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The Effects of the Monetary Transmission Mechanisms on Inflation in Türkiye

Sayım IŞIK[1]

Ümit BULUT[2]

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Abstract

The goal of this paper is to examine the impacts of the monetary transmission mechanisms on inflation in Türkiye using monthly data over the period 2006:M01-2021:M11. To this end, the paper considers the interest rate channel, the exchange rate channel, and the credit channel as the main monetary transmission channels. For unit root and cointegration analyses, the paper relaxes the assumption of linearity and employs time series methods based on nonlinear models. Besides, the paper performs a causality test based on the bootstrapping procedure. The findings indicate that the inflation rate is positively related to the interest rate, the exchange rate, and the credit growth rate and that all these variables have predictive power in forecasting future inflation rates in Türkiye. These results imply the existence of efficient monetary transmission channels in Türkiye. Theoretical and practical implications are discussed.

Keywords: *Transmission mechanism of monetary policy, inflation, the Central Bank of the Republic of Türkiye, cointegration test, causality test.*
JEL Codes: *E31, E52, E58.*

[1] *Akdeniz University, Faculty of Economics and Administrative Sciences, Department of Economics, Antalya, Türkiye. Email: sayim@akdeniz.edu.tr http://orcid.org/0000-0002-2708-0253*
[2] *Kirsehir Ahi Evran University, Faculty of Economics and Administrative Sciences, Department of Economics, Kirsehir, Türkiye. Email: ubulut@ahievran.edu.tr http://orcid.org/0000-0002-8964-0332*

Özet

Türkiye'de Parasal Aktarım Mekanizmalarının Enflasyona Etkileri

Bu çalışmanın amacı, 2006:M01-2021:M11 dönemine ait aylık verileri kullanarak Türkiye'de parasal aktarım mekanizmalarının enflasyon üzerindeki etkilerini incelemektir. Bu amaçla, çalışma faiz oranı kanalını, döviz kuru kanalını ve kredi kanalını ana parasal aktarım kanalları olarak ele almaktadır. Çalışma, birim kök ve eşbütünleşme analizleri için doğrusallık varsayımını gevşetmekte ve doğrusal olmayan modellere dayalı zaman serisi yöntemlerini kullanmaktadır. Bunun yanında, çalışma bootstrap prosedürüne dayalı bir nedensellik testi uygulamaktadır. Bulgular, enflasyon oranının faiz oranı, döviz kuru ve kredi büyüme oranı ile pozitif ilişkili olduğunu ve tüm bu değişkenlerin Türkiye'de gelecekteki enflasyon oranlarını tahmin etmede öngörü gücüne sahip olduğunu göstermektedir. Bu sonuçlar, Türkiye'de etkin parasal aktarım kanallarının varlığına işaret etmektedir. Teorik ve pratik çıkarımlar çalışmada tartışılmıştır.

Anahtar Kelimeler: *Para politikasının aktarım mekanizması, enflasyon, Türkiye Cumhuriyet Merkez Bankası, eşbütünleşme testi, nedensellik testi.*
JEL Kodları: *E31, E52, E58.*

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1. Introduction

Inflation is a major problem in many countries today and monetary policy is one of the most important tools in ensuring price stability. Therefore, the transmission mechanism of monetary policy is of great importance in controlling inflation. This mechanism reveals the channels through which monetary policy affects the real economy and inflation (Mishkin, 2016). While there is a debate in the monetary economics literature regarding the most effective channels of monetary transmission, it is generally accepted that monetary contractions reduce production and inflation. However, the debate continues as to which channel (the interest rate channel, the exchange rate channel, or the credit channel) of tight monetary policy has more effect on real output and inflation. Monetary policy has an uncertain impact on the economy because the effects of the monetary transmission mechanism spread and vary over

time. Therefore, monetary policy can be implemented more effectively if there is information about the possible effects of the implemented monetary policy. For central banks, a good understanding of the monetary transmission mechanism helps to control inflation and increases credibility of central banks. Therefore, knowing how the monetary transmission mechanism works and what its effects are will help central banks implement optimal monetary policy.

