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Effects of Exchange Rate, Output Gap, and Output Gap Volatility on Inflation Volatility in Turkey

Abstract: This study first investigates the short and long-run effects of exchange rate, output gap and output gap volatility on inflation volatility in Turkey by using the ARDL bounds testing approach. Second, we also examine the causal relationship among these variables by using Toda-Yamamoto and frequency domain causality tests developed by Breitung and Candelon. The results of the ARDL estimates indicate that the exchange rate, output gap and output gap volatility have statistically significant effects on inflation volatility. Also, causality tests results indicate that changes in the exchange rate, output gap volatility, and output gap will have permanent and temporary causal effects on inflation volatility. The policymakers should carefully consider these results to implement appropriate policies to reduce inflation volatility. The finding that the shocks are of temporary nature will have particularly important implications on the policies fighting against the inflation.

This study contributes to the empirical inflation literature by identifying both short run and long run effects of the exchange rate and output gap volatility and output gap together, as well as by providing evidence about the structure of the shocks created by these variables on inflation volatility. This study also identifies the sources of temporary and permanent shocks of inflation volatility.

Keywords: Inflation volatility, output gap/volatility, ARDL Bounds testing approach, Toda-Yamamoto causality test, Frequency Domain Causality Test.

JEL classifications: E31, F31, C22.

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1. Introduction

Inflation is one of the chronic and long-term problems of the Turkish economy that has been experiencing this problem starting from early 1970s. To control this problem, many economic programs have been initiated such as those on 24 January 1980, 5 April 1994, 1 January 2000, and 15 April 2001. Besides these programs, the country has entered many IMF arrangements since early 1980s.

Despite the fact that there are many programs implemented and stand-by arrangements with the IMF, none of these attempts serve the purpose of ensuring price stability in Turkey. This was the fact as well in many IMF stabilization policies implemented mostly in the so-called developing countries in 1980s following the second oil shock in 1978-79. Therefore, as a result of the serious strict mechanical targets several countries have faced hyperinflation (Bolivia, Brazil, Chile, Mexico, Argentina). Nowadays, emerging markets are highly vulnerable to the negative effects of high inflation (Yilmazkuday, 2011, 2013). A typical example of that trend is Turkey. Following the 2000 and the 2001 crises, the Central Bank of the republic of Turkey (CBRT) initially implemented implicit inflation targeting regime and then adopted explicit inflation targeting regime starting in 2006. Between 2006 and 2020, the average annual inflation was approximately 9.95% and well above the targeted inflation rates which was about 5% for the same period. Obviously, this large deviation between the average realized annual inflation rate and the average targeted rates (Figure 7) should be taken as an indication of failure of the CBRT's attempts to decrease inflation and inflation volatility. Moreover, at the end of 2021, CPI inflation has reached 36.08% annually, which is the record annual inflation rate in the last 19 years. Therefore, it is fair to say that inflation was a serious problem in the past, has been a serious problem since 1970s, is currently a most devastating and discussed problem, and will be a major problem in the future.

With this backdrop, the purpose of this study is to examine both short- and long-run effects of the two of the major macroeconomic determinants of inflation and inflation volatility. Also, it is aimed to produce some evidences about the causal relationship between inflation volatility and the exchange rate and the output gap volatility and output gap.

Thus, our study contributes to the empirical inflation literature by identifying the short-run and long-run effects of the exchange rate and output gap volatility and output gap together as well as providing evidence about the structure of shocks created by these variables on inflation volatility. The finding that the shocks are of temporary nature will have particularly important implications on the policies fighting against the inflation.

The rest of the paper is organized as follows: Section 2 presents a literature review, Section 3 explains data and methods used in the study, Section 4 presents and discusses the empirical results, and Section 5 concludes.

2. Literature review

Since we try to investigate the effects of the output gap, output gap volatility, and exchange rate on the inflation volatility, we summarize the existing empirical literature first by reviewing the studies on inflation volatility and output volatility and then extend it by including the studies examining the impact of the exchange rate on inflation volatility.

It is considered that Taylor's (1994) study was the first empirical attempt to investigate the inflation/output variability trade-off. While the study results show the existence of a short-term trade-off between inflation and output because of the slow adjustment of prices, it fails to provide empirical evidence of a long-term trade-off between inflation and output.

Following this study, most studies focused on the inflation/output variability trade-off by using different methods and different countries. For example, Fuhrer (1997) explored the dynamics of the trade-off between inflation and output variability in the long run. Also, the study concluded that responses of monetary policy to inflation and output implicitly assumed that variances of inflation and output vary significantly in the long run for the United States. Erceg, Henderson, and Levin (1998) studied the relationship between the output gap variability and inflation variability, assuming price stickiness and perfectly flexible wages but they failed to provide evidence for the trade-off between price-inflation variability and output variability. Lee (1999) analysed the same trade-off that Fuhrer (1997) studied by using a bivariate GARCH (1,1) model and emphasizing an approximate flat slope trade-off for the United States. Other studies analyzing the relationship between inflation/output variability by using ARCH/GARCH framework are those by Arestis, Caporale, and Cipollini (2002) for 13 countries, Apergis (2004) for G7 countries, and Karanasos and Kim (2005) for G3, Fountas, Karanasos, and Kim (2006) for G7 countries. Arestis, Caporale, and Cipollini estimated a stochastic volatility model to investigate the effects of inflation targeting on the trade-off between inflation/output variability for 13 countries in two groups. According to their study, the adoption of explicit targets has been successful. The findings of these studies indicate that output growth increases inflation uncertainty, but inflation uncertainty adversely affects output growth.

