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Araştırma Makalesi ● Research Article

Does the Exchange Rate Have a Pass-Through Effect on Domestic Food Prices in Türkiye? An Empirical Study Using a Combined ANN Algorithm and VAR Method

Türkiye'de Döviz Kurunun Yurtiçi Gıda Fiyatlarına Geçiş Etkisi Var Mı? YSA Algoritması ve VAR Yöntemi ile Ampirik Bir Çalışma

Salih ÇAM[a]*

[a] Dr., Çukurova Üniversitesi, Adana / TÜRKİYE
ORCID: 0000-0002-3521-5728

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ÖZ

Döviz kuru dalgalanmalarının ekonomiler, işletmeler ve özellikle de tüketiciler için geniş kapsamlı sonuçları vardır. Bu nedenle, bu dalgalanmaların yurtiçi piyasalardaki gıda fiyatlarını hangi mekanizmalar aracılığıyla etkilediğini anlamak önemlidir. Bu çalışma, döviz kurları ile yurt içi gıda fiyatları arasındaki karmaşık ilişkiyi incelenmekte ve döviz kurunun yurt içi gıda fiyatlarına geçiş etkisi hesaplanmaktadır. Döviz kurunun gıda fiyatlarına etkisini incelemek için Ocak 2003-Temmuz 2023 dönemine ait aylık USD/TRY döviz kuru, dünya gıda fiyat endeksi, gıda ihracat-ithalat oranı ve Türkiye'deki gıda üreticileri fiyat endeksi verileri kullanılmıştır. Analize dahil edilen değişkenlerin optimal gecikmelerini belirlemek için vektör otoregresyon (VAR) yöntemi, USD/TRY döviz kurunun yurtiçi gıda fiyatları üzerindeki geçiş etkisini hesaplamak için ise yapay sinir ağı (YSA) algoritması kullanılmıştır. Sonuçlar, değişkenlerin gıda fiyatları üzerindeki geçiş etkisinin cari ay, bir önceki ay ve iki önceki ay olmak üzere üç ay boyunca devam ettiğini göstermektedir. Döviz kurunun gıda fiyatları üzerindeki toplam geçiş etkisi %27'yi bulmaktadır. Bu etkinin yarısı gıda fiyatlarına bir önceki aydan aktarılmaktadır. Yanı sıra gıda ihracatının gıda ithalatını karşılama oranı yurtiçi gıda fiyatlarındaki artışın yaklaşık %12'sinden sorumludur. Sonuçlar ayrıca en yüksek geçişkenlik etkisine sahip değişkenin üretici fiyat endeksi olduğunu ve gıda fiyatlarındaki artışın %90'ının iç dinamiklerden kaynaklandığını, yurtdışındaki fiyat artışlarının yurtiçi gıda fiyatlarına etkisinin sadece %10 civarında olduğunu göstermektedir.

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ABSTRACT

Exchange rate fluctuations have far-reaching consequences for national economies, companies and, above all, consumers. It is therefore important to understand the mechanisms by which these fluctuations affect food prices in domestic markets. In this context, we examine the complex relationship between exchange rates and domestic food prices and attempt to calculate the pass-through effect of the exchange rate on domestic prices. To examine the pass-through effect of the exchange rate on food prices, we use monthly USD/TRY exchange rate data from January 2003 to July 2023 as well as the global food price index, the export-import rate for food and the producer price index for food in Türkiye. We employ the vector autoregression (VAR) method to determine the optimal lags of the variables included in the analysis and the artificial neural network (ANN) algorithm to calculate the overall pass-through effect of the USD/TRY exchange rate on domestic food prices. The results show that the pass-through effect of the variable on food prices persists for three months: the current month, the previous month and the two previous months. The total pass-through effect of the exchange rate on food prices reaches up to 27%. Half of this impact comes from the previous month's food prices. In addition, the ratio of food exports to imports accounts for about 12% of the increase in domestic food prices. The results also show that the variable with the highest pass-through effect is the producer price index and that 90% of the increase in food prices is due to domestic dynamics, while the effect of price increases in foreign markets is only about 10%.

* *Sorumlu yazar/Corresponding author*.
e-posta: scam@cu.edu.tr

Introduction

The pass-through effect of exchange rates on domestic consumer prices is a critical and complex phenomenon with far-reaching implications for the stability of economies (Vo, Ho and Vo, 2020). This economic interplay becomes even more complicated when focusing on the food sector, where price fluctuations have an immediate and direct impact on household wealth and the overall social fabric of a nation (Alola, Usman, and Alola, 2023). In the case of Türkiye, a country characterized by a unique mix of domestic food production and significant dependence on imports, the relationship between exchange rate fluctuations and food prices becomes even more important (Ertuğrul and Seven, 2023). Türkiye occupies a prominent position on the global economic stage. It serves as a bridge between Europe and Asia and has a diverse agricultural landscape that stretches from the fertile plains of Anatolia to the Mediterranean coast. As such, the Turkish economy is inherently linked to the international market, making it vulnerable to exchange rate fluctuations. Over the years, Türkiye has experienced various economic shocks and challenges, including periods of currency devaluation, which have had a noticeable impact on the cost of living, particularly for food.

