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The causal linkage between inflation and inflation uncertainty under structural breaks: Evidence from Turkey

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Abstract

The goal of this paper is to examine the relationship between inflation and inflation uncertainty for Turkey through monthly data spanning the period 2004:01–2019:12. To this end, the paper first builds the inflation uncertainty series using inflation data. Second, it examines the cointegration relationship between inflation and inflation uncertainty. Finally, it searches for causal relationships between inflation and inflation uncertainty. The paper employs econometric methods which explicitly consider structural breaks. After examining the inflation–inflation uncertainty nexus for the whole sample, the analysis also investigates this relationship in two subperiods, i.e., 2004:5–2010:10 and 2010:11:2019:12 considering the change in the monetary policy framework of the Central Bank of the Republic of Turkey (CBRT). The findings provide evidence that there exists unidirectional causality running from inflation to inflation uncertainty for both the whole sample and the second subperiod, while there is no causality between inflation and inflation uncertainty for the first subperiod. Overall, the results show that during the second subperiod (i) when the CBRT tried to achieve not only price stability, but also financial stability and (ii) when the inflation rate is more volatile and higher, the increase in the inflation rate results in an increase in inflation uncertainty.

KEYWORDS

inflation, inflation uncertainty, Turkey, new causality test, structural breaks

1 | INTRODUCTION

The goal of this paper is to investigate the nexus between inflation and inflation uncertainty for the case of Turkey using monthly data spanning the period 2004:01–2019:12. In addition to examining this nexus for the whole sample, the paper also divides the whole sample into two subperiods considering the change in the monetary policy framework of the Central Bank of the Republic of Turkey (CBRT) in October 2010.

The relationship between inflation and inflation uncertainty has been discussed in the economics literature especially since the study of Friedman (1977). According to Friedman (1977), the higher the inflation rate, the more variable it is likely to be. Hence, Friedman (1977) posits that there is unidirectional causal relationship that runs from inflation to inflation uncertainty, which in turn leads to a decrease in economic efficiency and output and also to an increase in the unemployment rate due to distorted price signals (Binder, 2017; Elder, 2004; Grier & Perry, 2000; Payne, 2008; Rahman & Serletis, 2009, among others). Therefore, one of the greatest costs of inflation is uncertainty about future inflation (Barnett et al., 2020). Considering the argument of Friedman (1977), Ball (1992) stresses that monetary policy practices may differ, and high inflation may bring uncertainty in a high inflation environment. Moreover, even if it is certain that the central bank will attempt to reduce inflation using contractionary monetary policies, the speed of transmission of those policy actions to inflation varies over time (Golob, 1994). Therefore, inflation uncertainty will remain high even if the stance of monetary policy is known. The argument that there occurs a causal relationship running from inflation to inflation uncertainty is called the Friedman–Ball hypothesis. In contrast, Cukierman and Meltzer (1986) postulate that the causal relationship between inflation and inflation uncertainty runs from inflation uncertainty to inflation. Accordingly, the ambiguous control mechanism of money supply enables the central bank to generate inflation surprise mechanisms when the central bank pays attention to economic stimulation. Put differently, when money supply increases because of exogenous reasons, which increases the variance of inflation, central banks have an incentive to generate inflation surprises to encourage real economic activities (Kontonikas, 2004). That is to say, increases in uncertainty about money growth and inflation result in higher inflation, as inflation uncertainty increases the incentive of central banks to generate inflation surprises to promote economic growth (Hajamini, 2019; Thornton, 2007; Varlik et al., 2017). Hence, the view that there exists causality running from inflation uncertainty to inflation is called the Cukierman–Meltzer hypothesis.

After high inflation rates over the period 1970–2000, the inflation rate was reduced by the Program of Transition to a Strong Economy in Turkey in 2001 and the implicit inflation targeting strategy, which was implemented during the period 2002–2005.[1] The inflation rate in Turkey was 9.3% in 2004, after the country experienced double-digit inflation rates for many years. Then, the CBRT endorsed the inflation targeting strategy in 2006. While price stability refers to a 2% inflation rate (European Central Bank, 2020), the average inflation rate in Turkey was about 9.5% during the period 2006–2019 (CBRT, 2020). Therefore, it is very clear that the CBRT is highly far from achieving price stability.

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[1] See Kara (2006) for the details of the implicit inflation targeting strategy in Turkey.

The question that becomes considerable for the Turkish economy is whether the high inflation rate the country experiences could lead to inflation uncertainty or inflation uncertainty could increase the inflation rate in Turkey. In order to provide a response to this question, this paper examines the causal nexus between inflation and inflation uncertainty in Turkey using monthly data spanning the period 2004:01–2019:12. The paper first calculates inflation uncertainty via inflation data. Second, the paper examines unit root properties of inflation and the produced inflation uncertainty series to determine the order of integration of variables. Third, the cointegration relationship between inflation and inflation uncertainty is investigated in the paper. Finally, the paper searches for the causal relationship between inflation and inflation uncertainty. Banerjee et al. (2017) stress that economic variables are subject to certain different forms of structural breaks and that ignoring these breaks can lead to inefficient findings. As it is stated by Becker et al. (2006), some macroeconomic variables are likely to exhibit a wide variety of structural breaks of unknown forms and numbers. Therefore, this paper takes both sharp and gradual structural breaks at all stages described above, namely producing inflation uncertainty and unit root, cointegration and causality tests to provide efficient and unbiased empirical findings. The tests employed in the paper take endogenous structural breaks explicitly into account using a Fourier approximation. Hence, a key strength of this paper is that it is the first empirical study that tests the relationship between inflation and inflation uncertainty under the presence of structural breaks in the extant monetary economics literature.