Conrad and Karanasos's (2015) study claims that output variability adversely affected the variability of inflation in the US.

Cobham, Macmillan, and Macmillan (2004) examine the relationship between inflation and output variability computing output gap by using different techniques, including different countries. They found evidence of a trade-off between the two. Arestis and Mouratidis (2004) studied the trade-off between inflation variability and output gap variability in eleven Economic and Monetary Union (EMU) countries. The findings of the study indicate varying trade-offs across the EMU countries.

Karanasos and Kim (2005) employ a bivariate VAR model by obtaining the inflation and output uncertainty using the GARCH(1,1) model for the G3 countries. In their findings, there seems no evidence of any relationship between inflation/output uncertainties. To investigate output-inflation volatility trade-off, Lee (2004) employs a multivariate GARCH model for the OECD countries, and he found statistical evidence supporting it for half of the sample countries. Moreover, the study results indicate that there is a wide variation in the size of the trade-off across countries.

There are also studies examining the relationship between the exchange rate and inflation volatility. Soon, Baharumshah and Wohar (2018) observe a nonlinear relationship between exchange rate pass-through and inflation volatility for six Asian countries by applying the threshold regression method developed by Hansen (1999). According to the Soon et al. study's findings, when inflation uncertainty is higher, pass-through is high. Furthermore, the degree of exchange rate pass-through varies depending on the levels of inflation volatility in the inflation targeting and non-inflation targeting Asian countries. Nkoro and Uko (2016) provide evidence for the relationship between the exchange rate, inflation volatility, and stock prices using GARCH (1,1)-S models for Nigeria. The study's findings show an inverse relationship between the volatility of stock market prices and the exchange rate and volatility of inflation in Nigeria. Finally, Ilzetzki, Reinhart, and Rogoff (2020) referred to the increasing stability of the exchange rate system at its core. Fabris and Lazić (2021) compared the role of exchange rate in monetary policy reaction function between emerging and developed countries on panel data of 37 world economies. They concluded that the exchange rate represents an important variable only in the monetary policy reaction function of emerging market economies.

Yilmazkuday (2022) investigates the drivers of Turkish inflation by using a structural vector autoregression model and his findings were that Turkish inflation in the long run is mostly explained by global oil price movements and exchange rate shocks, with the latter`s contribution increasing over time.

Some studies such as those by Bowdler and Malik (2017) and Johar, Iqbal, and Asif (2020) link inflation volatility with openness. Bowdler and Malik found a strong relationship between openness and inflation volatility by using a dynamic panel model of 96 countries. The findings of Johar, Iqbal, and Asif supported the findings of Bowdler and Malik by using the Generalized Method of Moment (GMM) for the South Asian Association for Regional Cooperation (SAARC).

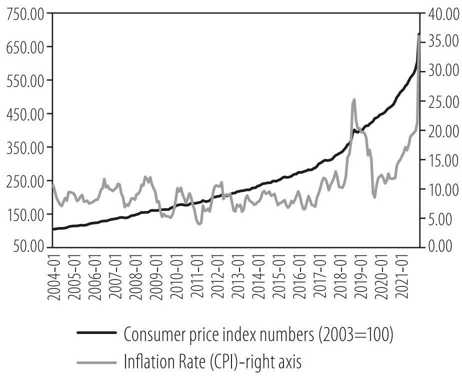
In his study using data on six emerging inflation targeting economies, Güler (2021) performed the empirical tests in order to understand the influence of credibility on inflation expectations and concluded that credibility is quite relevant to reduce inflation expectations and therefore it contributes to strength of inflation targets.

King (2012) and Taylor (2013) emphasized the importance of studying the variability in inflation and output to provide a better explanation of the trade-off between inflation and output. However, the existing studies in empirical literature mostly examined the relationship between inflation, inflation variability, output, output variability, exchange rate, and openness separately. Therefore, it is clear that there is an urgent need to study the effects of the exchange rate, output gap, and output gap volatility on inflation volatility. This study aims to do just that.

3. Stylized Facts of Inflation in Turkey

To properly understand the dynamics of inflation, we should highlight some stylized facts about the inflation in Turkey. To do this, we focus on the period after 2004, the period where the new data about inflation rates, calculated based on the CPI with the base year of 2003, are available. We start with examining the changes in price level and inflation rate in Figure 1.

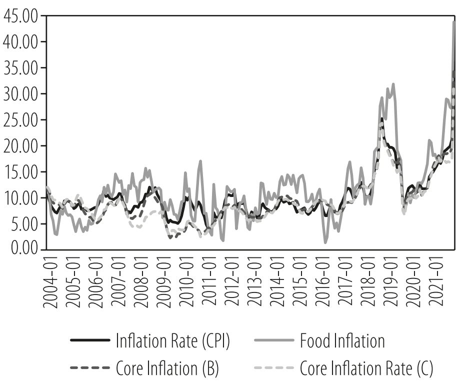
Figure 1: The CPI and the inflation rate



Source: TURKSTAT

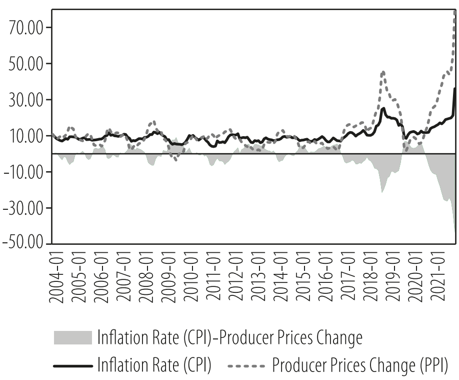
As seen clearly in Figure 1, there is constant increase in price level between 2004 and 2021. This increase in price level has skyrocketed after 2015. The relatively slow rise in price level prior to 2016 was accompanied by slowly increasing but fluctuating inflation rates between five to ten percent. There was a rapid increase in inflation rate between