Türkiye's economic history has been marked by a series of financial and currency crises over the last seven decades. These episodes have repeatedly led to significant food price inflation, highlighting the critical link between exchange rate fluctuations and food security in the country. This vulnerability is partly due to the crucial role that agriculture plays in the Turkish economy. The fragile structure of the Turkish agricultural sector makes it particularly vulnerable to the effects of financial turmoil. The country's dependence on both domestic agricultural production and food imports necessitates a thorough examination of the impact of exchange rate fluctuations on food prices. Throughout its modern history, Türkiye has experienced numerous economic crises during downturns. Each of these crises has had a demonstrable impact on the cost of living, with financial and currency crises leading to significant increases in food prices. After the World War II, Türkiye experienced a severe currency crisis in 1946. High inflation and depleted foreign exchange reserves led to a significant devaluation of the Turkish lira. This devaluation, combined with rising inflation, contributed to an increase in food prices. Political instability and economic mismanagement triggered another economic crisis in 1960. The government introduced exchange controls and fixed the exchange rate, which led to the emergence of black markets for foreign currency. During this time, there was a significant devaluation of the Turkish lira and a loss of confidence in the currency, which further affected the affordability of food. The oil crisis of the 1970s had a profound impact on the Turkish economy. Rising oil prices and inflation contributed to a devaluation of the currency and economic instability, leading to several devaluations during this period. These devaluations in turn increased the pressure on food prices. The 1980 military coup ushered in a period of economic restructuring and reform in Türkiye. The government attempted to stabilize the exchange rate, control inflation and attract foreign investment. Despite these efforts, Türkiye faced another currency crisis in 1994, triggered by high inflation and a growing current account deficit. The government's decision to allow the Turkish lira to float freely led to a significant devaluation and financial turmoil, which further fueled food price inflation. One of the most severe economic crises in Türkiye's recent history occurred in 2000-2001, when a confluence of factors, including a crisis in the banking sector, unsustainable fiscal policies and external debt problems, led to a sharp devaluation of the Turkish lira. This devaluation, combined with the general economic turmoil, led to a significant increase in food prices. Finally, in 2018, Türkiye faced another currency crisis triggered by a diplomatic dispute with the United States, economic policy concerns and high inflation. The Turkish lira experienced a significant devaluation against the US dollar, which led to economic challenges and a subsequent rise in food inflation. To summarize, historical analysis reveals a consistent

pattern: Every financial or currency crisis in Türkiye has led to a significant increase in food prices. This vulnerability underscores the urgent need for policy measures that strengthen the resilience of the agricultural sector and mitigate the pass-through of exchange rate fluctuations to food prices in order to ensure Türkiye's food security.

The pass-through effects of currency fluctuations to domestic prices is a complex phenomenon that is influenced by a variety of factors in the economic environment. These factors include market competition, price elasticity, prevailing monetary policy, expected inflation, the composition of imports and exports and various other economic dynamics. In addition, the transmission of currency fluctuations to domestic prices may be subject to delays due to contractual agreements, inventory considerations, information dissemination and other inherent economic complexities. Understanding the intricacies of this pass-through effect is critical for policy makers, central banks and businesses alike, as it allows for the anticipation and management of potential inflationary or deflationary consequences of exchange rate fluctuations. Therefore, a comprehensive analysis of the variables affecting food inflation requires the inclusion of their lagged values in order to capture the full impact of these factors. Consequently, this study develops a model that examines the relationship between the food price index and the exchange rate in addition to the relevant explanatory variables and their lagged values. Thus, we can observe the pass-through effect of the exchange rate on food prices in Türkiye from January 2003 to July 2023. A vector autoregression model is employed to determine the appropriate lagged structure of the explanatory variables affecting domestic food prices. Then, the determined lagged values of these explanatory variables are used as input to an artificial neural network algorithm in order to calculate the overall effect of each variable on food prices.

Literature Review

Agriculture is one of the crucial sectors for the Turkish economy (Günçavdi, Küçükçifçi, and Bayar, 2013). Although Türkiye's liberalization policies in the 1980s were a turning point for the fragile economy, the subsequent crises of 1994 and 2001 increased the pressure on the local currency. The high inflation rates observed during these periods have always been of interest to policymakers and researchers. Many valuable studies have been conducted to get rid of the inflationary scourge that has plagued the country for almost a century and to unravel the mysteries behind inflation. An important part of the existing studies has focused on the impact of exchange rate fluctuations on overall consumer prices (Volkan, Saatçi and Korap, 2007; Kara and Öğünç, 2012; Korkmaz and Bayır, 2015; Karamollaoglu, 2018; Çakır and Kaya, 2023), while some studies deal with the asymmetric effect of the exchange rate on domestic consumer prices (Arbalı, 2003; Gokce, 2021). Of course, consumer prices are affected by domestic phenomena such as the interest rate set by the central bank. Independent central banks are the main institutions for ensuring domestic price stability. The main instrument used by central banks to achieve price stability is the interest rate. Central banks use the weapon of interest rate to stabilize market prices, especially in times of hyperinflation. Therefore, interest rates have a significant impact on domestic prices (Teker, Alp, and Kent, 2012; Kose, Emirmahmutoglu, and Aksoy, 2012; Özen, Özdemir, and Grima, 2020; Turna and Özcan, 2021). Since Türkiye exports a significant share of its exports via imported intermediate goods, the contribution of the exchange rate to inflation via imports cannot be ignored (Aydın et al., 2010; Ulke and Ergun, 2011).