This paper performs time series methods with structural breaks to examine the inflation–inflation uncertainty nexus as this relationship may have changed because of some considerable developments in the Turkish economy, especially as relevant to the change in the monetary policy framework of theCBRT. These developments are associated with: First, the Turkish economy was seriously affected by the global financial crisis in 2007–2008. Second, while the CBRT adopted the implicit inflation targeting strategy during the period 2002–2005, it has implemented the inflation targeting strategy since 2006. Third, the CBRT extended the monetary policy framework and announced that it would try to achieve both price and financial stability beginning from October 2010, while the main objective of the CBRT was to achieve price stability until October 2010.[2] Fourth, monetary policy in Turkey sometimes became very complicated during the period under study. For instance, from October 2010 to June 2018, there was high uncertainty for banks about the interest rate at which banks can borrow from the CBRT. Put differently, the CBRT lent banks not only at the one-week policy rate, but also at the overnight lending rate and the late liquidity window facility during this period.

Therefore, we strongly believe that a causality test with endogenously determined structural breaks can present efficient results about the relationship between inflation and inflation uncertainty in the case of the Turkish economy. Moreover, to check out the robustness of the findings in the full sample, the analysis divides the full period into subperiods considering the new monetary policy framework of the CBRT. Hence, the first subperiod covers from the first observation to October 2010, while the second subperiod covers from November 2010 to the last observation of the sample.

The empirical findings indicate that there exists unidirectional causality running from inflation to inflation uncertainty in the whole sample and in the second subperiod, whereas there is no causality between inflation and inflation uncertainty in the first subperiod. Hence, the findings highlight that inflation causes inflation uncertainty, implying that one of the greatest costs of high inflation rates in Turkey is an increase in inflation uncertainty. In addition, different monetary policy frameworks in terms of the goals of the CBRT targets influence the inflation–inflation uncertainty nexus. Hence, the findings present evidence about (i) the costs of inflation and (ii) the impact of different monetary

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[2] See Kara (2016) for more information about the new monetary policy framework in Turkey.

policy frameworks/regimes on the relationship between inflation and inflation uncertainty. Hence, we believe that the CBRT and the public may benefit from the findings of this work.

The rest of the paper is organized as follows: Section 2 provides a review of the empirical literature. Data are described in Section 3, while the methodology is exhibited in Section 4. The empirical results are presented in Section 5. Finally, Section 6 concludes.

2 | LITERATURE REVIEW

The literature on the relationship between inflation and inflation uncertainty goes as far back as Okun's (1971) study titled “The Mirage of Steady Inflation” and Milton Friedman's Nobel Prize speech in 1977. For almost 50 years, a huge theoretical and empirical literature has been offered on the inflation–inflation uncertainty nexus. One can observe from the empirical literature that a major part of the previous studies found evidence in favour of the Friedman–Ball hypothesis. Some examples of these studies show that an increase in inflation led to an increase in inflation uncertainty in the G7 countries (Grier & Perry, 1998), in certain European countries (Fountas et al., 2004; Hasanov & Omay, 2011; Lawton & Gallagher, 2020; Pintilescu et al., 2014), in the United Kingdom (Kontonikas, 2004), in Japan (Wilson, 2006), in Taiwan (Chen et al., 2006), in the Caribbean countries (Payne, 2008), in El Salvador (Payne, 2009a), in Thailand (Payne, 2009b) and in Iran (Heidari et al., 2013). In addition, certain studies yielded that an increase in inflation uncertainty resulted in an increase in inflation in the United States (Berument et al., 2009; Bhar & Mallik, 2010), as well as in certain advanced economies (Fountas, 2010). Additionally, it can be observed from the literature that some studies have examined the relationship between inflation and inflation uncertainty in Turkey.

Table 1 reports the empirical literature on the relationship between inflation and inflation uncertainty for the Turkish economy. Accordingly, a larger part of the studies found evidence in favour of the Friedman–Ball hypothesis (see e.g., Karahan, 2012; Keskek & Orhan, 2008; Nas & Perry, 2000; Neyapti & Kaya, 2001; Ozdemir & Fisunoglu, 2008; Telatar & Telatar, 2003) while the findings of some studies supported the Cukierman–Meltzer hypothesis (see e.g., Berument et al., 2011; Varlik

TABLE 1 Empirical literature on the inflation–inflation uncertainty nexus for Turkey