Figure 2: Consumer inflation rates



Source: TURKSTAT

Figure 3: Consumer and producer inflations



Source: TURKSTAT

March and October 2018, followed by almost one-year decline. After the last period of 2019, inflation seemed to be out of control by constantly rising at increasing rates. Figure 2 shows the developments in different consumer inflation rates along with CPI inflation such as food inflation and core inflation rate (B), which is CPI excluding unprocessed food, energy, alcoholic beverages, tobacco and gold and core inflation (C), which is CPI excluding energy, food and non-alcoholic beverages, alcoholic beverages, tobacco and gold.

The most notable developments in the consumer inflation rates is that the increase in food inflation rates seems to be greater than that of any other consumer inflation measures. Also, it shows more fluctuations (volatility) that the others. Considering the unequal income distribution and average income in Turkey, the rising food inflation can be a cause of many economic and social problems.

Another stylized fact of inflation in Turkey is that there is wide divergence between consumer and producer prices (Figure 3).

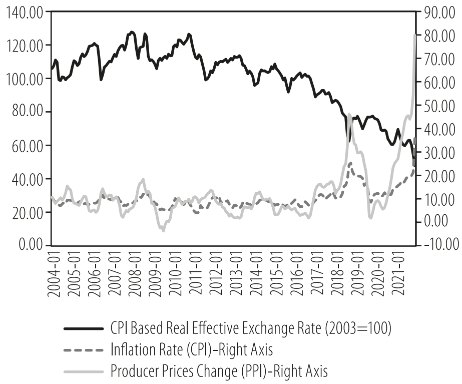
If these vast differences between consumer and producer inflations are not caused by any computational biases and errors, they will have some implications. First of all, sooner than later the consumer's prices and producer's prices will converge, leading to higher consumer prices. Secondly, this will complicate and make it even harder the attempts to fight against inflation. Finally, this will also have a potential to worsen the current macroeconomic problems of the Turkish economy such as worsening income distribution, unsustainable and non-inclusive economic growth and threating the stability of Turkish lira and financial system.

As is widely accepted and mentioned, one of the major determinants of inflation in Turkey is the exchange rate. Figures 4 and 5 beautifully illustrate these relations.

As Figure 4 shows, there is a close connection between external competiveness of the Turkish economy, measured by real effective exchange rate (REER), and both producers' and consumers' inflations. The relative stability of both inflation measures are associated with appreciations of the Turkish lira against the currencies of the country`s major trading partners. On the other hand, when the Turkish Lira has started to lose its value against these currencies, there has been constant and significant increase in both inflations indicating the presence of strong possibility of exchange rate pass through in the prices in Turkey. Figure 5 displays this close association between the exchange rate basket, which consists of the US Dollar and the EURO, and inflation rates.

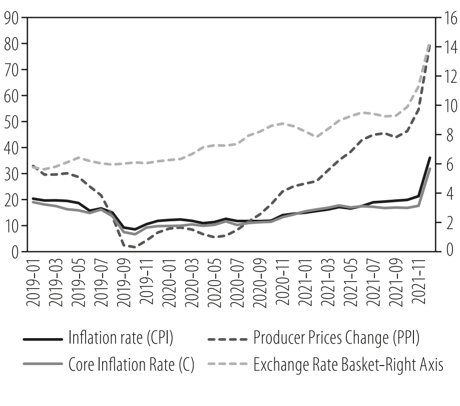
In addition to these stylized facts about inflation, there is a broken link between inflation and policy rate, which is the interest rate for 1-week repo

Figure 4: REER and inflation rates



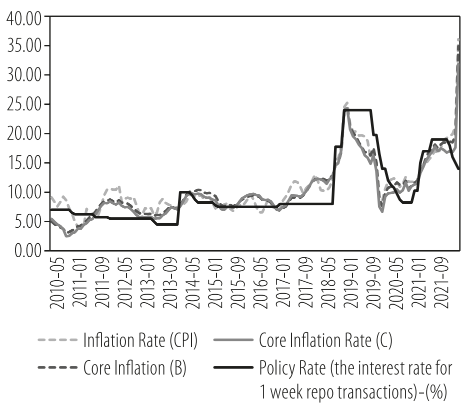
Source: TURKSTAT, CBRT

Figure 5: Exchange rate basket and inflation rates



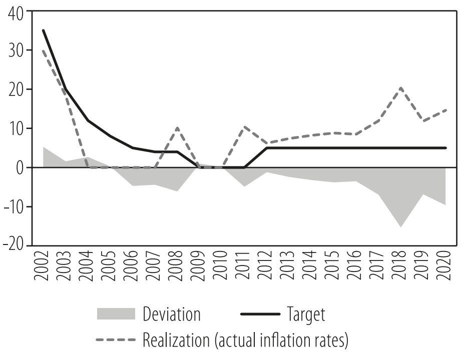
Source: TURKSTAT, CBRT

Figure 6: Policy rate and inflation rates



Source: TURKSTAT, CBRT

Figure 7: Targeted and realized inflation rates



Source: CRBT

transactions. Figure 6 provides visual evidence of the loosening connection between policy rate and inflation rates.