From 2006 to 2016, inflation in Türkiye averaged 8.3% before accelerating to 15% from 2017 to 2021. While inflation was under control until 2016, inflation expectations then worsened due to (i) the policies prioritizing employment and growth, (ii) the steps taken to make the central bank dependent and (iii) domestic and foreign political developments. These worsening expectations created an inflation dynamic in Türkiye. Given that high inflation remains a serious problem for the Turkish economy, it is necessary to investigate how the monetary transmission mechanisms affect inflation. Recent scientific research and discussions on the causes of inflation in Türkiye have focused on monetary transmission mechanism channels, such as the interest rate channel, the exchange rate channel, and the credit channel. Empirical studies suggest that one of the key variables affecting inflation in Türkiye is the exchange rate. Because the production structure of the Turkish economy depends on imports, a rising exchange rate (a depreciation of the Turkish Lira against foreign currencies) increases production costs and causes inflation. Since exchange rate shocks increase import costs, they are reflected in inflation after a certain period due to their cumulative effect. Empirical studies on the effects of credits on inflation show that an increase in credits lead to an increase in expenditures, which in turn leads to inflation. While studies examining the relationship between the central bank policy interest rate and inflation have revealed different findings, many studies suggest that interest rate changes can induce inflation.

It is thus essential to examine how monetary transmission channels affect inflation in Türkiye. For this reason, this paper investigates the effectiveness of the monetary transmission mechanisms by analyzing the dynamic relationships between monetary transmission channels and inflation during 2006–2021 in Türkiye. In his pioneering papers, Friedman (1961, 1968, 1972) states that monetary policy has a lagged effect on inflation. From an econometric analysis perspective, this implies that a cointegration test can be performed to catch the dynamic relationships between monetary transmission channels and inflation. Besides, forecasting inflation and implementing optimal monetary policy are very important for a central bank (Taylor, 2000; Faryna, 2016). Put differently, the selection of macroeconomic variables to forecast future inflation is a major concern for monetary policy. Since the seminal paper of Granger (1969), causality analysis is employed to examine whether a variable can be used for predicting another variable. Hence, the present paper performs not only a cointegration test but also a causality test while investigating the effectiveness monetary transmission channels in terms of affecting inflation in Türkiye. The authors of this paper have three motivations for preparing such a paper.

First, very few studies examined the monetary transmission mechanisms' impacts on inflation in Türkiye. This study aims to provide new findings and contributions to the relevant literature. Second, the previous studies analyzed shorter periods, whereas our study covers the period from 2006 to 2021, when the Turkish authorities used inflation targeting as the monetary policy strategy. Last but not least, the previous studies on this topic assumed the presence of linear monetary transmission mechanisms and focused on the linear impacts of monetary transmission channels on inflation in Türkiye. However, linearity is considered as a very strong assumption for economic data sets. This paper relaxes the linearity assumption and employs nonlinear models to estimate the impacts of monetary transmission channels on inflation in Türkiye.

The rest of the paper is structured as follows: Section 2 examines the theoretical and empirical literature. Section 3 presents the model and the data set. Estimation methods and empirical results are reported in Section 4. Section 5 concludes the paper.

2. Theoretical and empirical literature

It is extremely important to understand the impact of monetary policy on output and inflation and therefore how the financial system and the real economy work as a whole. Monetary transmission mechanisms are very complex phenomena as monetary policy affects macroeconomic variables in various ways. For this reason, Bernanke and Gertler (1995) defined the monetary transmission mechanism as a "black box". Economic research has shown that monetary policy affects production and inflation through three main channels: interest rates, exchange rates, and loans (Mishkin, 2016). The functioning and effectiveness of these channels are determined by various factors, such as the level of economic development, openness, financial structure, and institutional structure (Kakes, 2000). Many theoretical and empirical studies have identified which transmission channels are relatively more effective. This section first considers the monetary transmission mechanism's three main channels. It then reviews the empirical studies examining the effects of monetary transmission channels on inflation in some countries.

The traditional interest rate channel is an indirect transmission mechanism based on the standard IS-LM model. In this model, where the interest rate is determined in the money market, changes in money supply are transferred to the financial and real markets through interest rates. Thus, the interest rate channel works through the effect of monetary shocks on liquidity conditions and hence aggregate demand on interest-sensitive variables, such as investment and consumption expenditures. The interest rate channel relies on the assumption that expansionary

monetary policy reduces the interest rate and therefore the funding cost of investments. Low funding costs increase investments, leading to an increase in total demand and output. Although the interest rate channel is a widely accepted as a transmission mechanism, it cannot explain all changes in production, especially in small open economies (Taylor, 1995; Mishkin,1996, 2016). Bernanke and Gertler (1995) also claim that the interest channel which works through the cost of capital is not very important.