Food inflation is a subcategory of headline inflation. It is influenced by a number of factors such as climatic conditions, technological progress in agriculture and the extent of government support for the agricultural sector. While an increase in headline inflation naturally leads to an increase in food inflation, the critical nature of food as a basic requirement for feeding a growing population requires a separate and in-depth analysis of food inflation from

different perspectives (Bayramoğlu and Yurtkur, 2015; Barbaros, Kalayci, Bakir, 2019; Sezgin and Sezgin, 2021; Ozdurak, 2021; Schroeder et al., 2022; Kesici, 2023). Oil is an important input for agricultural production, among other factors, and there are important studies analyzing the relationship between oil prices and food inflation (Altıntaş, 2016; Algan, İşcan, and Serin, 2021; Güngör and Deniz, 2022; İçen, İçen, and Polat, 2022; Demirtaş, Yıldırım, and Dur, 2023). An increase in world food prices naturally cause to an increase in food prices in countries like Türkiye which import food. The impact of foreign prices on the domestic market is reflected in the exchange rate at which trade is conducted (Campa, Goldberg, 2005; Campa, Goldberg, Gonzalez-Minguez, 2005). While fluctuations in global food prices undoubtedly have an upward impact on domestic food prices, it is critical to recognize that a significant portion of this inflation is due to internal dynamics within Türkiye. These internal factors include, but are not limited to, labor and transportation costs. Moreover, there is evidence that the impact of exchange rate volatility on food inflation has increased in recent years, particularly in the context of external events such as the COVID-19 pandemic and related global economic shocks (Nicomedes and Avila, 2020; Stoevska, 2020; Aydın and Özer, 2020; Selvi and Cavlak, 2021). Among them, the exchange rate is within the scope of this study and has a significant impact on food prices in countries that have experienced high volatility of their domestic currency (Lopcu and Şengül, 2018; Durgun, 2019; Ozdurak, 2021; Demirkılıç, Özertan, and Tekgüç, 2022; Uysal, Yilmaz, and Kasa, 2022). The effect of the current exchange rate shock is usually transmitted to prices in the next few days or months. Therefore, using the lagged exchange rate would reflect its full effect on food inflation.

Artificial Neural Network

Artificial neural networks (ANNs) are a class of computational models that have been inspired by the structural and functional properties of biological neural networks, particularly the human brain. These models consist of interconnected processing units, analogous to biological neurons, organized in different layers such as input, hidden and output layers. Each unit or "neuron" within the network processes information and passes it on to subsequent units. This interconnected structure enables the formation of a complex network that can be trained for a variety of tasks, including pattern recognition, classification, regression analysis and decision making. ANNs have become particularly important in the fields of machine learning and artificial intelligence due to their remarkable ability to learn complex patterns from data and subsequently make predictions or classifications in a variety of applications such as image and speech recognition, natural language processing, recommendation systems and autonomous driving systems.

The general mathematical form of an ANN is follows:

$$\hat{Y}_t = F_2\left[\left(V_t^T F_1(W_t \cdot X_t)\right)\right] \quad (1)$$

Where, $X = \left(x_0, x_1, \dots, x_p\right)^T \in R^{(p+1)x1}$ is the input data matrix, $Y = (y_0, y_1, \dots., y_k)^t \in R^{(k+1)}$ is the output data vector/matrix, W is the weight matrix of the input layer and the hidden layer, F_1 is the function between the input layer and the hidden layer, V is the weight matrix of the hidden layer and the output layer, and F_2 is the activation function of the hidden layer and the output layer. Also $F_1(W_t \cdot X_t)$ in the equation (1) can be expressed as follows:

$$F_1(W_t X_t) = \left(F\left(\text{ net }_{0(t)}\right), F\left(\text{ net }_{1(t)}\right) \dots \dots F\left(\text{ net }_{q(t)}\right)\right)^T \in R^{q+1)x1} \quad (2)$$

Here, $net_{i(t)} = \sum_{j=0}^{P} W_{ij(t)} \cdot x_{j(t)}$ for $i = 0,1, \dots, q$ and $W_{i0(t)}$ is error term of hidden layer. Lastly, $v_{ij(t)} i = 1,2, \dots, q, j = 1,2, \dots k$ is the weights from hidden layer to output layer and $V_{i0(t)}$ is the error term of output layer (Çam, Balli, and Sigeze, 2017).

Data and Analysis

This study applies an empirical method to assess the extent and speed of the transmission of the exchange rate to food price inflation in the Turkish economy. It also examines the influence of various factors affecting this relationship, including the export-import (EI) ratio, the Producer Price Index for Food (PPI) and global movements in food prices as represented by the World Food Price Index (WFI). The analysis is based on monthly data, including the Consumer Price Index for Food (CPIF), the World Food Price Index (WFI), the USD/TRY exchange rate, food imports, food exports and the Producer Price Index for Food, covering the period from January 2003 to July 2023[1].