Author(s)	Period	Method	Result
Nas and Perry (2000)	1960–1998	Granger causality	INF → INFU
Neyapti and Kaya (2001)	1982–1999	ARCH modelling	INF → INFU
Telatar and Telatar (2003)	1995–2000	Time-varying parameter modelling	INF → INFU
Keskek and Orhan (2008)	1984–2005	GARCH modelling	INF → INFU
Ozdemir and Fisunoglu (2008)	1987–2003	GARCH modelling	INF → INFU
Turkyilmaz and Ozer (2010)	1997–2008	GARCH modelling	INF ↔ INFU
Berument et al. (2011)	1984–2009	Stochastic volatility in mean model	INFU → INF
Karahan (2012)	2002–2012	Granger causality	INF → INFU
Varlik et al. (2017)	1982–2016	Stochastic volatility in mean model	INFU → INF

Abbreviation: →, unidirectional causality; ↔, bidirectional causality; ARCH, autoregressive conditional heteroskedasticity; INF, inflation; INFU, inflation uncertainty; GARCH, generalized autoregressive conditional heteroskedasticity.

et al., 2017). Besides, one study explored both hypotheses prevailed about the inflation–inflation uncertainty nexus in Turkey (see e.g., Turkyilmaz & Ozer, 2010).

Hence, the previous studies do not exhibit clear-cut evidence on the nexus between inflation and inflation uncertainty in Turkey. Besides these evidence, one can notice that none of the previous papers considered structural breaks while examining the relationship between inflation and inflation uncertainty in Turkey. Hence, it is very clear from the previous studies that this paper points out a considerable gap in the existing literature.

3 | DATA

To examine the causal nexus between inflation (INF) and inflation uncertainty (INFU) in Turkey, this paper generates inflation uncertainty using actual inflation rates. Within this framework, monthly inflation data, spanning the period 2004:01–2019:12, are extracted from the CBRT database (2020). Inflation rates are calculated through the consumer price index (CPI) as the annual percentage change in the CPI.

Figure 1 displays the inflation series during the observed period in Turkey. Accordingly, the inflation rate fluctuated around 8% from 2004 to 2017, while it rapidly increased in 2018. Then, the inflation rate decreased and turned back to the level between 2004 and 2017. Hence, the inflation rate seemed to increase during the period when the monetary policy by the CBRT became complicated. Therefore, the complication of monetary policy may have a role in the high inflation rate during the period under study.

Descriptive statistics for inflation are reported in Table 2. Positive skewness of inflation implies that the distribution has a long right tail. Additionally, as the kurtosis of inflation is greater than 3, the distribution is peaked (leptokurtic) with respect to the normal. Finally, the Jarque–Bera statistic

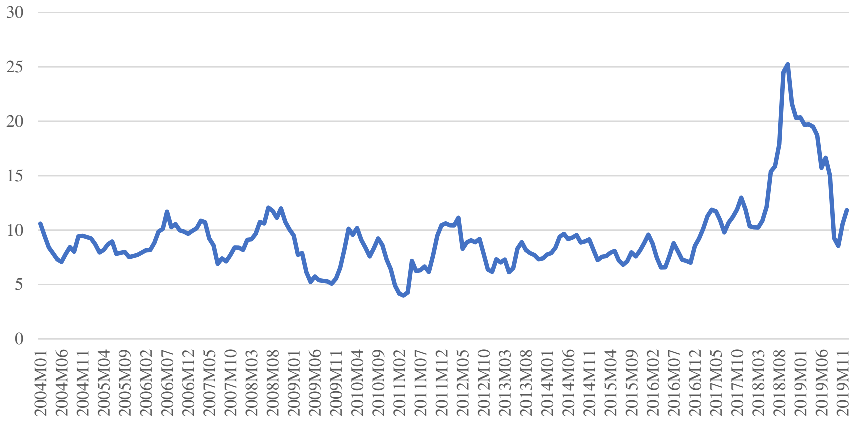

FIGURE 1 Time plot of inflation [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 2 Descriptive statistics for inflation

Descriptive statistics			
Mean	9.418	Standard deviation	3.391
Median	8.777	Skewness	2.171
Maximum	25.240	Kurtosis	8.938
Minimum	9.986	Jarque–Bera	4,325.203 (0.000)

indicates that the null hypothesis of the normal distribution is rejected at the 1% level of significance. Descriptive statistics imply that an ARCH-GARCH structure of the inflation series can be employed to study the link between inflation and inflation uncertainty.

4 | METHODOLOGY

4.1 | Unit root test

The first step in the ARCH/GARCH modelling is to analyse the stationarity properties of the series. Some papers on unit root analysis in the extant literature, such as Zivot and Andrews (1992) and Lee and Strazicich (2003), take a certain number of sharp structural breaks into account. Certain works in the literature have suggested the employment of unit root tests that consider both sharp and gradual/smooth breaks as the pioneering paper by Becker et al. (2006) who develop a unit root test based on the Fourier function. These tests not only consider sharp and gradual breaks, but also present efficient output regardless of the number of structural breaks. Therefore, the analysis performs the unit root test developed by Enders and Lee (2012a, hereafter E&L) that uses the Fourier component to capture the unknown number of sharp and gradual breaks. As their testing procedure relies on the Lagrange Multiplier (LM) method by Schmidt and Phillips (1992) and Amsler and Lee (1995), this test is called the Fourier LM test. E&L stress that this test has better size and power properties compared to the Dickey–Fuller (DF) version of the test (see Enders and Lee (2012b) for the Fourier DF test). E&L first consider the following regression using first differences:

$$\Delta y_t = \gamma_0 + \gamma_1 \Delta \sin(2\pi kt/T) + \gamma_2 \Delta \cos(2\pi kt/T) + u_t \tag{1}$$

where Δ is the first difference operator and k stands for the particular frequency. Then, they generate a detrended series using the estimated coefficient which can be respectively stated as $\tilde{\gamma}_0$, $\tilde{\gamma}_1$ and $\tilde{\gamma}_2$:

$$\tilde{S}_t = y_t - \tilde{\psi} - \tilde{\gamma}_0 t - \tilde{\gamma}_1 \sin(2\pi kt/T) - \tilde{\gamma}_2 \cos(2\pi kt/T), \quad t = 2, \ldots, T \tag{2}$$

where $\tilde{\psi} = \tilde{\gamma}_0 - \tilde{\gamma}_1 \sin(2\pi kt/T) - \tilde{\gamma}_2 \cos(2\pi kt/T)$, and y_1 is the first observation of y_t in the sample. Hence, the regression that is employed to determine whether the series has a unit root is based on the following regression using the detrended series:

$$\Delta y_t = \theta \tilde{S}_{t-1} + d_0 + d_1 \Delta \sin(2\pi kt/T) + d_2 \Delta \cos(2\pi kt/T) + \varepsilon_t \tag{3}$$

The null hypothesis of a unit root $\left(H_0 \colon \theta = 0\right)$ is tested using the LM test statistic. If the LM test statistic is greater than the critical values which are the function of k, then, the null hypothesis of a unit root is rejected.

4.2 | ARCH-GARCH modelling

To model the time-varying volatility, Engle (1982) suggests the ARCH modelling. According to an ARCH model, the variance of the error term at t period depends on the squares of the error terms in the previous periods (Ugurlu, 2014). Hence, an ARCH (p) model can be defined as:

$$\sigma_t^2 = \beta_0 + \sum_{i=1}^{p} \beta_i u_{t-i}^2 \tag{4}$$

In Equation (4), all parameters must be positive, while the sum of the β_i parameters must be less than one to indicate a mean reverting process (stationarity). The null hypothesis of no ARCH effects is tested against the alternative hypothesis of the presence of ARCH effects.

Bollerslev (1986) extends the ARCH modelling and propounds the GARCH modelling. The GARCH model lets the conditional variance be also dependent on previous own lags (Brooks, 2008; Vogelvang, 2005). A GARCH(q) model yields:

$$\sigma_t^2 = \beta_0 + \sum_{i=1}^{q} \beta_i u_{t-i}^2 + \sum_{i=1}^{q} \delta_i \sigma_{t-i}^2 \tag{5}$$

In Equation (5), all parameters must be positive and $\sum_{i=1}^{q} \beta_i + \sum_{i=1}^{q} \delta_i$ must be less than one for the same reason as above. One can observe from Equation (5) that we can use more information, namely news about the volatility in the previous periods (Ugurlu, 2014), through the GARCH modelling compared to the ARCH modelling.

Some recent studies yield that disregarding structural breaks can result in false conclusions in the conditional variance modelling as economic time series data are exposed to these breaks (Li & Enders, 2017; Pascalau et al., 2011). Hence, following Teterin et al. (2016) and Nazlioglu et al. (2020a, 2020b), this paper uses the Fourier approximation to consider structural breaks in modelling the conditional variance. The analysis extends the GARCH model above to capture breaks in the conditional variance through the Fourier approximation. Accordingly, Equation (5) can be rewritten as:

$$\sigma_t^2 = \beta_0 + \sum_{i=1}^{q} \beta_i u_{t-i}^2 + \sum_{i=1}^{q} \delta_i \sigma_{t-i}^2 + \sum_{k=1}^{n} \gamma_{1,1k} \sin\left(\frac{2\pi kt}{T}\right) + \sum_{k=1}^{n} \gamma_{1,2k} \cos\left(\frac{2\pi kt}{T}\right) \tag{6}$$

4.3 | Cointegration test

Banerjee et al. (2017) propound an autoregressive distributed lag (ADL) cointegration test based on the Fourier approximation. They use the following model to define the Fourier ADL cointegration testing procedure:

$$\Delta y_t = d(t) + \alpha y_{t-1} + \beta' x_{t-1} + \delta' \Delta x_t + \varepsilon_t \tag{7}$$

where β, δ and x_t are $nx1$ vectors of parameters and explanatory variables. Banerjee et al. (2017) follow E&L and describe the deterministic term $d(t)$ using the following Fourier approach:

$$d(t) = \theta_0 + \sum_{k=1}^{q} \theta_{1,k} \sin\left(\frac{2\pi kt}{T}\right) + \sum_{k=1}^{q} \theta_{2,k} \cos\left(\frac{2\pi kt}{T}\right) \tag{8}$$

where k stands for a particular single frequency, q denotes the number of frequencies and T is the number of observations. The null hypothesis of no cointegration, namely H_0: $\alpha = 0$, is tested against the alternative hypothesis of the existence of cointegration, namely H_1: $\alpha < 0$. They use the following test statistic to test these hypotheses:

$$t_{ADL}^F = \frac{\hat{\alpha}}{se(\hat{\alpha})} \tag{9}$$

where $\widehat{\alpha}$ stands for the ordinary least squares (OLS) estimator of α in Equation (7) and se $\left(\widehat{\alpha}\right)$ denotes the standard error of $\widehat{\alpha}$ from the OLS estimation in Equation (7).