Unlike baseless attempts and claims of policymakers and politicians in Turkey, lowering policy rates have stimulated the hikes in inflation. The results of these failed attempts and claims are fully reflected in the central bank's apparent failure to fight inflation. Figure 7 clearly shows that the CBRT has been constantly failing to achieve the inflation targets.

4. Data and econometric framework

4.1. Data

This study uses quarterly time series data for the consumer price index (CPI), real GDP, and real exchange rate. All data are extracted from the Electronic Data Delivery System (EVDS) of the CBRT. We calculate the output gap as the difference between actual and potential GDP as a percent of potential GDP. The Hodrick-Prescott filtering is used to obtain the Potential GDP data. Since output gap exhibits strong seasonality, we remove the seasonality by using Tramo/Seats method. To derive both inflation volatility (INFVOL) and output gap volatility (OUTGAPVOL), we estimated GARCH (1,1) model. In estimating GARCH (1,1) to get the inflation volatility, we use the first differences of logarithmic values of CPI as a dependent variable, since CPI is the first difference stationary variable. Table 1 summarizes the descriptive statistics of these variables.

Table 1: Descriptive Statistics

	INFVOL	LEXRATE	OUTGAP	OUTGAPVOL
Mean	0.0501	4.6081	-0.0120	0.0501
Median	0.1471	4.6489	0.4717	0.1524
Maximum	2.2955	4.8498	8.8358	2.3179
Minimum	-1.9919	4.1324	-1.4684	-4.7481
Std. Dev.	1.0064	0.1740	3.5416	1.0023
Skewness	0.1296	-1.2113	-1.1770	-1.5654
Kurtosis	2.5655	3.7864	6.4118	9.1067
Jarque-Bera	0.7575 (0.6847)	1.9193 (0.0000)*	5.0828 (0.0000)*	1.3932 (0.0000)*

Out of all variables, OUTGAP is the only variable with a negative mean value. Also, it displays the highest volatility. Both OUTGAP and OUTPUTGAPVOL have an excess Kurtosis, and all variables other than INFVOL do not have a normal distribution. In Table 2, we present pairwise correlations and their significance.

Table 2: Pairwise Correlations

	INFVOL	EXRATE	OUTGAP	OUTGAPVOL
INFVOL	-----			
EXRATE	-0.4127 (0.0003)*	-----		
OUTGAP	0.1351 (0.2613)	0.0812 (0.5007)	-----	
OUTGAPVOL	0.1002 (0.4060)	0.1457 (0.2254)	0.9850 (0.0000)*	-----

There is a significant negative correlation between INFVOL and EXRATE. Even though there are positive correlations between OUTGAP, OUTPUTGAPVOL and INFVOL, they are not significant.

4.2. Econometric methods

To obtain the study's empirical results, we will start examining the time series properties of variables by using the traditional unit root tests of ADF, PP, and KPSS. After establishing that none of the variables are I (2) and they are a mix of I (0) and I (1), we will investigate the existence of cointegration among variables by using ARDL Bounds testing approach. To do this, we specify the following equations:

$$infvol_t = \beta_{10} + \beta_{11} exrate_t + \beta_{12} outgapvol_t + u_{1t} \tag{1}$$

$$infvol_t = \beta_{20} + \beta_{21} exrate_t + \beta_{22} outgap_t + u_{2t} \tag{2}$$

Where u is error term. To test the existence of cointegration between variables in both equations, we estimate following tests equations:

$$\Delta infvol_t = \alpha_{10} + \sum_{i=1}^{k} \theta_{1i} \Delta infvol_{t-i} + \sum_{i=1}^{l} \theta_{1i} \Delta exrate_{t-i} + \sum_{i=1}^{m} \theta_{1i} \Delta outgapvol_{t-i} + \delta_{11} infvol_{t-1} + \delta_{12} exrate_{t-1} + \delta_{13} outgapvol_{t-1} + \varepsilon_{1t} \tag{3}$$

$$\Delta infvol_t = \alpha_{20} + \sum_{i=1}^{p} \theta_{2i} \Delta infvol_{t-i} + \sum_{i=1}^{q} \theta_{2i} \Delta exrate_{t-i} + \sum_{i=1}^{r} \theta_{2i} \Delta outgap_{t-i} + \delta_{21} infvol_{t-1} + \delta_{22} exrate_{t-1} + \delta_{23} outgap_{t-1} + \varepsilon_{2t} \tag{4}$$

where α_0's are the drift components, ε_{1t} and ε_{2t} white noise error terms, k, l, m, p, q, r are lag lengths.

To test presence of cointegration among variables, we estimate Eq. (3) and Eq. (4) by ordinary least squares (OLS) and then implement an F-test for the joint significance of the coefficients of the lagged levels of the variables in Equations (3) and (4). Thus, the null hypothesis of no cointegration among the variables for Eq. (3) is:

$$H_0: \delta_{11} = \delta_{12} = \delta_{13} = 0$$

against the alternative hypothesis of cointegration

$$H_1: \delta_{11} \neq \delta_{12} \neq \delta_{13} \neq 0$$

For Eq. (4), the hypotheses are,

$$H_0: \delta_{21} = \delta_{22} = \delta_{23} = 0$$

against the alternative hypothesis of cointegration

$$H_1: \delta_{21} \neq \delta_{22} \neq \delta_{23} \neq 0$$

When the computed value of F-statistics is greater than upper bound table critical value, we reject the H null hypothesis and then conclude there is cointegration among the variables.