Table 1. Descriptive Statistics

	CPIF	PPI	USD	WFI	EI
Mean	364.378	175.833	4.059	104.551	0.614
Median	227.537	109.029	1.851	102.540	0.618
Maximum	2155.380	1190.396	26.510	156.671	0.940
Minimum	92.408	43.916	1.178	64.604	0.367
Std. Dev.	376.926	206.327	4.659	20.403	0.109
Skewness	2.623	3.132	2.451	0.181	0.196
Kurtosis	9.967	12.587	8.712	2.556	2.925

The average of CPIF and PPI is 364.38 and 175.83, respectively. The lowest value of CPIF is 92.41 and the lowest value of PPI is 43.92 during the same period. The maximum increase of CPIF is 2232% and that of PPI is 2604%. From January 2003 to July 2023, the minimum, maximum and average values of USD/TRY exchange rate are 1.18, 26.51 and 4.06, respectively. The increase of USD from bottom to top during the analysis period is about 2150%. World food prices increase by about 142.5% during the same period. The difference between WFI and CPIF reflects the domestic impact on food prices. It can be concluded that the impact of domestic shocks on domestic food prices is much larger than the impact of foreign shocks.

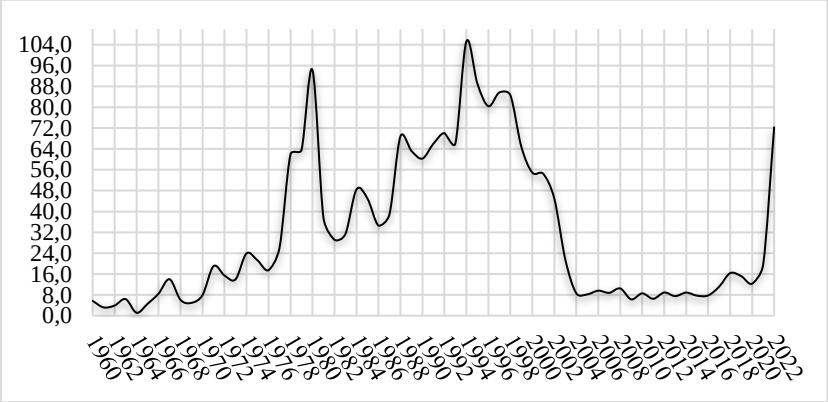

Figure 1. Annual Inflation Rate

Figure 1 shows the annual inflation rate for Türkiye. The figure shows the high inflation during the crisis periods. Until the introduction of inflation targeting in 2005, inflation in Türkiye was high on average. From 2005 to 2016, the average inflation rate was around 8%.

[1] Consumer price index for food, import and export data are obtained from TURKSTAT. World food price index is obtained from Trading Economics and USD/TRY exchange rate is obtained from database of the Central Bank of Türkiye.

However, it started to rise again with the currency crisis in 2018 and the Covid 19 pandemic in 2020. It is expected that the effects of the increase will last for at least another year. A similar situation may be observed in food prices. Food inflation accelerates, especially in times of exchange rate fluctuations.

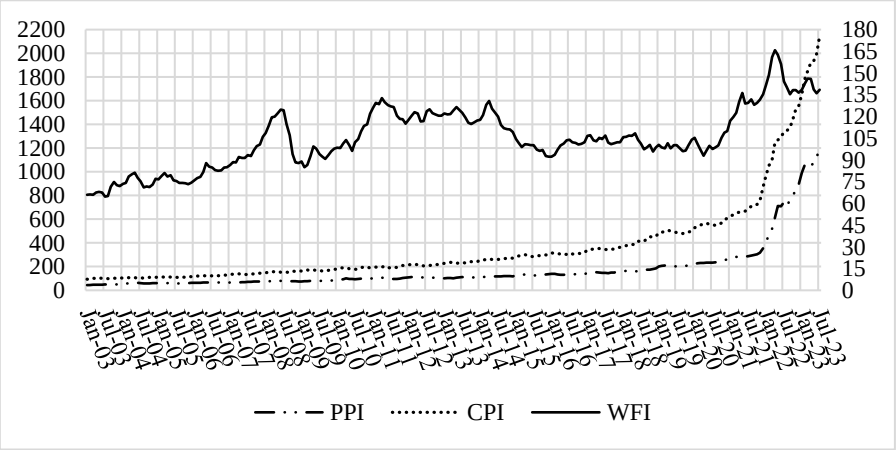

Figure 2. Domestic, World Food Prices, and Production Prices

Figure 2 shows the monthly evolution of the World Food Price Index (WFI), the Consumer Price Index for Food (CPIF) and the Producer Price Index for Food (PPI) from January 2003 to July 2023. A pattern emerges in which the PPI and the CPIF generally show a congruent trend, while the WFI shows periods of both growth and decline. In particular, the period from 2003 to 2008 is characterized by a sustained upward trend in global food prices, followed by a decline coinciding with the mortgage crisis of 2008 and 2014. After a period of relative stability between 2015 and 2020, the pandemic era triggered a dramatic increase in global food prices. Domestic food prices also show a steady upward trend from 2003 to 2020, which accelerated after the COVID-19 pandemic outbreak. The domestic food PPI shows a trend that is broadly consistent with the domestic food CPIF. It is noteworthy that the average CPIF remains higher than the average PPI throughout the analysis period.