4.4 | Causality test

The last step of the empirical analysis is to examine the causal nexus between inflation and inflation uncertainty. Differing from the previous papers that do not consider structural breaks in examining the relationship between inflation and inflation uncertainty in Turkey, this paper employs the version of Granger causality test that is suggested by Nazlioglu et al. (2016, 2019) and that takes structural breaks into account.

Nazlioglu et al. (2016, 2019) develop a new causality test by augmenting the causality approach of Toda and Yamamoto (1995, hereafter TY) with a Fourier approximation and this test is called the Fourier TY test. This new method has the advantages that the TY test. Accordingly, the Fourier TY test is robust to unit root and cointegration properties across variables and uses the level values of the variables. On the top of those advantages, this method explicitly considers structural breaks when searching for causality between variables as it uses the Fourier approximation. This test can also provide efficient findings about causality between variables, regardless of the number and the form, namely sharp/abrupt or gradual/smooth, of the structural breaks.

To consider the structural breaks, Nazlioglu et al. (2016) first define the VAR ($p+d$) model, where p is the lag length and d is the maximum number of the integration degree of the variables, as follows:

$$y_t = \alpha(t) + \beta_1 y_{t-1} + \ldots + \beta_{p+d} y_{t-(p+d)} + \varepsilon_t \tag{10}$$

where y denotes K endogenous variables, the intercept terms, namely $\alpha(t)$, are functions of time and indicate the presence of structural breaks in y_t, β stands for coefficient matrices and ε is the error term. To capture structural breaks, the Fourier approximation is described as follows:

$$\alpha(t) = \alpha_0 + \sum_{k=1}^{n} \delta_{1k} \sin\left(\frac{2\Pi kt}{T}\right) + \sum_{k=1}^{n} \delta_{2k} \cos\left(\frac{2\Pi kt}{T}\right) \tag{11}$$

where n is the number of frequencies, k denotes the particular frequency and T indicates the number of observations. If we substitute Equation (7) into Equation (6), we get:

$$y_t = \alpha_0 + \sum_{k=1}^{n} \delta_{1k} \sin\left(\frac{2\Pi kt}{T}\right) + \sum_{k=1}^{n} \delta_{2k} \cos\left(\frac{2\Pi kt}{T}\right) + \beta_1 y_{t-1} + \ldots + \beta_{p+d} y_{t-(p+d)} + \varepsilon_t \tag{12}$$

Nazlioglu et al. (2019) use the bootstrap distribution of the Wald statistic and denote that the optimal lag length in the causality analysis and the number of Fourier frequencies can be determined through the AIC or SIC. Additionally, Nazlioglu et al. (2019) point that the Fourier TY test with cumulative frequencies is capable of presenting more reliable findings if the sample size is over 100. To search for causality between inflation and inflation uncertainty, the models can be defined as follows:

$$\mathrm{INF}_t = \alpha_{1,0} + \sum_{k=1}^{n} \delta_{1,1k} \sin\left(\frac{2\Pi kt}{T}\right) + \sum_{k=1}^{n} \delta_{1,2k} \cos\left(\frac{2\Pi kt}{T}\right) + \sum_{j=1}^{p+d} \beta_{1,1j} \mathrm{INF}_{t-j} + \sum_{j=1}^{p+d} \beta_{1,2j} \mathrm{INFU}_{t-j} + \varepsilon_{1,t} \tag{13.1}$$

$$\mathrm{INFU}_t = \alpha_{2,0} + \sum_{k=1}^{n} \delta_{2,1k} \sin\left(\frac{2\Pi kt}{T}\right) + \sum_{k=1}^{n} \delta_{2,2k} \cos\left(\frac{2\Pi kt}{T}\right) + \sum_{j=1}^{p+d} \beta_{2,1j} \mathrm{INF}_{t-j} + \sum_{j=1}^{p+d} \beta_{2,2j} \mathrm{INFU}_{t-j} + \varepsilon_{2,t} \tag{13.2}$$

The null hypothesis of no causality is tested for the Fourier TY test. For instance, the null hypothesis of no causality, running from inflation uncertainty to inflation, is tested by setting $\beta_{1,2j} = 0$ ($j = 1, \ldots, p$), while the null hypothesis of no causality from inflation to inflation uncertainty is tested by establishing $\beta_{2,1j} = 0$ ($j = 1, \ldots, p$).