After switching to the inflation targeting regime in 2006, the Central Bank of the Republic of Türkiye (CBRT) used the policy rate to control liquidity conditions in the economy and thus aggregate demand. Changes in the policy rate affect consumption and investment expenditures through interest rates on loans and deposits. While the CBRT has generally used the policy rate to control inflation, it has sometimes acted to increase economic growth and employment. For example, while the CBRT implemented tight monetary policies and structural measures against high inflation during 2002-2009 (orthodox policies), its expansionary (heterodox) policies implemented from 2010 to 2021 accelerated inflation.

The exchange rate channel includes the effects of the interest rates and therefore works in harmony with the interest channel (Mishkin, 2016). In countries with a flexible exchange rate system, the exchange rate channel influences aggregate demand and inflation through capital movements and net exports. A fall in interest rates makes foreign currency assets more attractive than domestic assets. Consequently, as the local currency depreciates, the value of foreign currencies increases. The depreciation of the domestic currency increases net exports, which in turn affects aggregate demand. Therefore, the exchange rate influences production and inflation. As a result, interest rates indirectly affect the exchange rate channel (Tran, 2018; Brandao-Marques et al., 2020). Especially in small open economies, the interest channel and the exchange rate channel reinforce and support each other.

After the 2001 economic crisis, the CBRT adopted the inflation targeting regime to regain control over inflation. The authorities used high interest rates as a monetary policy tool while implementing a floating exchange rate regime. During this period, Türkiye also benefited from the expansionary monetary policies of central banks in developed countries (Akçay, 2021). The tight monetary policy increased domestic capital movements, lowered the exchange rate, and led to decreases in inflation. As a result, high interest rates, plenty of hot money, and cheap imports increased national income, decreased inflation, and lowered interest rates. After 2013, developed countries implemented contractionary monetary policies while Türkiye turned to expansionary (heterodox) policies. This damaged economic growth and increased inflation due to capital movements. Especially in recent periods, despite the CBRT's high interest rate policy, the exchange rate continued to rise and made the control of inflation more difficult. Therefore, the interest rate in Türkiye has successfully controlled inflation to the extent that it suppressed the exchange rate.

The credit channel is especially important in economies whose financial system is based on bank loans. In a financial system where banks are important in financial mediation and companies depend on bank loans, the central bank's monetary policy determines the credit volume.[3] The credit channel assumes that expansionary monetary policy that increases bank reserves and bank deposits raises available bank credits (Bernanke & Gertler, 1995; Kashyap & Stein, 1995, 2000; Mishkin, 2016). Because many borrowers rely on banks to fund their economic activities, an expansion in bank loans increases consumption and investment spending. The increase in total spending affects production and inflation. Conversely, tight monetary policy that restricts reserves and deposits affects total spending, production, and inflation by reducing the volume of credits. As long as interest rates on loans affect the amount of bank loans, the relationship between loans and the interest channel is

[3] For a detailed discussion, see e.g., Bernanke and Blinder (1988), Bernanke (1992-1993), Bernanke and Gertler (1989, 1995), Kashyap and Stein (1994, 1995), Hubbard (1995), and Cecchetti (1995), among others.

quite strong. According to Bernanke and Gertler (1995), the credit channel is not an alternative to the interest channel but rather complements it by increasing and strengthening the latter's effect.

Türkiye's financial system is largely based on the banking system, and the banking sector's total assets exceed 100% of GDP. While loans determine the banking sector's assets, deposit accounts determine the liabilities. Consumption and investment decisions are largely based on bank loans in Türkiye. As of 2021, the shares of commercial loans, small and medium-sized enterprises (SMEs) loans, and consumer loans were respectively 54%, 24%, and 22% in Türkiye. Except for the 2008 global crisis and 2019, credit growth rates were higher than the inflation rate. During 2011–2019, however, the growth in loans reversed. Especially in recent years, low interest policies and loan facilities for companies, such as the Public Guarantee Fund, have begun to strengthen demand conditions.

Many empirical studies in the monetary economics literature have investigated the monetary transmission mechanisms so far. This section also reviews the empirical studies examining the effects of the monetary transmission mechanisms on inflation in countries where inflation targeting is implemented. These studies generally use the vector autoregressive (VAR) model and the vector error correction (VEC) model to analyze the influences of monetary policy. There is a large literature analyzing the dynamic effects of monetary policy transmission channels, especially in countries where inflation targeting is endorsed. For instance, applying the VAR model for Poland, Chmielewsk et al. (2018) showed that the interest rate channel had an increasingly strong effect on production and inflation. Furthermore, they argued that the pass-through of the exchange rate to inflation was decreasing while the credit channel was getting stronger. Employing the VAR model for Czechia, Arnostova and Hurnik (2005) showed that the exchange rate channel became increasingly important after the country's transition to inflation targeting. Brandao-Marques et al. (2020) investigated the effects of the monetary transmission mechanisms on production and

inflation for 40 emerging and developing countries including Türkiye. They concluded that the effect of tight monetary policy on production and inflation strengthened when it was combined with the supportive effects of the exchange rate channel. In particular, the effect of contractionary monetary policy (the interest rate channel alone) on inflation was quite weak. However, when the exchange rate channel was considered, this effect became more significant. Thus, this study demonstrated that the exchange rate played an important role in the monetary transmission mechanism in small open economies where inflation targeting is adopted.