To capture the short-run dynamics among the variables, we estimate the following equations,

$$\Delta infvol_t = \alpha_{10} + \sum_{i=1}^{k} \theta_{1i}\, \Delta infvol_{t-i} + \sum_{i=1}^{l} \theta_{1i}\, \Delta exrate_{t-i} + \\ + \sum_{i=1}^{m} \theta_{1i}\, \Delta outgapvol_{t-i} + \gamma_{11} ect_{t-1} + v_{1t} \quad (5)$$

$$\Delta infvol_t = \alpha_{20} + \sum_{i=1}^{p} \theta_{2i}\, \Delta infvol_{t-i} + \sum_{i=1}^{q} \theta_{2i}\, \Delta exrate_{t-i} + \\ + \sum_{i=1}^{r} \theta_{2i}\, \Delta outgap_{t-i} + \gamma_{21} ect_{t-1} + v_{2t} \quad (6)$$

Where ect_{t-1} is the lagged error correction term, γ_{11} and γ_{21} the speed of adjustment coefficients which are expected to be negative and significant, and v_{1t} and v_{2t} are error terms.

After testing the presence of cointegration among variables and estimating the short-and long-run effects of exchange rate output gap and output gap volatility on inflation volatility, we also investigate the causal relations between variables by using Toda-Yamamoto (T-Y) and Frequency Domain Causality (FDC) test developed Breitung and Candelon (2006).

As mentioned in Zapata and Rambaldi (1997), one can use the T-Y test to test presence of Granger causality between variables without worrying about the problems arising from the power and size properties of unit root and co-integration tests. To carry out the T-Y test, we estimate a VAR model in levels. But this VAR model includes additional lag, called d_{max}, which is the maximal order of integration. The inclusion of d_{max} solves the problems of violating the stability condition of VAR model and validity of test statistics, the x^2 (Wald) test statistics for Granger causality which allow us to test the joint significance of each of the other lagged endogenous variables in VAR system caused by the use of the non-stationary variables in VAR system. Based on Equation (1), we can express the T-Y version of VAR ($l + d_{max}$) as follow:

$$\begin{bmatrix} infvol_t \\ exrate_t \\ outgapvol_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \end{bmatrix} + \begin{bmatrix} A_{11,1} & A_{12,1} & A_{13,1} \\ A_{21,1} & A_{22,1} & A_{23,1} \\ A_{31,1} & A_{32,1} & A_{33,1} \end{bmatrix} \vdots \begin{bmatrix} infvol_{t-1} \\ exrate_{t-1} \\ outgapvol_{t-1} \end{bmatrix} + \cdots + \\ \begin{bmatrix} A_{11,l} & A_{12,l} & A_{13,l} \\ A_{21,l} & A_{22,l} & A_{23,l} \\ A_{31,l} & A_{32,l} & A_{33,l} \end{bmatrix} \begin{bmatrix} infvol_{t-l} \\ exrate_{t-l} \\ outgapvol_{t-l} \end{bmatrix} + \begin{bmatrix} A_{11,p} & A_{12,p} & A_{13,p} \\ A_{21,p} & A_{22,p} & A_{23,p} \\ A_{31,p} & A_{23,p} & A_{33,p} \end{bmatrix} \begin{bmatrix} infvol_{t-p} \\ exrate_{t-p} \\ outgapvol_{t-p} \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \end{bmatrix} \quad (7)$$

where p equals $l + d_{max}$. To test the hypothesis that if the exchange rate does not Granger cause inflation volatility, we test the following null hypothesis by using a modified Wald test (MWALD) for the causality test proposed by Toda and Yamamoto (1995):

$$H_0 : A_{21,1} = A_{22,1} = A_{23,1} = 0$$

When the computed values of test statistics are greater than Wald table critical value, we reject the null hypothesis and conclude that the exchange rate Granger causes inflation volatility in the long run.

However, one of the drawbacks of this kind of Granger causality testing is that it only provides one statistics which describes the causal relations for the whole sample. In fact, this causal relation can be varied at the different frequencies. Thus, to capture the causal relations between variables across different frequencies, we will use Breitung and Candelon (2006)'s the frequency domain causality test of building on Hosoya (1991), Geweke (1982) and Granger (1969). Due to Geweke (1982), we can express the linear feedback from $exrate$ to $infvol$ at frequency ω as follow:

$$M_{exrate \to infvol}(\omega) = log\left\{\frac{2\pi f infvol(\omega)}{|\psi 11(e^{-i\omega})|^2}\right\} = log\left\{1 + \frac{|\psi 12(e^{-i\omega})|^2}{|\psi 11(e^{-i\omega})|^2}\right\} \tag{8}$$

If $|\psi_{12}(e^{-i\omega})|^2 = 0$ in Equation (8), then $M_{exrate \to infvol}(\omega)$ equals 0 and implies that $exrate$ does not Granger cause $infvol$ at frequency ω.

We can also express the null hypothesis of $M_{exrate \to infvol}(\omega) = 0$ in corresponding null hypothesis which includes linear restrictions:

$$H_0 : R(\omega)\beta = 0$$

where is the vector of coefficients exrate and R(ω) is a 2 × q restriction matrix.

$$R(\omega) = \begin{bmatrix} \cos(\omega) \cos(2\omega) \ldots \cos(q\omega) \\ \sin(\omega) \sin(2\omega) \ldots \sin(q\omega) \end{bmatrix} \tag{9}$$

We use the standard F test to test the null hypothesis of no Granger causality at frequency ω. F statistic follows an F(2, T–2p) distribution for $\omega \in (0, \pi)$, where 2 is the number of restrictions, T is the number of observations and p is the order of VAR model.

