# The Causal Relationship Between Inflation and Inflation Uncertainty in Iran Under Structural Breaks

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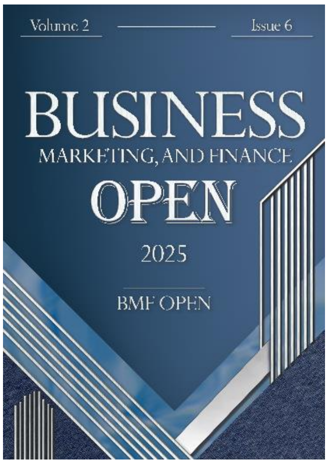


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**Abstract:** Given the double-digit inflation and various shocks—including economic sanctions and the COVID-19 pandemic—in Iran, the present study aims to investigate the causal relationship between inflation and inflation uncertainty during the period from April 2013 to September 2024 using econometric methods such as conditional variance modeling, the Autoregressive Distributed Lag (ARDL) cointegration test, and the Toda–Yamamoto causality test with Fourier approximation, which account for structural breaks. Accordingly, inflation uncertainty is first extracted from inflation data. After testing the stationarity of the inflation and inflation uncertainty variables, the cointegration relationship between them is examined. Subsequently, the causal relationship between inflation and inflation uncertainty is analyzed. The results indicate a unidirectional causal relationship from inflation to inflation uncertainty, consistent with the findings of Latan and Galag (2020) and Apergis et al. (2021). Therefore, considering that one of the critical challenges of Iran's economy is inflation—which exacerbates inflation uncertainty and influences economic decisions such as consumption, investment, and production—the importance of adopting economic stabilization policies aimed at reducing inflation is emphasized.

**Keywords:** Causality test under structural breaks, Fourier approximation, inflation uncertainty

## 1. Introduction

The relationship between inflation and inflation uncertainty has long been a central topic in macroeconomic theory and policy due to its implications for investment, consumption, and overall economic stability. Particularly in economies characterized by persistent inflationary pressures and frequent structural disruptions, such as Iran, understanding the dynamics of this relationship is essential for designing effective stabilization policies. Inflation uncertainty, often conceptualized as the conditional variance of inflation, introduces noise into price signals, thereby distorting economic agents' expectations and decision-making processes. This uncertainty complicates monetary policy formulation and impedes economic growth by reducing the predictability required for long-term contracts and investments [1, 2].

The Iranian economy has experienced recurrent inflationary episodes, exacerbated by various structural shocks such as international sanctions, political instabilities, and global pandemics. In such an environment, the interplay between inflation and its associated uncertainty becomes particularly salient. Several studies have posited that higher inflation is often accompanied by higher inflation uncertainty, a proposition aligned with Friedman's (1977) hypothesis. Others have proposed the reverse causality—that inflation uncertainty can itself be a source of inflationary pressure, especially in economies with weak institutional credibility or ineffective monetary frameworks [3, 4].

Empirical investigations into this causal linkage have produced mixed results, often contingent upon the methodology, data frequency, or specific economic context under examination. For instance, the study by [5] on Turkey employed conditional variance modeling under structural breaks and found a unidirectional causality running from inflation to inflation uncertainty. Similarly, [6] employed a nonparametric regression and GARCH-based approach for the Iranian context, reaffirming the importance of structural changes in analyzing such dynamics. In contrast, [7] demonstrated in a panel of OIC countries that the relationship is bidirectional and sensitive to economic openness and institutional robustness.

To reconcile these divergent findings, recent econometric advances have emphasized the need to account for structural breaks and nonlinearities. Techniques such as the Fourier approximation and smooth transition models have gained traction for their ability to capture both abrupt and gradual shifts in economic relationships without prior knowledge of break dates [8, 9]. These methods improve the power and reliability of unit root, cointegration, and causality tests, particularly in macroeconomic time series where policy regime changes and external shocks are commonplace.