Following the VEC model for Vietnam, Tran (2018) analyzed the effectiveness of the monetary transmission mechanisms in controlling inflation. He concluded that the most important variables in the long run were the credit growth and the interest rates. In the short run, however, he found a significant causal relationship between the credit growth rate and interest rates leading to inflation. Because Vietnam implemented policies to suppress the exchange rate, there was no short- or long-term relationship between the exchange rate and inflation. Using both VAR and VEC models for Indonesia, Fikri (2018) investigated the effects of monetary transmission mechanisms on inflation. He reported that credits and interest rates enhanced inflation in the long run but not in the short run. Rocha et al. (2022) applied a Bayesian VAR analysis to examine the effects of the monetary transmission channels on inflation in Brazil. They showed that contractionary monetary policy reduced aggregate demand and therefore inflation. While the exchange rate channel affected inflation, loans had no significant impact on inflation. Şen et al. (2020) examined the long-term relationship between interest rates, the exchange rate, and inflation in five EMEs (Brazil, India, Indonesia, South Africa, and Türkiye), via a cointegration analysis. In all five countries, there was a long-term positive relationship between inflation and interest rates and a cointegration relationship between the exchange rate and inflation. The pass-through from the exchange rate to inflation was quite high in all countries, indicating that the exchange rate channel could be used to control inflation.

It can be observed from the empirical literature that some studies have examined the effects of monetary transmission channels on inflation for Türkiye. Çatik and Akdeniz (2019) applied the time-varying VAR model to examine the relationship between interest rates, the exchange rate, credits, and inflation. While the exchange rate channel had significant effects on production and prices, the credit channel had more effect on production than inflation. They also concluded that combining the interest rate channel (tight monetary policy) with inflation targeting was more effective in controlling inflation. Demirgil (2019) applied a VAR analysis to analyze the effects of the policy rate, money supply, import prices, and the exchange rate on inflation. He reported that a 1% increase in the interest rate increased inflation by 0.31%, while a 1% increase in the exchange rate increased inflation by 0.85%. Okur et al. (2019) applied the VAR model to show that the exchange rate and credit channels played important roles in the monetary transmission mechanism while the credit channel had more effect on inflation. Altunöz (2020) applied the autoregressive distributed lag (ARDL) approach to examine the relationship between the interest rate and inflation. The model showed that 1 unit increase in the interest rate increased inflation by 0.81 unit. Can et al. (2020) examined the relationship between the interest rate, the exchange rate, production, and inflation using VAR and structural VAR analyses. They found that the interest rate and exchange rate channels were important determinants of both inflation and production. More specifically, positive shocks to the policy rate reduced inflation whereas positive shocks to the exchange rate increased inflation. Tümtürk (2020a, 2020b) used the VAR method to show that monetary policy shocks (interest rate increases) increased inflation. He claimed that this finding was due to the cost channel and the CBRT's loss of credibility. Bozkurt and Çamoğlu (2021) performed the VAR technique to show that the interest rate affected both the exchange rate and inflation through loans. They found that the exchange rate channel had a greater effect on inflation, although credits and the exchange rate were the most important determinants of inflation as a result of interest rate shocks. Yıldırım (2021) used an

SVAR analysis to show that the exchange rate, credits, and inflation reacted negatively to a positive shock to the policy rate. On the other hand, the interest rate, exchange rate, and inflation reacted positively to a positive shock to credits. Turna and Özcan (2021) examined the long-term relationship between the interest rate, exchange rate, and inflation using the ARDL method. They reported that the interest rate and the exchange rate boosted inflation in both the short and long terms. More specifically, a 1% increase in the interest rate increased inflation by 0.21% while a 1% increase in the exchange rate increased inflation by 0.8% in the long run. Doğanalp (2022) applied the VAR analysis to show that positive interest rate shocks reduced exchange rates but increased inflation. On the other hand, the most important determinants of inflation were the interest rates and the exchange rate. Bulut (2023) employed an SVAR analysis with structural breaks and found that consumer prices positively reacted to a shock to the depreciation of national currency against foreign currencies and negatively reacted to a positive shock to the interest rates.

