$$

The series of error terms obtained from the estimated equations (5) and (6) are subjected to unit root test analysis. According to the unit root analysis results of the error terms, if it is concluded that the series are stationary at the level, that is, they are I(0), it is concluded that the series of the examined X and Y variables are in a long-term relationship (Engle and Granger, 1987, p.264).

Granger Causality Analysis

While the value of any variable in the current period is explained, if the lagged values of another variable affect the value of this variable, it can be said that there is a causal relationship between these variables. When a model is established for the value of a Y variable at time t, when the lagged values of the Y variable as well as the lagged values of the X variable are added to the model, if the explanatory power of the model increases, it is stated that the X variable is the cause of the Y variable in the sense of Granger (Mert and Çağlar, 2019, p.339). Granger causality test analysis is performed using simple bivariate equations (7) and (8) given below.

$$Y_t = \sum_{t=1}^{m} a_i \, Y_{t-i} + \sum_{j=1}^{m} \beta_j \, X_{t-j} + u_{1t} \qquad (7)$$

$$X_t = \sum_{t=1}^{m} \lambda_i \, Y_{t-i} + \sum_{j=1}^{m} \delta_j \, Y_{t-j} + u_{2t} \qquad (8)$$

In these given equations; m represents the lag length, u_{1t} and u_{2t} error terms, and equation (7) indicates causality from X to Y, and equation (8) indicates causality from Y to X (Granger, 1969, p.431). Here the null hypothesis is that x_t is not the cause of y_t; the alternative hypothesis is formed as x_t is the cause of y_t. Four different results can be obtained from a causality equation for two variables (Mert and Çağlar, 2019, p.340). X is the Granger cause of Y; Y is the Granger cause of X; There is no Granger causality between X and Y; It is concluded that there is a bidirectional causality between X and Y in the sense of Granger. In Granger causality analysis, the F statistical value developed by Wald is calculated and if the calculated F statistical value exceeds the F table value at the significance level to be taken as a basis, a Granger causality relationship can be mentioned between the variables.

Empirical Findings

In Table 1 below, the ADF unit root test results of the series of energy inflation and real exchange rate variables, which are the variables used in the analysis, are given within the framework of both the fixed model and the fixed and trend model.

Table 1: ADF Unit Root Test Results

Variables	Intercept			Trend and Intercept		
	t-Statistics	Critical Value	Prob.	t-Statistics	Critical Value	Prob.
lnee	2.740385	-3.487046	1.0000	0.735505	-4.038365	0.9997
Δlnee	-5.418352	-3.486551	0.0000	-6.256404	-4.038365	0.0000
lnk	0.979964	-3.487046	0.9962	-2.146402	-4.038365	0.5144
Δlnk	-7.531499	-3.487046	0.0000	-7.775595	-4.038365	0.0000

Note: Critical values from MacKinnon (1996) are given at 1% error level according to Schwarz information criterion. The symbol Δ means taking the 1st difference of the variables.

According to the ADF unit root analysis results in Table 1, the t-statistics values calculated at the serial level and at the %99 significance level of the lnee and lnk variables are greater than the critical values. This result means that the series subject to the analysis contain unit root. However, after the difference process, it was concluded that the t-statistics values calculated at %99 significance level for the Δlnee and Δlnk series were smaller than the critical values. In this case, the null hypothesis that the series contain a unit root is rejected; The alternative hypothesis that the series do not contain unit roots is accepted. This result means that according to the ADF unit root test, all series used in the analysis are integrated to the same degree, that is, they are I(1). In Table 2, the Phillips-Perron unit root test results of the series of energy inflation and real exchange rate variables, which are the variables used in the analysis, are given within the framework of both the fixed model and the fixed and trend model.

Table 2: Phillips-Perron Unit Root Test Results

Variables	Intercept			Trend and Intercept		
	t-Statistics	Critical Value	Prob.	t-Statistics	Critical Value	Prob.
lnee	2.839565	-3.486064	1.0000	1.115954	-4.036983	0.9999
Δlnee	-5.361819	-3.486551	0.0000	-5.281270	-4.037668	0.0001
lnk	1.995284	-3.486064	0.9999	-1.591880	-4.036983	0.7906
Δlnk	-5.480768	-3.486551	0.0000	-5.497099	-4.037668	0.0001

Note: Critical values from MacKinnon (1996) are given at 1% error level. The symbol Δ means taking the 1st difference of the variables.