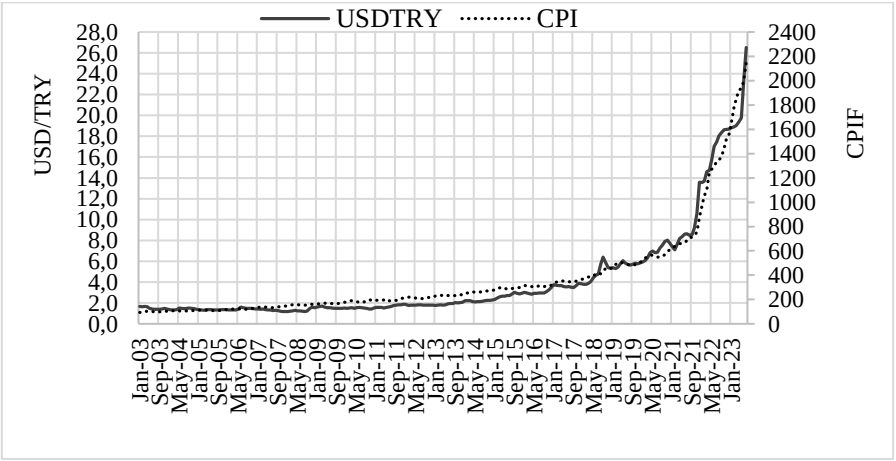

Figure 3. USD/TRY and Food Price Index

Figure 3 shows the series for the USD/TRY exchange rate and the domestic food price index. All series except USD/TRY are seasonally adjusted because the monthly data contain seasonality, which causes some technical problems in the analysis. Here, the graphs of the two series almost coincide. Whenever the exchange rate has increased, food prices have also increased in similar periods. Since 2018, the year of the currency crisis, the upward trend has accelerated for both series. Intuitively, this chart suggests a strong relationship between the two

series. Türkiye imports a significant share of the inputs and intermediates used in agriculture. As imports increase, so does the sensitivity of domestic prices to the exchange rate. Thus, the decline in foreign investment exerts price pressure on all consumer goods in times of crisis. The time series graphs above illustrate this fact. Thus, as long as dependence on imported goods is not reduced, it is not possible to reduce the pressure of exchange rate fluctuations on prices.

Agricultural products are a sector in which Türkiye has a trade surplus. While the country's exports are increasing, imports are also increasing. Imports and exports are concentrated in certain products. In 2021, hazelnuts ($1.3 billion), flour ($1.1 billion), and pasta ($0.80 billion) were the most exported products, with these products accounting for about 13.9% of total exports. In 2021, wheat ($2.3 billion), soybeans ($1.5 billion), and crude sunflower oil ($1.1 billion) were the top import items. These 3 products account for about 28.5% of total imports. Figure 4 shows the log difference between food exports and imports for the period 2003-2023. Although the difference between exports and imports decreases in some years and months, it increases steadily over the analysis period. As exports increase, imports also increase. Therefore, the reduction in import dependence is limited.

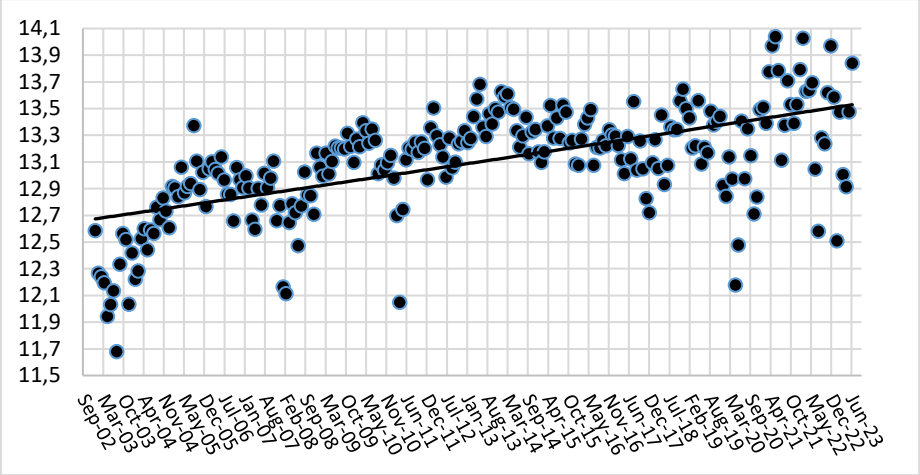

Figure 4. Difference Between Food Export and Food Import

ANN have proven to be powerful tools in various fields, including tasks such as clustering, pattern recognition, and prediction. In this study, the ANN algorithm is used for both prediction and duality analysis of the FPI with respect to explanatory variables such as the EI, USD/TRY exchange rate, PPI and WFI. It is well documented that the effects of currency crises, external shocks, and political interventions are often felt with a lag of days or months. Therefore, in order to accurately capture the overall effect of a variable on domestic food prices, the model must take into account not only the current values of the explanatory variables, but also their lagged values. The inherent advantage of ANN duality analysis is the ability to quantify the specific effect of each lagged variable. The inclusion of lagged variables serves two purposes: first, to isolate the unique effect of each lagged variable on food prices, and second, to calculate the cumulative effect of all lagged values associated with a particular variable. Consequently, the ANN duality results provide the pass-through effect for each variable, including the exchange rate. However, choosing the right number of lags to include in the ANN model is critical. Including statistically insignificant lags can lead to an overestimation of the overall effect of a variable, while omitting relevant lags can lead to an underestimation. Both scenarios affect the accuracy of the calculated effects. To overcome this challenge, this study uses a vector autoregression (VAR) model in conjunction with various information criteria to determine the optimal number of lags to include in the ANN algorithm.