As this review shows, the empirical studies about the recent effects of monetary transmission channels on inflation in Türkiye report both similar and different findings regarding the effects of monetary channels on inflation. Besides, all these studies examined the linear impacts of monetary transmission channels on inflation. The present study, therefore, aims to add new findings to the monetary economics literature regarding the nonlinear effects of the main monetary transmission channels on inflation in Türkiye.

3. Model and data set

This paper establishes an empirical model to examine the impacts of monetary transmission mechanisms on inflation in Türkiye. Accordingly, the model can be described as the following:

$$INF_t = \gamma_0 + \gamma_1 INT_t + \gamma_2 lnEXC_t + \gamma_3 CREDITG_t + \varepsilon_t \quad (1)$$

where INF, INT, EXC, CREDITG, and ε are respectively the inflation rate, the interest rate, the nominal exchange rate, the credit growth rate, and the error term. The annual inflation rate is calculated based on the consumer price index while the interest rate is the weighted average cost of the CBRT funding for banks. Besides, the exchange rate is the USD/TRY exchange rate (TRY units per unit of USD) while the credit growth rate is annually computed. The average funding rate, the exchange rate, and the credit growth rate respectively represent the interest rate channel, the exchange rate channel, and the credit channel. The inflation, interest, and credit growth rates are expressed as percentages while the exchange rate is used in its logarithmic form described by ln. The monthly data cover the period 2006:M01-2021:M11 with 191 observations. Data for all variables are extracted from the CBRT (2022).

Table 1 Descriptive statistics and correlation matrix

	INF	INT	lnEXC	CREDITG
Mean	10.199	12.221	0.933	24.858
Median	9.218	10.030	0.723	22.841
Maximum	25.240	25.500	2.355	59.216
Minimum	3.986	4.520	0.162	-7.138
Std. deviation	3.964	5.606	0.603	13.147
Correlation matrix				
INF	1			
INT	0.679	1		
lnEXC	0.701	0.249	1	
CREDITG	-0.189	0.016	-0.379	1

Table 1 reports the descriptive statistics and correlation matrix for the variables under consideration to present initial information about them. Accordingly, all descriptive statistics except the minimum of CREDITG are greater than those of other variables. Besides, INF is positively correlated with INT and lnEXC and is

negatively correlated with CREDITG. Finally, there is no high correlation among INT, lnEXC, and CREDITG, meaning the multicollinearity problem does not exist in the empirical model.

4. Methodology and findings

The descriptive statistics and correlation matrix provide us with some initial information about the monetary transmission mechanisms in Türkiye. Yet, to obtain efficient and reliable outputs about the monetary transmission mechanisms in Türkiye, we should employ time series methods, such as unit root, cointegration, and causality tests. The selection of the proper method is especially important for parameter estimations. As is stressed by Enders (2015), time series variables usually demonstrate nonlinear behaviors rather than linear behaviors. Furthermore, the parameters in an empirical model tend to slowly change, meaning smooth transition models can capture the relationships between variables better (Terasvirta, 1994). Within this scope, the paper first tests whether linear or nonlinear methods for parameter estimations must be performed. The paper performs the linearity tests of Broock et al. (1996, hereafter BDS) and Luukkonen et al. (1988) to check for possible nonlinearity. Both methods test the null hypothesis of linearity against the alternative hypothesis of nonlinearity.

Table 2 demonstrates the results of the BDS and Luukkonen et al. (1988) tests. As is seen, the null hypothesis of the presence of linearity is rejected by both tests at 1% level of significance. Put differently, the relationship between the inflation rate, the interest rate, the exchange rate, and the credit growth rate exhibit a nonlinear characteristic. Therefore, this paper performs nonlinear unit root and cointegration tests that rely on smooth transition models for the econometric analyses.