Within this methodological landscape, the present study employs a robust empirical framework that integrates the ARCH-GARCH family of models for volatility estimation with the Fourier-augmented unit root test [9], Fourier-ADL cointegration test [8], and Fourier-based Toda–Yamamoto causality test [10]. This approach is particularly suitable for the Iranian economy, which has undergone major structural transformations in the past decade, such as the U.S. withdrawal from the JCPOA, the COVID-19 pandemic, and the removal of subsidized exchange rates—all of which may have altered the statistical properties of inflation and its uncertainty.

Studies that ignore such structural breaks may arrive at misleading conclusions. For instance, [11] and [12] caution that failing to model volatility shifts accurately results in biased estimates of uncertainty and misrepresentation of its drivers. In the Iranian context, this warning is particularly pertinent given the economic volatility and policy shifts documented in multiple periods by [13, 14]. Consequently, this research builds on the existing Iranian literature by integrating advanced volatility and causality frameworks with structural break considerations, aiming to yield more reliable insights into the inflation–uncertainty nexus.

Furthermore, prior research on Iran provides a fragmented picture. While [13] utilized Markov-switching regressions to identify regime changes in the inflation process, their models did not account for continuous volatility transitions. Similarly, [15] employed ARFIMA-GARCH models to estimate long-memory effects in inflation uncertainty but did not incorporate the potential for smooth or abrupt structural shifts. This study advances the field by synthesizing these perspectives with modern Fourier-based methods, offering a more nuanced and temporally adaptive analysis.

The importance of refining these methodological choices is highlighted in studies from other developing economies. For example, [16] and [17] emphasized the interconnectedness of inflation, output growth, and macroeconomic uncertainty, suggesting that shocks in one domain can propagate across others if not adequately controlled for. This underscores the rationale for using conditional heteroskedasticity models like GARCH and its extensions to capture the time-varying behavior of inflation volatility, especially under regime shifts.

In addition to methodological innovations, the theoretical implications of understanding the inflation–uncertainty relationship are profound. According to [18], macroeconomic uncertainty is not just an empirical artifact but a structural feature that affects the behavior of households, firms, and policymakers. As such, properly identifying its sources and dynamics is key to designing forward-looking policy frameworks. Similarly, [19] argued that incorporating deterministic components like trigonometric terms in GARCH structures enhances the model's ability to reflect cyclical or seasonal patterns in volatility, a relevant feature in economies with policy-driven cycles like Iran.

While the dominant view, as presented by [1], supports the inflation-to-uncertainty causality in both developed and emerging markets, dissenting views suggest this linkage may not be stable over time. Structural breaks, evolving monetary policy targets, and changes in public expectations may lead to nonlinear or time-varying relationships. As noted by [20], the time-varying nature of this relationship in Turkey implies that similar volatility adaptations could occur in Iran.

This study aims to investigate the causal relationship between inflation and inflation uncertainty during the period from April 2013 to September 2024. The present study thus seeks to contribute to the literature in several key ways. First, it employs advanced econometric techniques that are specifically tailored for non-linear, non-stationary time series data characterized by structural breaks. Second, it revisits the Iranian inflation–uncertainty nexus in a period marked by unprecedented economic shocks and policy transitions, offering fresh empirical insights. Third, it operationalizes a robust identification strategy by integrating unit root testing, volatility modeling, cointegration analysis, and causality testing—all under the unified Fourier approximation framework.

## 2. Methodology

This study, drawing upon the theoretical foundations and the empirical research of Apergis et al. (2021), investigates the causal relationship between inflation and inflation uncertainty using econometric methods including conditional variance modeling, Autoregressive Distributed Lag (ARDL) cointegration test, and the Toda–Yamamoto (1995) causality test with Fourier approximation, over the period from April 2013 to September 2024.