According to the PP unit root analysis results in Table 2, the t-statistics values calculated at the serial level and at the %99 significance level of the lnee and lnk variables are higher than the critical values. This result means that the series subject to the analysis contain unit root. However, here too, it was concluded that the t-statistics values of the Δlnee and Δlnk series calculated at the %99 significance level were smaller than the critical values after the difference process. In this case, the null hypothesis that the series contain a unit root is rejected; The alternative hypothesis that the series do not contain unit roots is accepted. This result means that, according to the PP unit root test, all series used in the analysis are integrated to the same degree, that is, they are I(1).

In both ADF and PP unit root analysis, after it is decided that the series of the variables are integrated to the same degree, that is, they are I(1), Engle-Granger cointegration analysis can be applied to investigate the long-term relationship between the variables.

In this direction, the model was estimated by using the least squares method for energy inflation and real exchange rate variables and the error terms of this model were obtained. In Table 3, Engle-Granger cointegration results of energy inflation and real exchange rate variables are given. Belonging to the error terms we obtained in the given table; ADF unit root test results are given in the unconstant and trendless model, the fixed model, the fixed and trend model.

Table 3: Engle Granger Cointegration Analysis Results of Energy Inflation and Real Exchange Rate Variables

Dependent Variable	None			Intercept			Trend and Intercept				
	t-Stat.	Critical Value	Prob.	t-Stat.	Critical Value	Prob.	t-Stat.	Critical Value	Prob.	Latency Length	Integrated Level
ϵ_1	-6.868	-2.584	0.00	-6.832	-3.487	0,00	-7.298	-4.038	0,00	2	I(0)
ϵ_2	-8.684	-2.584	0,00	-8.642	-3.487	0,00	-8.671	-4.038	0,00	2	I(0)

Note: ε_1 error term; While the dependent variable is lnk, it expresses the error terms obtained from the model, while the ε_2 error term expresses the error terms obtained from the model when the dependent variable is lnk. All error variables were analyzed within the framework of ADF unit root analysis and MacKinnon critical values were given for 1% error level.

According to the information in Table 3, it was concluded that the error terms ϵ_1 and ϵ_2 obtained from the least squares model established by the energy inflation and real exchange rate variables being dependent variables, respectively, are stationary at level levels, that is, their integrated level is I(0). This situation reveals that there is a long-term cointegration relationship between the Inee and Ink variables, that is, the series are cointegrated. For the long-term equilibrium equation between the variables, the long-term parameters given in Table 4 are reached when the energy inflation is estimated according to the dependent variable.

Table 4: Long-Term Forecast Results for Energy Inflation

Variables	Parameters	Std. Error	t-Statistics	Prob.
C	11.01409	0.115769	95.13860	0.0000
lnk	-1.167298	0.025876	-45.11098	0.0000

With the parameters in Table 4, we can write the long-term equilibrium equation (9) for energy inflation. In this direction, the long-run equation is;

$$lnee_t = 11.01409 - 1.167298 lnk_t + \epsilon_t \qquad (9)$$

Since equation (9) is in full logarithmic form, the parameters are elasticity parameters. In this direction, we can say that a %1 increase/decrease in the real exchange rate in the long run leads to a %1.16729 decrease/increase in energy inflation at the %99 significance level. In addition, the long-term error correction model can be estimated by obtaining the residuals in equation (9). The error correction model gives us the parameters of the short-term equation (Mert and Çağlar, 2019, p.258). The error correction model estimation parameters are given in Table 5 below.