5. Empirical results

5.1. Unit root test results

To analyse the short- and long-run effects of the exchange rate, output gap volatility, and output gap on inflation volatility, we first examine the unit root properties of variables. For this purpose, we use the traditional unit root tests of ADF, PP, and KPSS and their results are presented in Table 3.

Table 3: ADF, PP and KPSS Unit Root Test Results

Variables	ADF test		PP test		KPSS test	
	Level	1st dif.	Level	1st dif.	Level	1st dif.
infvol	-8.2744*	-36.7570*	-2.5653	-11.1729*	0.5192*	0.2444
exrate	-0.5015	-9.7589*	-0.3218	-9.9069*	0.7845*	0.3040
outgap	-4.3897*	-7.5084*	-4.3215*	-12.0017*	0.0756	0.0630
outgapvol	-4.3897*	-7.5084*	-4.3215*	-12.0017*	0.0756	0.0630

Note: * denotes the rejection of the unit root at 1% level of significance.

According to the unit root tests results in Table 3, all variables are integrated as either I(0) or I(1), that is, none of them is I(2). Therefore, we satisfy the pre-condition of using ARDL Bounds Testing Approach for Cointegration.

The results of ARDL cointegration tests and estimates

Table 4 includes the results of ARDL Bounds cointegration tests.

Table 4: The Results of ARDL Cointegration Tests

Models[1]	Optimal lag length	F-statistics	Bound critical value		Outcome
			I(0)	I(1)	
infvol = f(exrate,outgapvol)	(8,1,2)	4.4490*	3.1	3.87	Cointegration
infvol = f(exrate, outgap)	(8,2,1)	3.9255*	3.1	3.87	Cointegration

Note: * denotes the rejection of the unit root at 5% level of significance.

[1] Yilmazkuday, H. (2011).

Since the computed values of the test statistics (F- Statistics) are greater than upper limit table value, we rejected the null hypothesis of no cointegration for both models and conclude that all variables are cointegrated. After finding the cointegration among the variables, we estimated both models by using the appropriate lag lengths, and Table 5 presents the results of both models.

Table 5: Long-Run and Short-Run Estimation

Dependent variable = infvol							
Model 1				Model 2			
Variable	coefficient	t-statistic	Prob. Values	Variable	coefficient	t-statistic	Prob. values
Long-run results							
Outgapvol	0.403	1.839	0.0720	Outgap	0.098	1.792	0.0793
Exrate	-2.683	-3.766	0.0004	Exrate	-2.477	-3.747	0.0005
Constant	12.373	3.762	0.0005	Constant	11.452	3.743	0.0005
Short-run results							
D(infvol(-1))	-0.209805	0.201797	0.3036	D(infvol(-1))	-0.183708	0.217776	0.4030
D(infvol(-2))	-0.304620	0.193950	0.1227	D(infvol(-2))	-0.283945	0.205957	0.1743
D(infvol(-3))*	-0.583965	0.184716	0.0027	D(infvol(-3))*	-0.565210	0.193968	0.0054
D(infvol(-4))*	-0.425256	0.189308	0.0292	D(infvol(-4))*	-0.408305	0.195784	0.0423
D(infvol(-5))*	-0.375672	0.157824	0.0212	D(infvol(-5))*	-0.360158	0.162476	0.0313
D(infvol(-6))*	-0.404079	0.132492	0.0037	D(infvol(-6))*	-0.383615	0.135926	0.0069
D(infvol(-7))*	-0.359344	0.102779	0.0010	D(infvol(-7))*	-0.348757	0.104899	0.0017
D(outgapvol)	0.129234	0.094873	0.1794	D(outgap)	0.026768	0.029260	0.3647
D(exrate)	-2.382238	1.515667	0.1224	D(exrate)	-2.208826	1.536716	0.1570
D(exrate(-1))*	-3.287593	1.593247	0.0444	D(exrate(-1))*	-3.289799	1.628155	0.0488
ecm(-1)*	-0.958038	0.222646	0.0001	ecm(-1)*	-0.979029	0.239834	0.0002
Test	Test statistic		Probability	Test	Test statistic		Probability
Normality	1.069304		0.585873	Normality	29.985		0.2233
Functional form	0.244605		0.7763	Functional form	0.249123		0.7805
Heteroscedasticity	14.28050		0.3544	Heteroscedasticity	11.06988		0.0862
Serial correlation	5.427362		0.2462	Serial correlation	57.841		0.2159
CUSUM	Stable			CUSUM	Stable		
CUSUMSQ	Stable			CUSUMSQ	Stable		

Note: * denotes the rejection of null hypothesis at 5% level of significance.

According to the long-run estimates of the coefficients in Model 1, there is a significantly negative relationship between exchange rate and inflation volatility. As expected, appreciation of the Turkish Lira will cause a decrease in both inflation rate and inflation volatility. This is because most of the inputs used by the industrial sector in Turkey are imported. Appreciation of the Turkish Lira makes these imported inputs cheaper and reduces the cost of the inputs. This point is supported by studies claiming that there is a high degree of exchange rate pass-through in Turkey (Leigh and Rossi, 2002; Arbalı, 2003; Choudhri and Hakura, 2006; Kara, Küçük-Tuğer, Özlale, Tuğer and Yücel, 2007). Also, as Gumata and Ndou (2019) explained, if there is a negative term of trade shock that leads to depreciation of the Turkish Lira and results in more inflation and decreasing growth, it eventually increases the inflation/output gap volatility. Unlike the exchange rate, raising output gap volatility increases the inflation volatility since the Turkish economy's growth mostly depends on rising domestic demand, mainly driven by credit-induced consumption expenditures pushing the real GDP over its potential level. We almost got the exact long-run estimates of the coefficient, except the magnitude of the output gap is lower than output gap volatility.