According to Becker et al. (2006), certain macroeconomic variables may exhibit a wide range of structural breaks of unknown number and type. Gallant (1981) and Gallant & Souza (1991) proposed that Fourier approximation can capture multiple unknown structural breaks. Banerjee et al. (2017) also showed that Fourier approximation performs best with smooth breaks but can accommodate sharp breaks as well. Therefore, to assess the causal relationship between inflation and inflation uncertainty in the presence of both smooth and abrupt structural breaks, the inflation uncertainty is first estimated from inflation data. Then, the stationarity of the inflation and inflation uncertainty series is tested to examine the existence of cointegration. Subsequently, the cointegration relationship and the direction of causality are evaluated.

In the present study, the causal relationship between inflation and inflation uncertainty is investigated with structural breaks using Fourier approximation. This approach is justified due to the significant shocks and transformations in Iran's economy over the last decade, including the U.S. withdrawal from the JCPOA in May 2018, the COVID-19 pandemic, and the removal of subsidized foreign exchange in May 2022. Hence, a causality test accounting for endogenous structural breaks may provide more efficient results regarding the relationship between inflation and its uncertainty in Iran's economy.

The first step in modeling Autoregressive Conditional Heteroskedasticity (ARCH) and Generalized ARCH (GARCH) is to examine the stationarity of the time series. Some studies such as Zivot and Andrews (1992) and Lee and Strazicich (2003) consider a limited number of structural breaks. Other research, including Becker et al. (2006), suggests using unit root tests that incorporate both smooth and abrupt structural breaks. These tests yield robust results regardless of the number of breaks. The unit root test developed by Enders and Lee (2012) incorporates Fourier components to capture both smooth and sharp structural changes. The Dickey-Fuller test with a deterministic time function is represented in Equation (1):

(1) $y_t = \alpha(t) + \rho\, y_{t-1} + \gamma\, t + \varepsilon_t$

In Equation (1), $\alpha(t)$ is a deterministic function of time. The unknown form of $\alpha(t)$ is approximated using the Fourier expansion in Equation (2):

(2) $\alpha(t) = \alpha_0 + \sum_{k=1}^{n} \alpha_k \sin(2\pi kt/T) + \sum_{k=1}^{n} \beta_k \cos(2\pi kt/T);\ n \leq T/2$

In this equation, $n$ denotes the number of frequencies, $k$ is a specific frequency, and $T$ is the number of observations. Assuming only one frequency $k$ is used:

(3) $\Delta y_t = \rho\, y_{t-1} + c_1 + c_2\, t + c_3 \sin(2\pi kt/T) + c_4 \cos(2\pi kt/T) + e_t$

Here, $\Delta$ is the first difference operator. To determine $k$, Equation (3) is estimated for all integers $1 \leq k \leq 5$, and the regression with the lowest residual sum of squares is selected as optimal $k$. For the application of the Lagrange Multiplier principle, the null hypothesis is tested by estimating Equation (4):

(4) $\Delta y_t = \gamma_0 + \gamma_1\, \Delta\sin(2\pi kt/T) + \gamma_2\, \Delta\cos(2\pi kt/T) + u_t$

Using the estimated coefficients $\tilde{\gamma}_0$, $\tilde{\gamma}_1$, and $\tilde{\gamma}_2$, a trend-free series is generated as shown in Equation (5):

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

Where $\tilde{\psi}$ is defined in Equation (6) and $y_1$ is the first observation:

(6) $\tilde{\psi} = \tilde{\gamma}_0 - \tilde{\gamma}_1 \sin(2\pi kt/T) - \tilde{\gamma}_2 \cos(2\pi kt/T)$

The null hypothesis of a unit root ($\theta = 0$) is tested using the LM statistic based on the regression in Equation (7):

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

Engle (1982) proposed the ARCH model for modeling time-varying volatility. In an ARCH(p) model, the conditional variance depends on past squared residuals (Uğurlu, 2014):

(8) $\sigma_t^2 = \beta_0 + \sum_{i=1}^{p} \beta_i\, u_{t-i}^2$

All parameters should be positive, and the sum of $\beta_i$ must be less than 1 to ensure mean reversion (stationarity). The presence of ARCH effects is tested against the null of no ARCH effects. Bollerslev (1986) extended ARCH to the GARCH model, allowing the conditional variance to depend on its own lags (Brooks, 2008):