Table 5: Short-Run (Error Correction Model) Forecast Results for Energy Inflation

Variables	Parameters	Std. Error	t-Statistics	Prob.
C	0.007361	0.001629	4.520057	0.0000
d(lnk)	-0.233579	0.050135	-4.659038	0.0000
ect(-1)	-0.080825	0.027955	-2.891199	0.0046

According to the results in Table 5, the real exchange rate has a %99 significant effect on energy inflation in the short run. According to Table 5, a %1 increase/decrease in the real exchange rate causes a %0.233579 decrease/increase in energy inflation in the short run. Another important result obtained from Table 5 is that the error correction parameter is negative and significant. Because the error correction coefficient is negative and significant, it shows that the error correction mechanism works and the short-term equilibrium deviations are corrected and the long-term equilibrium is reached. The error correction coefficient tells us how much of the deviations from the balance will be corrected in each period (Mert and Çağlar, 2019, p.258). Accordingly, according to the information in Table 5, approximately %8 of the imbalances that will occur in the short term will be corrected in the first period. In other words, an imbalance that will occur in the short-term will improve after approximately 1/0.080825 ≈ 12 periods (144 months since each period is twelve months) and reach a long-term balance.

In our analysis, we need to examine the estimation results we obtained for energy inflation for the real exchange rate variable. When the long-term equilibrium equation between the series is estimated when the real exchange rate is the dependent variable, the long-term parameters given in Table 6 are reached.

Table 6: Long-Term Forecast Results for Real Exchange Rate

Variables	Parameters	Std. Error	t-Statistics	Prob.
C	9.163344	0.104159	87.97479	0.0000
lnee	-0.809727	0.017950	-45.11098	0.0000

With the parameters in Table 6, we can write the long-run equilibrium equation (10) of the real exchange rate. In this direction, the long-run equation is;

$$lnk_t = 9.163344 - 0.809727 lnee_t + \epsilon_t \qquad (10)$$

Here too, since equation (10) is in full logarithmic form, the parameters are elasticity parameters. In this direction, we can say that a %1 increase/decrease in energy inflation in the long term leads to a %0.809727 decrease/increase in the real exchange rate at the %99 significance level. In addition, the long-term error correction model can be estimated by obtaining the residuals in equation (10). The error correction model gave us the parameters of the short-run equation. The error correction model estimation parameters are given in Table 7 below.

Table 7: Short-Run (Error Correction Model) Forecast Results for Real Exchange Rate

Variables	Parameters	Std. Error	t-Statistics	Prob.
C	-0.000203	0.003020	-0.067251	0.9465
d(lnee)	-0.713893	0.147257	-4.847936	0.0000
ect(-1)	-0.212631	0.056703	-3.749920	0.0003

According to the results in Table 7, energy inflation has a %99 significant effect on the real exchange rate in the short run. According to Table 7, a %1 increase/decrease in energy inflation causes a %0.713893 decrease/increase in the real exchange rate in the short run. Another important result obtained from Table 7 is that the error correction coefficient is negative and significant. Because the error correction coefficient was negative and significant, it showed that the error correction mechanism was working and the short-term equilibrium deviations were corrected and the long-term equilibrium was reached. Here, too, the error correction coefficient tells us how much of the deviations from the equilibrium will be corrected in each period. Accordingly, according to the information in Table 7, approximately %21 of the imbalances that will occur in the short term will be corrected in the first period. In other words, an imbalance that will occur in the short term will recover after approximately 1/0.212631 ≈ 5 periods (60 months after each period is twelve months) and reach a long-term balance.

Engle-Granger cointegration analysis results show us that energy inflation and real exchange rate variables move together in the long run. However, Engle-Granger cointegration analysis does not provide any information about the short-term direction of the relationship between these variables. For this reason, Granger causality analysis is used to determine the direction of the short-term relationship between the variables. Granger causality analysis results of energy inflation and real exchange rate variables, which have a cointegration relationship between them, are given in Table 8 below.

Table 8: Granger Causality Analysis Results of Energy Inflation and Real Exchange Rate Variables

Null Hypotheses	F Stat.	Prob.	Latency Length	Obs.
Energy Inflation is not the Granger cause of the Real Exchange Rate.	13.8898	0,00004	2	118
The Real Exchange Rate is not the Granger cause of Energy Inflation.	7.23211	0.00110	2	118

In line with the information in Table 8, the null hypothesis, which states that energy inflation is not the Granger cause of the real exchange rate, is rejected. At the same time, the null hypothesis, which states that the real exchange rate is not the Granger cause of energy inflation, is also rejected. As can be understood from this result, a bidirectional Granger causality relationship was found between energy inflation and real exchange rate variables in the short run.