Table 2 Results of linearity tests

Panel A: BDS test					
Variable	Dimensions				
	2	3	4	5	6
INF	0.161*	0.263*	0.326*	0.363*	0.384*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
INT	0.181*	0.301*	0.378*	0.424*	0.451*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
lnEXC	0.195*	0.329*	0.422*	0.487*	0.532*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
CREDITG	0.171*	0.283*	0.353*	0.392*	0.411*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Panel B: Luukkonen et al. (1988) test					
Test tatistic			Prob. value		
12.599*			0.000		

*Notes: * indicates 1% significance. Values in parentheses show probability.*

Kapetanios et al. (2003) use a nonlinear exponential smooth transition autoregressive (ESTAR) model as follows to propound a unit root test:

$$\Delta x_t = \phi x_{t-1} + \delta x_{t-1}\left[1 - \exp\left(\theta x_{t-d}^2\right)\right] + \varepsilon_t \quad (2)$$

They assume ϕ is equal to 0 and d is equal to 1 and obtain the model below:

$$\Delta x_t = \delta x_{t-1}\left[1 - \exp\left(\theta x_{t-1}^2\right)\right] + \varepsilon_t \quad (3)$$

Using a first-order Taylor series approach, they demonstrate the equation below:

$$\Delta x_t = \lambda x_{t-1}^3 + \varepsilon_t \quad (4)$$

Then, they obtain the following test statistic, namely t_{NL}, for $\lambda = 0$ against $\lambda < 0$:

$$t_{NL} = \frac{\hat{\lambda}}{s.e.(\hat{\lambda})} \quad (5)$$

where $\hat{\lambda}$ and $s.e.(\hat{\lambda})$ are respectively the ordinary least squares (OLS) estimation for λ and the standard error for $\hat{\lambda}$. If the computed t_{NL} statistic is higher than the critical values produced by Kapetanios (2003), the null hypothesis that implies the series is not stationary is rejected.

Table 3 Kapetanios (2003) unit root test

Variable	Test statistic	
	Level	1st difference
INF	0.170	-2.990*
INT	-1.796	-4.452*
lnEXC	2.994	-2.979*
CREDITG	-0.773	-5.875*

*Notes: 1%, 5%, and %10 critical values are -2.82, -2.22, and -1.92, respectively. * indicates 1% statistical significance.*

The outputs of the Kapetanios (2003) unit root test are demonstrated in Table 3. As is seen, the null hypothesis of a unit root (non-stationarity) is not rejected for level values, but it is rejected for the first differences of the variables. These findings imply that all series under consideration are integrated of order one and that the possible cointegration relationship in the empirical model can be examined through a cointegration test.

The cointegration test propounded by Kapetanios et al. (2006) is based on the nonlinear exponential smooth transition (ESTR) error correction models. Kapetanios (2006) produce the ESTR error correction model as follows:

$$\Delta y_t = \alpha u_{t-1} + \lambda u_{t-1}\left(1-e^{\theta(u_{t-1}-c^2)}\right) + \delta \Delta x_t + \sum_{i=1}^{p} \omega_i \Delta z_{t-i} + e_t \quad (6)$$

$$\Delta x_t = \sum_{i=1}^{p} \Gamma_{xi} \Delta z_{t-i} + \varepsilon_{xt} \quad (7)$$

$$\hat{u}_t = y_t - \hat{\beta}_x x_t \quad (8)$$

where $\hat{\beta}_x$ is the OLS estimation of β_x. Kapetanios (2006) suggest some test statistics to test for cointegration. The t_{NEC} statistic is calculated based on the estimation of the model below:

$$\Delta y_t = \widehat{\lambda u}_{t-1}^{3} + \delta \Delta x_t + \sum_{i=1}^{p} \omega_i \Delta z_{t-i} + \varepsilon_t \quad (9)$$

Besides, the t_{NEG} statistic is computed based on the estimation of the following model:

$$\Delta \hat{u}_t = \lambda \hat{u}_{t-1}^{3} + \sum_{i=1}^{p} \vartheta_i \Delta \hat{u}_{t-i} + \varepsilon_t \quad (10)$$

The null hypothesis of no cointegration is indicated as H_0: $\lambda = 0$ for both tests. If the calculated t_{NEC} and t_{NEG} statistics are greater than the critical values, there exists cointegration in the empirical model.

The outputs for the Kapetanios (2006) cointegration test are reported in Table 4. Panel A and panel B of the table present the findings of the cointegration test and the long-run parameters of the independent variables in the model, respectively. As is seen, the null hypothesis of no cointegration is rejected by both tests, implying the long-run coefficients could be estimated. Besides, INT, lnEXC, and CREDITG respectively have the estimations of 0.421, 4.305, and 0.035 while all coefficients are statistically significant. These findings show that all variables have a positive impact on inflation. Put differently, the inflation rate is positively related to the interest rate, the exchange rate, and the credit growth rate in Türkiye.