Table 2. ADF Unit Root Test

Variable	**Model 1**	**Model 2**	**Model 3**
CPIF	3.705	2.308	1.023
CPIF(%)	**-11.544**	---	---
PPI	6.985	6.239	2.270
PPI(%)	**-7.225**	---	---
USD	5.337	6.480	6.288
USD(%)	**-11.644**	---	---
WFI	-2.238	-1.640	0.858
WFI(%)	**-11.117**	---	---
EI	**-6.977**	**-3.560**	-0.115
1% level	*-3.998*	*-3.459*	*-2.575*
5% level	*-3.429*	*-2.874*	*-1.942*
10% level	*-3.138*	*-2.573*	*-1.616*
Note: *Model 1 includes trend and constant, Model 2 includes constant only, and Model 3 includes no trend and no constant.*			

A basic principle of time series analysis is that a prerequisite for meaningful modeling is the verification of the stationarity of the variables used. For this purpose, a series of unit root tests are usually performed, with the Augmented Dickey-Fuller (ADF) test being a widely used method. As shown in Table 2, the results of the ADF test show that all variables except EI exhibit stationarity in their first difference. This indicates the presence of unit roots in their level forms, which require transformation to achieve stationarity. Consequently, the percentage change of each variable was calculated, making the time series stationary and suitable for further analysis. Following the VAR method, the lag structure was determined by finding the optimal number of lagged terms that minimizes the commonly used information criteria, such as the Schwarz Information Criterion (SIC) and the Akaike Information Criterion (AIC). Based on this analysis, a two lag structure was established, which means that domestic food prices are modeled as a function of the explanatory variables and their values in two previous time months. This paves the way for the application of the Artificial Neural Network algorithm, which is formulated as follows;

$$CPI_t = f(\sum_{i=0}^{2} PPI_{t-i}, \sum_{i=0}^{2} USD_{t-i}, \sum_{i=0}^{2} EI_{t-i}, \sum_{i=0}^{2} WFI_{t-i})$$

The estimated weights associated with the artificial neural network algorithm are shown in Table 3. The input layer of the ANN consists of twelve independent variables, while the output layer consists of a single dependent variable. The architecture of the ANN is a multi-layered feed-forward structure that includes an input layer, a hidden layer and an output layer. Both the hidden layer and the output layer consist of six neurons, which have been shown to be the optimal configuration for the desired predictive performance of the ANN model.

Table 3. Parameters of ANN Algorithm

		Predicted						
		Hidden Layer 1						Output Layer
Predictor		**H(1:1)**	**H(1:2)**	**H(1:3)**	**H(1:4)**	**H(1:5)**	**H(1:6)**	**CPIF**
Input Layer	**(Bias)**	0.25	0.32	-0.93	0.08	-0.03	-0.13	
	WFI	-0.26	0.17	-0.06	0.27	-0.30	-0.15	
	PPI	0.33	0.40	0.28	0.27	0.08	0.07	
	USD	-0.35	0.01	0.35	-0.22	-0.07	-0.37	
	EI	-0.04	0.03	0.05	-0.28	-0.04	-0.13	
	WFI(-1)	0.03	0.17	-0.07	-0.27	0.08	-0.15	
	PPI(-1)	0.21	0.23	-0.14	0.30	0.20	-0.37	
	USD(-1)	-0.03	0.42	-0.46	0.25	0.18	-0.32	
	EI(-1)	-0.40	-0.47	0.34	0.14	-0.05	-0.35	
	WFI(-2)	0.20	-0.31	-0.01	-0.15	0.53	0.33	
	PPI(-2)	-0.07	0.04	0.39	-0.10	0.01	0.37	
	USD(-2)	0.16	0.18	-0.11	-0.05	-0.12	0.09	
	EI(-2)	-0.40	0.28	-0.27	-0.06	0.10	-0.35	
Hidden Layer 1	**(Bias)**							0.75
	H(1:1)							0.88
	H(1:2)							0.42
	H(1:3)							1.34
	H(1:4)							0.60
	H(1:5)							0.69
	H(1:6)							-1.01

The performance of the ANN algorithm can be measured by its ability to fit the predicted values to the realized values of the dependent/output variables. The more the predicted and actual values lie on a linear line, the better the performance of the model. The linear line is the union of the points where the model accurately predicts the actual values. In other words, the error terms on this line are zero.