Conclusion and Evaluation

It is generally accepted that in order for developing countries to reach the level of economically developed countries, they must first increase their production levels by entering the industrialization process. In line with this general acceptance, developing countries have rapidly entered the process of increasing their industrial production, one of the biggest input items of which is energy. Developing Türkiye is also in a rapid industrialization process in order to be among the economically developed countries. However, in this industrialization process, Türkiye is a country that is largely dependent on foreign energy because it is a poor country in terms of energy, which is one of the biggest inputs of industry. At the same time, Türkiye does not only need energy resources for industrial production; it also needs energy for consumption purposes due to Türkiye's ever-increasing population. Therefore, we can say that Türkiye is a country that is both poor in terms of energy resources and has a high demand for energy in terms of both production and consumption. This fact has made Türkiye a foreign dependent country in terms of energy.

Based on this fact, this study empirically examines the relationship between energy inflation and the real exchange rate due to the high demand for energy in Türkiye and Türkiye's foreign energy dependence. The study examines the long-run relationship between energy inflation and real exchange rate variables using monthly data for the period between 2012:M01 and 2021:M12 in Türkiye by using Engle-Granger cointegration analysis. At the same time, the short-run causality relationship between energy inflation and real exchange rate is tested by Granger causality analysis. According to the results of Engle-Granger cointegration analysis, it is concluded that the variables are cointegrated in the long run, that is, the variables move together in the long run. At the same time, from the estimated long-run equation, it is also determined that a 1% increase/decrease in the real exchange rate leads to a 1.16% decrease/increase in energy inflation in the negative direction. On the other hand, it is also determined from the estimated long-run equation that a 1% increase/decrease in energy inflation leads to a 0.80% decrease/increase in the real exchange rate in the negative direction. This result is evidence of the theoretical relationship between energy prices and exchange rates in energy-dependent countries. In fact, this result is in line with the results of studies in the literature for different countries. According to the results of the Granger causality analysis, which shows the short-run causality relationship between energy inflation and real exchange rate variables, there is a bidirectional causality relationship between the variables in the Granger sense. Again, this result is in line with the studies conducted in the literature for different countries.

Chaudhuri and Daniel's study for 16 OECD countries in 1998, Chen and Chen's study for G7 countries in 2007, Benhmad's study for the US in 2012, Reboredo, Rivera and Zebende's study for the US in 2012, Reboredo, Rivera and Zebende's study for the US in 2013, Shafi, Hua and Idrees' study for Germany in 2015, Kisswani's study for ASEAN countries in 2015 concluded that the energy price variable and the exchange rate variable are cointegrated and the causality between the variables is bidirectional. The results obtained in these studies and the results obtained in our study are in complete parallelism with each other.

Tiwari and Albulescu's 2016 study for India concluded that the exchange rate is the cause of energy prices in the long run, while it is the cause of energy prices in the short run. Although the result of Tiwari and Albulescu's study is in parallel with the result of our study, it is concluded that the direction of causality they find changes over time.

Amano and Norden's study in 1998 concluded that the causality is unidirectional from exchange rate to energy prices and this result partially differs from the bidirectional causality between exchange rate and energy prices variables found in our study. In the studies conducted by Öztürk, Feridun and Kalyoncunun in 2008 and Yılmaz and Altay in 2016 for Turkey, the direction of causality between exchange rate and energy prices variables was found to be unidirectional from energy prices to exchange rate. Considering that the causality between the exchange rate and energy prices variables is bidirectional in our study, it can be said that there is a partial parallelism between the results of the studies.

The results of both long-run cointegration analysis and short-run causality analysis, which analyze the relationship between the variables, show that there is a significant relationship between energy inflation and real exchange rate in Türkiye. Due to this relationship, it is concluded that in Türkiye, which is in the process of industrialization, real exchange rate stability should be taken into account in the fight against energy inflation in order to combat the fluctuations in the price of energy, which is considered as one of the biggest inputs of the industry. Likewise, it should be taken into account that the high foreign energy demand in Türkiye, which is a result of Türkiye's dependence on foreign energy for both production and consumption purposes, may also destabilize the real exchange rate. Considering the results of this study, the strength of the relationship between energy inflation and exchange rate in Türkiye and the extent of the exchange rate transmission mechanism may be the subject of further studies.

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