5 | FINDINGS

The results for the E&L unit root test are reported in Table 3. As can be seen, the test provides evidence that the null hypothesis of non-stationarity cannot be rejected at level, whereas it is rejected at difference. Hence, the E&L unit root test explores that the inflation rate is stationary in first differences, implying the series is integrated of order one. Therefore, the first difference of INF (DINF) is used to obtain the variance of inflation in Turkey.

The second step is to find the proper ARIMA structure of the series. The paper uses the lowest AIC to find the proper ARIMA model. The paper discovers that the ARIMA (3,1,2) model provides the lowest AIC. Hence, the paper estimates the model defined as $\mathrm{DINF}_t = \alpha_0 + \sum_{i=1}^{3} \alpha_i \mathrm{DINF}_{t-i} + \sum_{j=0}^{2} \beta_j e_{t-j}$. Table 4 presents the coefficients for the ARIMA (3,1,2) model along with the results of the serial correlation and heteroskedasticity tests.

The paper focuses on the serial correlation and heteroskedasticity tests' results. On the one hand, the null hypothesis of no serial correlation is not rejected, implying there exists no serial correlation in the ARIMA (3,1,2) model. On the other hand, the null hypothesis of no ARCH effects can be rejected

TABLE 3 E&L unit root test to produce INFU

Variable	Optimal frequency	Test statistic
INF	1	−1.788
DINF	1	−5.664*

Note: Optimal frequency and lag are determined by the Akaike Information Criterion (AIC). D is the first difference operator.
*$p \le .01$.

TABLE 4 ARIMA (3,1,2) model

Variable	Coefficient	Std. error	t-stat.
Intercept	0.028	0.022	1.257
AR (1)	0.311*	0.074	4.180
AR (2)	0.691*	0.060	11.430
AR (3)	−0.173**	0.073	−2.354
MA (1)	0.002	0.015	0.116
MA (2)	−0.975*	0.014	−66.840

Note: Breusch–Godfrey serial correlation test: 0.089 (0.956). ARCH heteroskedasticity test: 5.458** (0.019).
*$p \le .01$; **$p \le .05$.

at 5% level, supporting the presence of ARCH effects. This finding implies that the ARCH-GARCH structure of the model can be examined and that the variance of inflation can be found through the ARCH-GARCH modelling process.

Considering the statistical significance and the sum of parameters, certain ARCH-GARCH structures are investigated and the analysis determines the ARCH-GARCH (1,0) model. Table 5 reports the coefficients of the ARCH-GARCH (1,0) model.

The next step calculates inflation uncertainty using the variance of the inflation rate obtained from the ARCH-GARCH (1,0) model. Figure 2 exhibits inflation (INF) and inflation uncertainty (INFU) in Turkey. The paper generates inflation uncertainty over the period 2004:05–2019:12, because it uses the first difference of INF and the third-order autoregressive process, namely AR(3). As the figure shows, after fluctuations period over 2004-mid 2018, both inflation and inflation uncertainty began rising in Turkey. Then, starting from January 2019, both variables tended to decrease. Hence, there appears to be a co-movement between inflation and inflation uncertainty.

TABLE 5 ARCH-GARCH (1,0) model

Variable	Coefficient	Std. error	z-stat.
Intercept	0.019	0.026	0.756
AR (1)	0.226^{**}	0.095	2.373
AR (2)	0.567^{*}	0.064	10.145
AR (3)	-0.210^{**}	0.097	−2.164
MA (1)	0.045	0.043	1.062
MA (2)	-0.930^{*}	0.041	−22.863
Variance equation			
Intercept	0.689^{*}	0.100	6.887
u_{t-1}^{2}	0.328^{*}	0.110	2.995
sin ($2\pi kt/T$)	0.394^{*}	0.112	3.495
cos ($2\pi kt/T$)	0.223^{***}	0.122	1.822

Note: Optimal frequency and lag are determined by the AIC.

$^{*}p \leq .01$; $^{**}p \leq .05$; $^{***}p \leq .10$.

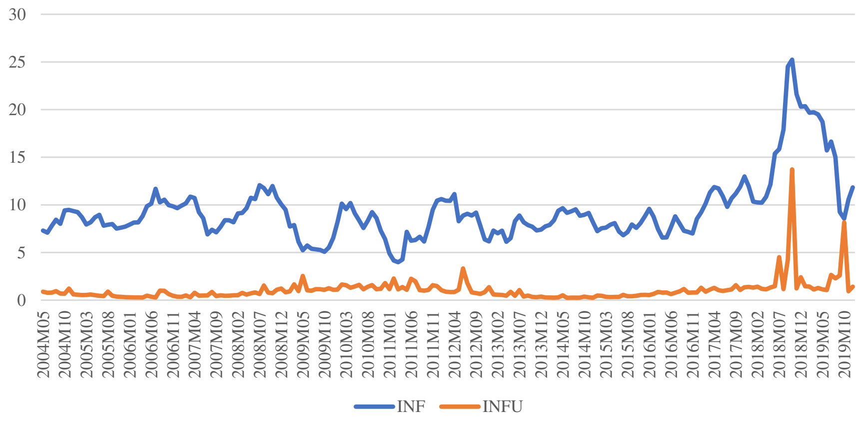

FIGURE 2 Inflation (INF) and inflation uncertainty (INFU) in Turkey [Colour figure can be viewed at wileyonlinelibrary.com]

Prior to running the causality test, the analysis first performs the E&L unit root test to determine the order of integration of INF and INFU for the period 2004:05–2019:12. Table 6 depicts the new results of the E&L unit root test. Accordingly, the E&L unit root test discovers that both series are stationary at first differences, implying that they are integrated of order one.