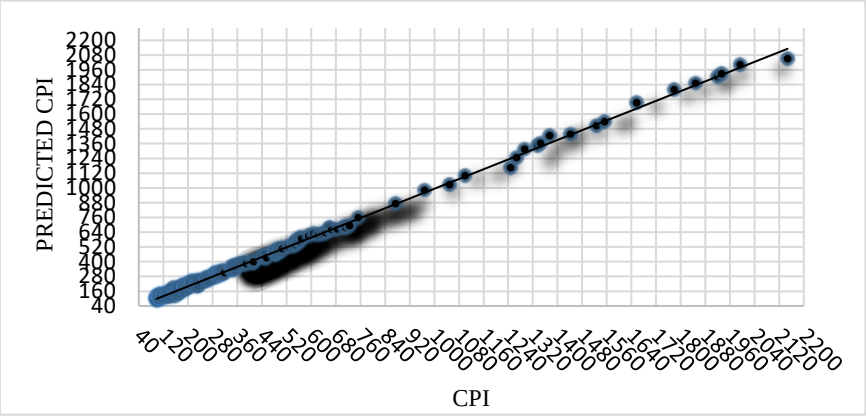

Figure 5. Predicted and Realized Values of Domestic CPIF

Table 4 provides a visual representation of the predicted values versus realized values of domestic food prices. The high degree of correlation between these values, with the vast majority falling on the predicted line, demonstrates the effectiveness of the artificial neural network model used. However, a closer look reveals that the artificial neural network has a superior performance and shows a higher accuracy in predicting lower values of the Consumer Price Index for Food (CPIF). In particular, the model achieves a deviation close to zero at a CPIF of 1000, indicating a robust ability to capture the pass-through effect of the USD/TRY exchange rate on domestic food prices in this range. In addition, the ANN algorithm uses the concept of duality to assess the relative importance of each input variable. Duality quantifies the sensitivity of the dependent variable (CPIF) to changes in the independent variable (e.g.,

the USD/TRY exchange rate). Essentially, it measures the extent to which a 1% increase in the independent variable results in a corresponding change in the CPIF. This sensitivity analysis provides valuable insight into the extent of the pass-through effect under different economic conditions. By including this analysis, the study goes beyond simply demonstrating the predictive power of the artificial neural network model. It explores the underlying dynamics of the pass-through effect and provides a more complete understanding of the relationship between exchange rate fluctuations and domestic food price movements.

Table 4. Duality of ANN Algorithm and Total Importance

Period	Variable	Importance	Pass-through effect of (t)	Pass-through effect of (t)+(t-1)	Pass-through effect of (t)+(t-1)+(t-2)
t	***WFI***	0.018	***1.8%***	***4.4%***	***7.1%***
	PPI	0.253	***25.3%***	***46.9%***	***53.3%***
	USD	0.107	***10.7%***	***24.0%***	***27.3%***
	EI	0.018	***1.8%***	***9.4%***	***12.3%***
t-1	***WFI(-1)***	0.026			
	PPI(-1)	0.216			
	USD(-1)	0.133			
	EI(-1)	0.076			
t-2	***WFI(-2)***	0.027			
	PPI(-2)	0.063			
	USD(-2)	0.032			
	EI(-2)	0.030			

The results of the importance analysis of the estimated artificial neural network model, shown in Table 4, illustrate the relative influence of different factors on the variation of domestic food prices. In particular, the current producer price index for food has the largest impact, accounting for 25% of a 1% increase in domestic food prices. This means that the producer price index has the highest current pass-through effect, i.e. it has an immediate and direct impact on domestic food prices in the current period. Although the other variables have less pronounced direct effects, their contributions are still noteworthy. Current world market prices have a small impact, accounting for only 0.018% of the 1% increase. The current USD/TL exchange rate has a moderate effect, contributing 10.7% to the change of food price. Similarly, the current food export/import ratio has a negligible direct impact, contributing only 0.018%. It is important to recognize that the pass-through effect of these variables is not limited to the current period. While part of the effect is immediate, the remaining effect may manifest itself in subsequent periods, increasing or decreasing the overall impact on domestic food prices over time. This lagged effect requires further investigation to fully understand the complex dynamics at play in the food price system. In essence, the importance analysis highlights the predominant role of the producer price index for food in the fluctuations of domestic food prices in the current period. However, the contributions of other variables, even if less pronounced in the short term, should be further investigated to gain a holistic understanding of the complex interplay of factors influencing the dynamics of domestic food prices.

WFI(-1), PPI(-1), USD(-1), and EI(-1) are lagged values of the World Food Price Index, the Producer Price Index for Food, the USD/TRY exchange rate, and the export/import ratio for food, respectively. Compared to the previous period, the impact of all variables except the USD has decreased. While the PPI still has the highest pass-through effect, the effect of the USD exchange rate increases from 10% to 13% from period (t) to period (t-1). The effect of world food prices in period (t-1) on current domestic food prices almost disappears. Overall, the two-month effects of the WFI, PPI, USD, and EI variables on current domestic food prices

are 4.4%, 46.9%, 24%, and 9.4%, respectively. These values show that 46.9% of a 1% shock to current domestic food prices is caused by the two-month total effect of the PPI variable and 24% is caused by the two-month total effect of the USD/TRY exchange rate. The first two-month effects show that most of the impact of an exchange rate shock occurs in the second month. While 10% of the total exchange rate effect is reflected in prices in the first month, it is 13% in the second month and 24% in the sum of period t and t-1.