Table 4 Kapetanios (2006) cointegration test

Panel A: Kapetanios (2006) cointegration test			
t_{NEC}		t_{NEG}	
-4.148*		-3.887**	
Panel B: Long-run coefficients			
Variable	Coefficient	Std. error	t-stat.
INT	0.421*	0.024	17.215
lnEXC	4.305*	0.229	18.790
CREDITG	0.035*	0.009	4.090

*Notes: For t_{NEC} statistic, 10%, 5%, and 1% critical values are -2.95, -3.28, and -3.93, respectively. For t_{NEG} statistic, 10%, 5%, and 1% critical values are -3.34, -3.66, and -4.23, respectively. * and ** respectively indicate 1% and 5% statistical significance.*

It can be observed throughout the extant literature that many causality tests have been suggested so far. The Granger causality test of Hacker and Hatemi-J (2012) which is based on bootstrapping becomes prominent as it has many advantages over other causality tests. Accordingly, this test (i) allows the optimal lag length to be endogenously determined, (ii) well performs in small samples, and (iii) is robust to autoregressive conditional heteroskedasticity effects. Hacker and Hatemi-J (2012) use the following VAR model to test causality:

$$y_t = B_0 + B_1 y_{t-1} + \ldots + B_k y_{t-k} + u_t \quad (11)$$

In Equation (11), the error vector, namely u_t, has a zero-expected value. There is no Granger causality from the rth element of y_t to the jth element of y_t concerning the following null hypothesis:

$$H_0: \text{the element in } B_i\text{'s row j, column r is zero for } i = 1,\ldots,k \quad (12)$$

The lag order k is determined through an information criterion. The VAR model can be described as the following:

$$Y = DZ + \delta \tag{13}$$

The next stage is to estimate δ_U. The variance-covariance of these residuals is calculated as $S_u = \left(\delta_U \delta S_U^{'}\right)/\left(T-(1+nk)\right)$, where 1 + nk stands for the number of estimated parameters. Besides, $\beta = vec(B_0,B_1,\ldots,B_k)$ or $\beta = vec(D)$, where vec is the column-stacking operator and $\hat{\beta}$ is the OLS estimation of β. The following Wald test statistic is utilized to test the null hypothesis of no Granger causality:

$$Wald = \left(Q\hat{\beta}\right)^{'}\left[Q\left(\left(Z^{'}Z\right)^{-1} \otimes S_U\right)Q^{'}\right]^{-1}\left(Q\hat{\beta}\right) \sim \chi_k^2 \tag{14}$$

where $\otimes$ denotes the Kronecker product, and Q indicates a k x n(1 + nk) matrix. The null hypothesis of no Granger causality can also be exhibited as the following:

$$H_0: Q\beta = 0 \tag{15}$$

When the Wald statistic is greater than the bootstrap critical values, the null hypothesis of no Granger causality is rejected.

The results of the Hacker and Hatemi-J (2012) causality test are depicted in Table 5. As is seen, the null hypothesis of no causality running from INT to INF is rejected at 10% level, while the null hypothesis of no causality running from lnEXC to INF is rejected at 5% level. Besides, the null hypothesis of no causality running from CREDITG to INF is rejected at 1% level. These results imply that the interest rate, the exchange rate, and the credit growth rate have predictive power for forecasting future inflation in Türkiye. In other words, these variables not only influence the current inflation rate but also help the CBRT predict future inflation

rates. Hence, these monetary transmission channels provide the CBRT with valuable information in terms of implementing monetary policy to achieve inflation targets.

Table 5 Hacker and Hatemi-J (2012) Granger causality test

Null hypothesis	Test statistic	Critical values		
		1%	5%	10%
INT ≠→ INF	10.726***	15.921	11.433	9.443
lnEXC ≠→ INF	11.817**	13.733	9.592	7.874
CREDITG ≠→ INF	53.523*	15.703	11.385	9.492

*Notes: Critical values are obtained via 10,000 bootstrap replications. The results for the causal relationships running from INF to the independent variables are not presented here, but they are available upon request. ≠→ implies the null hypothesis of no causality. * indicates 1% statistical significance. ** indicates 5% statistical significance. *** indicates 10% statistical significance.*