Then, the analysis employs the Fourier ADL cointegration test to investigate the cointegration relationship between INF and INFU. Table 7 displays the results of the Fourier ADL cointegration test. As is seen, the null hypothesis of no cointegration can be rejected, implying the causal relationship between inflation and inflation uncertainty can be examined.

Table 8 reports the results for the TY and Fourier TY Granger causality tests. Accordingly, panel A reports the results for the TY test, while panel B presents the output for the Fourier TY test. The

TABLE 6 E&L unit root test for causality

Variable		Optimal frequency	Test statistic
INF	Level	1	−2.347
	1st dif.	1	−4.653*
INFU	Level	2	−2.676
	1st dif.	1	−7.650*

Note: Optimal frequency and lag are determined by the AIC.

*$p \leq .01$.

TABLE 7 Cointegration test

Optimal frequency	Test statistic
2	−6.949*

Note: Optimal frequency and lag are determined by AIC.

*$p \leq .01$.

TABLE 8 Causality tests

Panel A: TY test				
Null hypothesis	Wald stat.	Bootstrap p value	p	
INF does not Granger cause INFU	13.598*	.013	3	
INFU does not Granger cause INF	4.188	.210	3	
Panel B: Fourier TY test				
Null hypothesis	Wald stat.	Bootstrap p value	k	p
INF does not Granger cause INFU	10.357*	.021	3	2
INFU does not Granger cause INF	2.641	.236	3	2

Note: Optimal frequency and lag are detected by the AIC. Bootstrap p values are calculated through 1,000 replications.

*$p \leq .05$.

null hypothesis of no causality running from INF to INFU can be rejected at the 1% level in both tests. Put differently, there exists Granger causality running from INF to INFU, irrespective of whether we consider structural breaks for causality. Furthermore, the null hypothesis that INFU does not Granger cause INF cannot be rejected, meaning there exists no causality from inflation uncertainty to inflation.

The next step in the paper is to test for causality between inflation and inflation uncertainty across the two subperiods. Prior to running the causality test, the paper performs the E&L unit root test to detect the maximum integration order of the variables and the Fourier ADL cointegration test to examine the cointegration relationship between INF and INFU. Table 9 reports the results of the E&L unit root test for INF and INFU across the two subperiods. As it can be seen, for both subperiods, both INF and INFU are stationary in first differences. Hence, the maximum integration number is equal to 1 for both subperiods.

The results of the cointegration test for subperiods are reported in Table 10. Accordingly, the null hypothesis of no cointegration is rejected for both subperiods, implying causality between variables across the subperiods.

The results of the causality tests for the subperiods are depicted in Table 11. Accordingly, panel A presents the results of the causality tests over the period 2004:05–2010:10, while panel B reports the results of the causality tests for the period 2010:11–2019:12. More specifically, the null hypothesis of no causality from INF to INFU and the null hypothesis of no causality from INFU to INF cannot

TABLE 9 E&L unit root test for subperiods

Panel A: First subperiod (2004:05–2010:10)			
Variable		Optimal frequency	Test statistic
INF	Level	1	−2.990
	1st dif.	3	−4.907*
INFU	Level	1	−2.120
	1st dif.	1	−4.317**
Panel B: Second subperiod (2010:11–2019:12)			
Variable		Optimal frequency	Test statistic
INF	Level	1	−2.075
	1st dif.	4	−4.062*
INFU	Level	1	−2.781
	1st dif.	1	−7.792*

Note: Optimal frequency and lag are determined by the AIC.

**p* ≤ .01; ***p* ≤ .05.

TABLE 10 Cointegration test for subperiods

Panel A: First subperiod (2004:05–2010:10)	
Optimal frequency	Test statistic
1	−5.249*
Panel B: Second subperiod (2010:11–2019:12)	
Optimal frequency	Test statistic
1	−5.568*

Note: Optimal frequency and lag are determined by the AIC.

**p* ≤ .01.

TABLE 11 Causality tests for subperiods

Panel A: First subperiod (2004:05–2010:10)				
Panel A1: TY test				
Null hypothesis	Wald stat.	Bootstrap *p* value	*p*	
INF does not Granger cause INFU	2.572	.475	3	
INFU does not Granger cause INF	1.005	.803	3	
Panel A2: Fourier TY test				
Null hypothesis	Wald stat.	Bootstrap *p* value	*k*	*p*
INF does not Granger cause INFU	0.004	.948	1	1
INFU does not Granger cause INF	0.822	.376	1	1
Panel B: Second subperiod (2010:11–2019:12)				
Panel B1: TY test				
Null hypothesis	Wald stat.	Bootstrap *p* value	*p*	
INF does not Granger cause INFU	13.017*	.033	3	
INFU does not Granger cause INF	2.625	.401	3	
Panel B2: Fourier TY test				
Null hypothesis	Wald stat.	Bootstrap *p* value	*k*	*p*
INF does not Granger cause INFU	8.509*	.040	1	2
INFU does not Granger cause INF	1.875	.329	1	2

Notes: Optimal frequency and lag are detected by the AIC. Bootstrap *p* values are calculated through 1,000 replications.