According to the VAR model, the optimal number of lags was calculated to be two. The results of the VAR analysis show that the effect of the variables world food prices, USD/TRY exchange rate, food export/import ratio and food producer price index on food prices ends after two months. In other words, the effect of a shock on these variables lasts for two months. After two months, the pass-through effect of these variables on domestic food prices is muted. In fact, we find that the effects of all variables except the USD decline significantly from the current month to the previous month. From the figures in Table 4, we can see that the pass-through effect is almost over in period t-2 for all variables. Accordingly, the effects of PPI, WFI, EI, and USD were realized at 6.3%, 2.7%, 3%, and 3.2%, respectively, in period t-2. These rates also confirm the results of the VAR analysis. In particular, in periods t and t-1, the effects of the variables PPI and USD, which had the largest impact, almost disappeared. As a result, the total pass-through effect of world food prices on domestic food prices is 7.1%, while it is 12.3% for the ratio of exports to imports of food. The pass-through effect of the export-import coverage ratio is only 1.8% in the current month, while this effect was almost four times higher in the previous month. The producer price index for food has the largest pass-through effect on domestic food prices. This is not an unexpected situation for food prices as the Producer Price Index includes many cost items such as labor costs, transportation costs, storage costs, and fuel costs. In the case of an increase in labor costs, the producer must increase the price of the product he sells by at least the same amount as the increase in labor costs to avoid a loss. Therefore, an increase in labor costs will be reflected in food prices over the same period. However, the pass-through effect of the exchange rate is spread over time. Therefore, the producer price index for food will have the largest effect in the current month, while the exchange rate will have the largest effect in the following month or months.

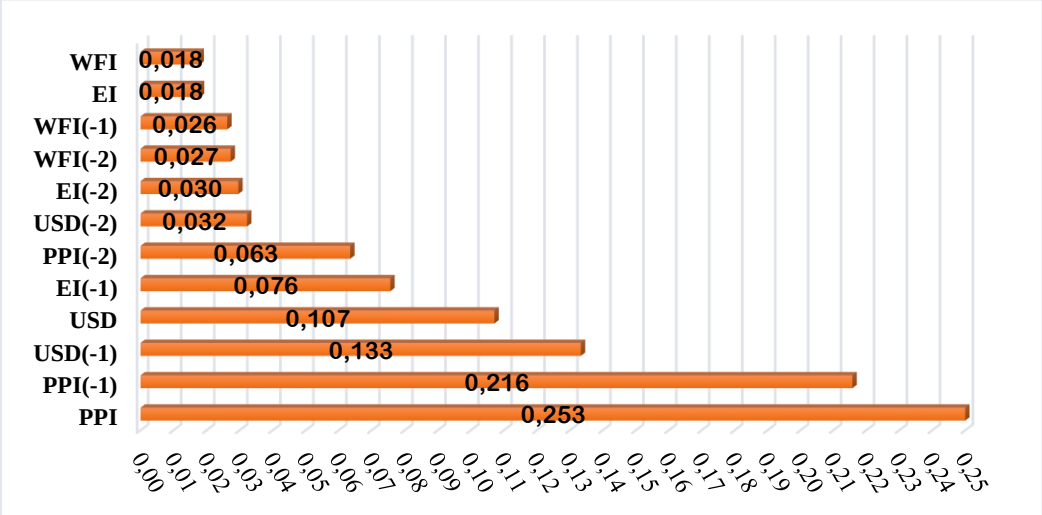

Figure 6. The Individual Pass-Through Effect of Variables to the Food Prices

Figure 6 shows the individual impact of each variable, including lagged variables, on domestic food prices. Among the variables used in the analysis, the PPI has the largest impact on food prices, while world food prices have the smallest impact. The total impact of the exchange rate on food prices is calculated to be 27.3%. This means that almost a third of a unit

increase in food prices is due to the pass-through effect of the exchange rate. Half of the total pass-through effect of 27.3% comes from period t-1, while the other half comes from periods.

Conclusion

The dynamic interplay between exchange rate fluctuations and domestic food prices is a complex and multifaceted phenomenon with far-reaching consequences for economies, firms, and individuals. Understanding this intricate relationship is crucial in the broader context of macroeconomic analysis, as it directly affects the well-being of societies. This paper examines the mechanisms through which exchange rate fluctuations affect domestic food prices, including the producer price index for food, the world price index for food, and the export-import ratio for food. Our empirical results show a significant pass-through effect of exchange rate fluctuations on domestic food prices, reaching about 27.3%. In particular, a substantial part of this effect occurs within the first month after an exchange rate shock. Interestingly, half of the effect occurs only in period t-1, while the other half is spread over periods t and t-2. This suggests a relatively fast transmission of exchange rate fluctuations to domestic food prices. Moreover, the analysis using the Artificial Neural Network algorithm emphasizes the limited impact of global food price increases on domestic food price inflation in Türkiye. Our results suggest that more than 90% of domestic food price increases originate from the Turkish market, highlighting the country's vulnerability to domestic market forces in this area. Given the critical role that food prices play in ensuring food access and food security, it is crucial to understand the impact of exchange rate fluctuations on this important sector. Fluctuations in food prices are a significant barrier to food access and have a direct impact on the well-being of individuals and communities. Overall, the observed impact of exchange rates on domestic food prices underscores the interconnectedness of the global economy. Further, economic policies and robust market mechanisms are essential to mitigate food price volatility.

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