When we examine the short-run dynamics of relationships expressed by the two models, most of the lagged values of the inflation volatility are statistically significant, implying that the past inflation volatilities have a quiet influence on present volatility. Neither the lagged values of output gap volatility nor output gap have a significant effect on the inflation volatility. The first lagged value of the exchange rate does have a significant negative effect on inflation volatility in both models. For Model 1, approximately 96% of the short-run corrections take place in just one quarter. Therefore, it takes two quarters to reach the new long-run equilibrium.

Furthermore, the speed of adjustment in the second model is higher than that of the first model. Finally, this speed of adjustment coefficients is statistically significant and less than one. All diagnostic test results indicate that the models yield robust results.

5.2. Causality tests results

To examine the causal relationship between variables, we carry out T-Y and frequency domain causality tests. Figure 8 displays the results of frequency domain causality tests and Table 6 presents the results of both causality tests.

Figure 8: Frequency Domain Causalities (Model 1)

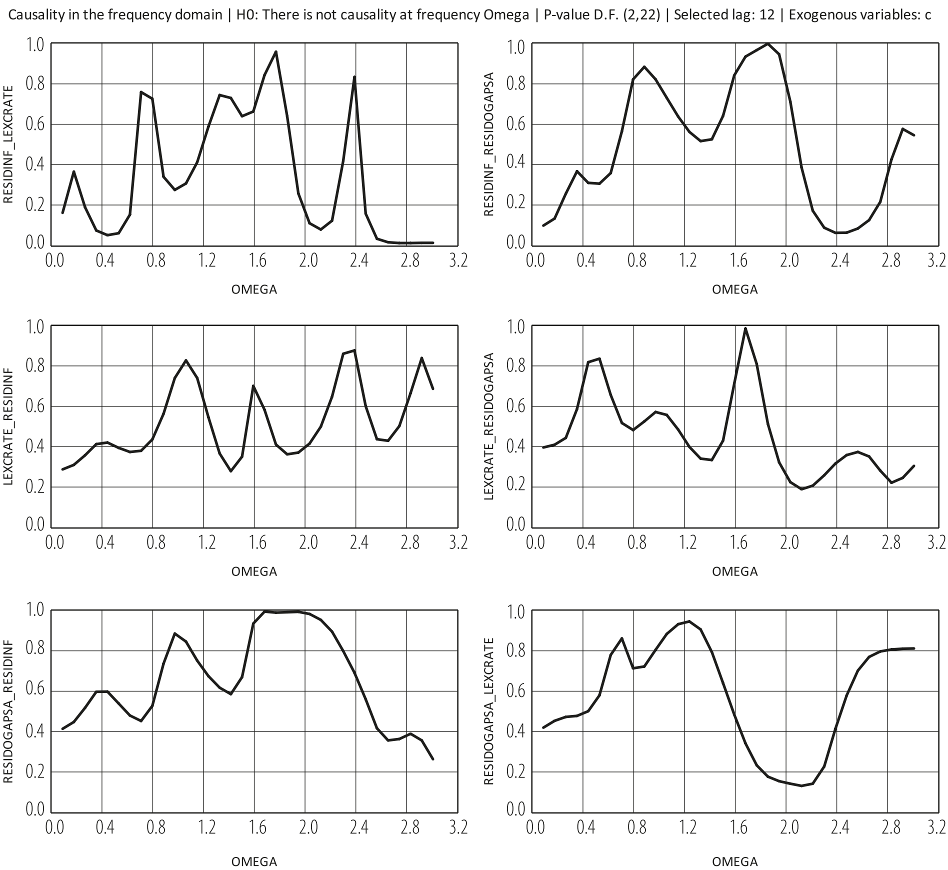


Table 6: Causality Test Results (Model 1)

Null Hypothesis	Toda-Yamamoto		Frequency Domain	
	X^2 Test Statistics	P-Value	Permanent	Temporary
exrate $\nrightarrow$ infvol	9.777	0.0018	√	√
infvol $\nrightarrow$ exrate	0.185	0.6670	-	-
outgapvol $\nrightarrow$ infvol	7.464	0.0063	√	√
infvol $\nrightarrow$ outgapvol	0.291	0.5893	-	-
exrate $\nrightarrow$ outgapvol	0.849	0.3567	-	-
outgapvol $\nrightarrow$ exrate	0.124	0.7252	-	-

According to T-Y test results in Table 6, there is a unidirectional causality running from both exchange rate and output gap volatility to inflation volatility. Results of the FDC tests support these findings. Besides, FDC tests tell us if these casual relationships are permanent or temporary, providing results at different frequencies. In Figure 8, the horizontal axis in each figure gives the frequencies (value of omega), and the vertical axis denotes the p-value of F-statistics. As is seen in the first two graphs, we can only reject the null hypothesis that both the exchange rate and output gap volatility do not granger cause inflation volatility. FDC test results show both permanent and temporary causalities between the exchange rate and inflation volatility and between output gap volatility and inflation volatility. For example, changes in the exchange rate cause inflation volatility permanently at frequencies of between 0,353982 and 0,530973 (between 10,24 and 15,36 quarters) and temporarily at frequencies between 2,566371 and 3,008849 (between 1,81 and 2,12 quarters). Also, changes in output gap volatility Granger causes inflation volatility permanently at frequency 0.088496 (70,97 quarters) and temporarily at frequencies between 2,300885 and 2,566371 (between 2,12 and 2,36 quarters). Figure 9 and Table 7 present the results of causality tests of Model 2.