*$p \leq .01$.

be rejected with regard to both tests over the period 2004:05–2010:10, implying there is no causality between INF and INFU. Additionally, both TY and Fourier TY tests' results indicate that the null hypothesis of no causality running from INF to INFU is rejected at 1%, whereas the null hypothesis of no causality running from INFU to INF cannot be rejected over the period 2010:11–2019:12. In other words, there exists one-way causality running from INF to INFU.

Based on the causality empirical findings across subperiods, the paper explores that during the period when the main objective of the CBRT was to achieve price stability there is no causality between inflation and inflation uncertainty. One may observe from Figure 2 that the inflation rate and inflation uncertainty were relatively consistent in Turkey during this period even though the inflation rate was not compatible with price stability. The paper also illustrates that during the period when the CBRT tried to achieve price stability along with financial stability, there exists a causal relationship running from inflation to inflation uncertainty. One may also notice through Figures 1-2 that the inflation rate was more volatile and higher during this period compared to the first subperiod. Moreover, there was a dramatic increase in the inflation rate and in inflation uncertainty in 2018. Hence, the paper yields that the increase in the inflation rate led to an increase in inflation uncertainty in Turkey over the period

2010:M11-2019:M12. Therefore, it can be argued that the results for the full sample that indicate the presence of causality from inflation to inflation uncertainty stem from the causal relationship from inflation to inflation uncertainty in the second subperiod.

These results imply that the consistent inflation rate in Turkey during the period 2004–2010 led to steady inflation uncertainty and so did not create serious uncertainty about future inflation even though price stability was not achieved. The findings also indicate that the relatively higher and more volatile inflation produced uncertainty about future inflation, and thus, resulted in an increase in inflation uncertainty during the period 2011–2019 when the CBRT tried to achieve both price and financial stability. Therefore, the empirical findings provide evidence that it was easier to predict future inflation in the first subperiod compared to the second subperiod. In other words, the extension of the monetary policy framework in Turkey to achieve financial stability seemed to make predicting future inflation harder.

Overall, the paper yields that the Friedman–Ball hypothesis prevails in Turkey for the whole period and the second subperiod. Hence, the findings concur with those provided by Nas and Perry (2000), Neyapti and Kaya (2001), Telatar and Telatar (2003), Keskek and Orhan (2008), Ozdemir and Fisunoglu (2008) and Karahan (2012).

6 | CONCLUSION

After the implicit inflation targeting experience during the period 2002–2005, the CBRT adopted the inflation targeting strategy in 2006. Then, in October 2010, the CBRT changed the monetary policy regime, extended the scope of the inflation targeting strategy and explicitly announced that it would try to achieve not only price stability, but also financial stability. Hence, monetary policy in Turkey over the last years can be divided into two subperiods: the period when the CBRT tried to ensure price stability (the first subperiod) and the period when the CBRT tried to achieve both price stability and financial stability (the second subperiod).

This paper analysed the causal relationship between inflation and inflation uncertainty for Turkey over the period 2004–2019. After computing inflation uncertainty using a GARCH model, the paper performed a new developed causality test that considered the presence of endogenous structural breaks. The empirical findings of this test for the whole period indicated the presence of unidirectional causality from inflation to inflation uncertainty. Then, the paper took the change in the monetary policy regime Turkey into account and divided the whole period into two subperiods. The empirical findings implied that there was no causality between inflation and inflation uncertainty for the first subperiod, whereas there was a unidirectional causal relationship running from inflation to inflation uncertainty for the second subperiod. Hence, the empirical findings for the whole period and for the second subperiod implied the validity of the Friedman–Ball hypothesis for Turkey. Hence, the analysis yielded that the inflation rate in Turkey increased after the extension of the monetary policy regime to ensure financial stability, which in turn resulted in an increase in inflation uncertainty. Put differently, the empirical findings indicated that the extension of the monetary policy framework in Turkey made predicting the future inflation rates harder.

Accordingly, one of the greatest costs of inflation is an increase in uncertainty in relative prices and the future price levels in Turkey, which in turn (i) negatively affects investment expenditures of firms by contracting their planning horizon, (ii) reduces long-term credit opportunities, (iii) makes nominal assets more attractive and (iv) eventually decreases economic efficiency (Friedman, 1977; Mishkin, 1998). Therefore, the paper argues that price stability should certainly be achieved in Turkey to avoid any negative effects associated with inflation uncertainty. Within this scope, monetary policy in Turkey should primarily focus on price stability without underestimating other goals and priorities.

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