The results of this paper show that the inflation rate is positively related to the interest rate in Türkiye. That is, an increase (decrease) in interest rates increases (decreases) inflation. This finding is similar to the findings of Demirgil (2019), Tümtürk (2020a, 2020b), Altunöz (2020), Şen et al. (2020), Turna and Özcan (2021), Doğanalp (2022) for Türkiye. Similarly, these results are compatible with the results of Tran (2018), Fikri (2018), and Şen et al. (2020) for other emerging economies. On the contrary, the findings of this study about the influence of interest rates on inflation contradict with those of Çatik and Akdeniz (2019), Can et al. (2020), Yıldırım (2021), and Bulut (2023) for Türkiye. Theoretically, these results of this paper also conflict with the traditional monetary transmission mechanism/interest rate channel. The traditional monetary transmission mechanism suggests there is a negative relationship between interest rates and inflation. That is to say, contractionary monetary policy of a central bank raises interest rates, increases the cost of funding, and reduces aggregate demand and inflation. Arellano et al. (2020) argue that this theoretical approach is only valid for countries with highly developed financial markets. However, higher interest rates in open developing countries with high foreign debt,

such as Türkiye, increase country risk and lead to a rapid depreciation of the national currency, which in turn leads to high inflation rates (Blanchard, 2004; Favero & Givazzi, 2004; Tran, 2018; Arellano et al., 2020). Inflation has increased faster than expected due to ongoing high inflation, high foreign debts, and the loss of credibility of the CBRT in Türkiye. The CBRT increased the policy rate only when inflation was too high, meaning the policy rate was not used as a proactive tool. The findings also indicate that there exists the exchange rate pass-through to inflation and that the credit channel influences inflation in Türkiye. The findings of this paper meaning the exchange rate channel and the credit channel affect inflation are consistent with those of the previous studies on Türkiye and other emerging economies.[4]

5. Conclusion

This study investigated the effects of the main monetary transmission channels on inflation in Türkiye for the period 2006–2021. More specifically, the study relaxed the assumption of linearity and employed nonlinear unit root and cointegration tests relying on the smooth transition models. Besides, the study performed a causality test based on the bootstrapping procedure. Hence, the study estimated the long-term effects of the interest rate, the exchange rate, and the credit growth rate on the inflation rate and examined whether these variables can be used for forecasting future inflation rates in Türkiye. The study discovered that the inflation rate was positively related to the interest rate, the exchange rate, and the credit growth rate. The study also yielded that there was causality from these variables to inflation, meaning these variables could be utilized to forecast future inflation rates. Hence, the empirical analyses produced the following main results:

[4] For Türkiye, see e.g., Çatik and Akdeniz (2019), Okur et al. (2019), Demirgil (2019), Can et al. (2020), Şen et al. (2020), Turna and Özcan (2021), Bozkurt and Çamoğlu (2021), Yıldırım (2021), Doğanalp (2022), and Bulut (2023), among others. For other emerging economies, see e.g., Arnostova and Hurnik (2005), Brandao-Marques et al. (2020), Rocha et al. (2022), and Şen et al. (2020), among others.

First, the findings indicate that the credit channel affects inflation. This is of great importance for policy makers. The political implication of this finding is that while expansionary credit policies increase inflation, restrictive credit policies can be used to control inflation.

Second, inflation is sensitive to changes in exchange rates because there is pass-through from the exchange rate to inflation. This finding is also important for policy makers, given that emerging economies like Türkiye are highly vulnerable to domestic and international shocks. It suggests that the policy makers in Türkiye must take measures to limit certain economic activities, such as high current account deficits and high foreign debts, that increase foreign exchange liabilities.

Third, the study indicates that the policy rate of the CBRT affects inflation. That is, increasing the policy rate to reduce inflation ultimately leads to higher inflation. This finding is also consistent with many previous studies on Türkiye and emerging economies. There may be many factors that weaken the effectiveness of monetary policy and thus the interest rate channel in Türkiye. Since Türkiye's economic growth initially depends on capital movements, high policy rates increase capital inflows and suppress the exchange rate. In conditions of an ongoing high current account deficit and increasing foreign borrowing, rising interest rates increase the country's risk and cause exchange rates to depreciate. This in turn increases import prices of foreign-sourced items, such as intermediate goods, investment goods, and energy. The rise in the prices of imported goods then increases domestic inflation. On the other hand, high borrowing costs together with the deterioration in foreign financial conditions cause the exchange rate to increase and inflation expectations to deteriorate. In Türkiye, the deterioration of future expectations about inflation and the CBRT's loss of credibility caused the exchange rate to depreciate rapidly and inflation to increase. Finally, rising inflation caused the exchange rate and interest rates to rise even more.

Consequently, it is both difficult and unsustainable for Türkiye to permanently control inflation by raising interest rates. The study's finding highlights a serious dilemma faced by the policy makers in Türkiye. It is difficult to reduce inflation only with the CBRT's existing monetary policy tools without developing structural economic policies for sustainable external debt and current account deficit.

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