Figure 9: Frequency Domain Causalities (Model 2)

Causality in the frequency domain | H0: There is not causality at frequency Omega | P-value D.F. (2,22) | Selected lag: 12 | Exogenous variables: c

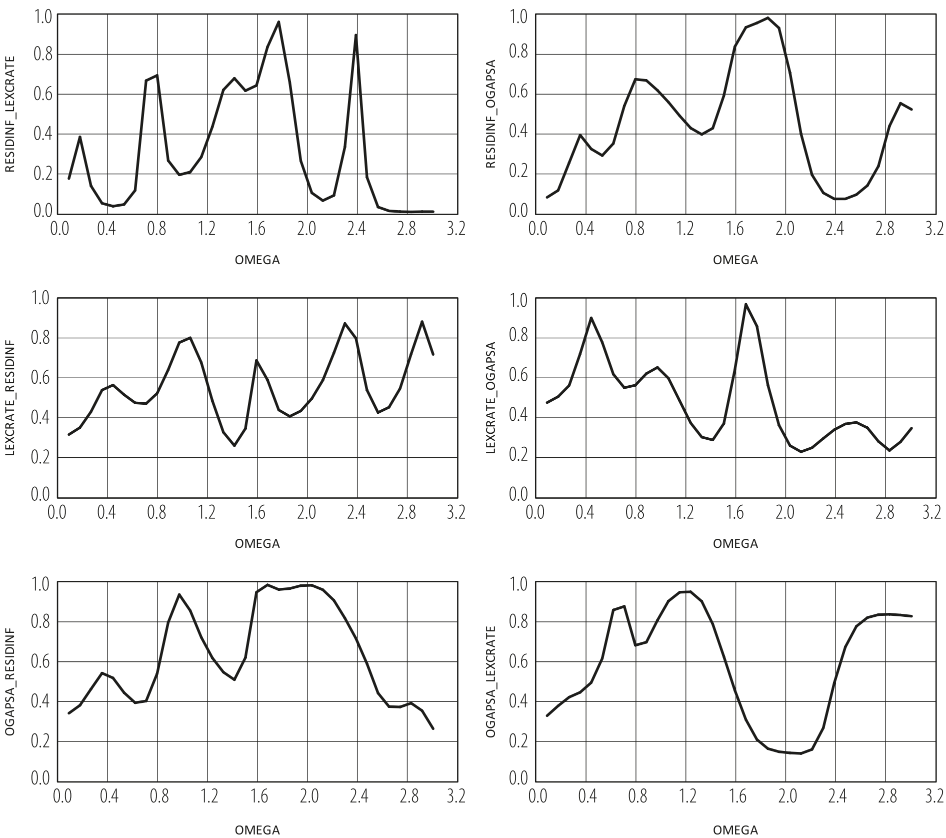


Table 7 Causality Test Results (Model 2)

Null Hypothesis	Toda-Yamamoto		Frequency Domain	
	X^2 Test Statistics	P-Value	Permanent	Temporary
exrate ↛ infvol	9.337	0.0022	√	√
infvol ↛ exrate	0.267	0.6051	-	-
outgap ↛ infvol	7.327	0.0068	√	√
infvol ↛ outgap	0.684	0.4085	-	-
exrate ↛ outgap	0.911	0.3398	-	-
outgap ↛ exrate	0.041	0.8402	-	-

As is seen in both Figure 9 and results in Table 7, we got similar results for the directions and frequency of causalities. For example, changes in the exchange rate cause inflation volatility permanently at frequencies of between 0,353982 and 0,530973 (between 10,24 and 15,36 quarters) and temporarily between 2,566371 and 3,008849 (between 1,81 and 2,56 quarters). Also, changes in output gap volatility Granger causes inflation volatility permanently at frequency 0.088496 (70,97 quarters) and temporarily at frequencies between 2,389381 and 2,566371 (between 2,12 and 2,28 quarters). When we use the output gap, the exchange rate does still have a temporary effect on inflation volatility and the output gap itself. The study results confirm the consensus view of the macroeconomic determinants of inflation volatility in Turkey reflected in both academic research and the CBRT reports (Mendoza, 2012; CBRT, Inflation Report, 2018-III; Kara, Ogunc and Sarikaya, 2017; Antonakakis, Christou, Gil-Alana and Gupta, 2021).

6. Conclusion

This study examines the short- and long-run effects of the major macroeconomic determinants of inflation volatility, such as the exchange rate, output gap, and output gap volatility by using the ARDL Bounds testing approach and searching the direction of causalities implementing T-Y causality test and Bretung Calderon FDC test. The study's major findings indicate that all variables do have a significant effect on inflation volatility both in the short-run and the long-run. Also, causality tests results provide evidence that both the exchange rate and output gap volatility and output gap do have a temporary effect on inflation volatility.

These results do have a serious implication on the current policies adopted by the CBRT to curb inflation. It seems that without controlling the depreciation of the Turkish Lira and not reducing the volatility of the output gap and the size of the output gap, there is no chance of reducing the inflation volatility in the short- and the medium-run. The rise in inflation volatility caused by these macroeconomic variables is an inevitable reflection of the structural problems of the Turkish economy. Therefore, it should be remembered that combating inflation and/or reducing inflation volatility can only be achieved by solving the structural problems of the Turkish economy, especially reducing the heavy reliance on the industrial sector's imports and stimulating domestic demand by credit expansion. As a result, it is hard to argue that the current monetary policy of inflation targeting regime will effectively reduce inflation volatility, at least in the short- and medium-term.

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