(9) $\sigma_t^2 = \beta_0 + \sum_{i=1}^{p} \beta_i\, u_{t-i}^2 + \sum_{i=1}^{q} \delta_i\, \sigma_{t-i}^2$

Again, all parameters must be positive and $\sum\beta_i + \sum\delta_i < 1$ to confirm mean reversion. Several studies show that ignoring structural breaks can result in incorrect conditional variance models since macroeconomic time series are subject to such breaks (Lee & Enders, 2017). Thus, following Tatrin et al. (2016), the current study employs Fourier approximation to incorporate structural breaks into the conditional variance model. Accordingly, Equation (9) can be rewritten as:

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

Determining the number of Fourier frequencies is based on criteria such as the Akaike or Schwarz Information Criterion (Pascalau et al., 2011). Banerjee et al. (2017) reformulated the ARDL cointegration model using Fourier approximation as in Equation (11):

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

Where $\beta$, $\delta$, and $x_t$ are (n×1) vectors of parameters and explanatory variables. The deterministic term $d(t)$ is defined in Equation (12):

(12) $d(t) = \theta_0 + \sum_{k=1}^{q} \theta_{1,k} \sin(2\pi kt/T) + \sum_{k=1}^{q} \theta_{2,k} \cos(2\pi kt/T)$

In Equation (12), $k$ is a specific frequency, $q$ the number of frequencies, and $T$ the number of observations. The null hypothesis of no cointegration ($\alpha = 0$) is tested against the alternative ($\alpha < 0$) using the statistic in Equation (13):

(13) $t_{ADL}^{F} = \hat{\alpha} / se(\hat{\alpha})$

Where $\hat{\alpha}$ is the estimate from Equation (11), and $se(\hat{\alpha})$ its standard error. According to Enders and Lee (2012), the F-max test is used to detect nonlinear trends and determine the optimal $k$.

The Toda–Yamamoto (1995) causality test is widely used since it allows testing series with different integration orders and does not require pre-testing for unit roots or cointegration. Nazlioglu et al. (2016) extended the Toda–Yamamoto test using Fourier approximation, yielding a new causality test that incorporates structural breaks and generates efficient results regardless of the number or form (smooth or abrupt) of the breaks (Apergis et al., 2021). Ignoring structural breaks when testing for cointegration may result in spurious rejection of the null, leading to false conclusions about cointegration (Banerjee et al., 2017).

Initially, Nazlioglu et al. (2016) defined the VAR(p+d) model in Equation (14), where $p$ is the lag length and $d$ the maximum order of integration:

(14) $y_t = \alpha(t) + \beta_1\, y_{(t-1)} + \cdots + \beta_{p+d}\, y_{(t-p-d)} + \varepsilon_t$

Here, $\alpha(t)$ is specified to account for structural breaks as in Equation (15):

(15) $\alpha(t) = \alpha_0 + \sum_{k=1}^{n} \delta_{1k} \sin(2\pi kt/T) + \sum_{k=1}^{n} \delta_{2k} \cos(2\pi kt/T)$

Substituting Equation (15) into Equation (14) yields:

(16) $y_t = \alpha_0 + \sum_{k=1}^{n} \delta_{1k} \sin(2\pi kt/T) + \sum_{k=1}^{n} \delta_{2k} \cos(2\pi kt/T) + \beta_1\, y_{(t-1)} + \cdots + \beta_{p+d}\, y_{(t-p-d)} + \varepsilon_t$

Nazlioglu et al. (2016) show that the optimal lag length and number of Fourier frequencies can be determined using Akaike or Schwarz information criteria. To examine causality between inflation and inflation uncertainty, the models are defined as follows:

(17) $INF_t = \alpha_{1,0} + \sum_{k=1}^{n} \delta_{1,1k} \sin(2\pi kt/T) + \sum_{k=1}^{n} \delta_{1,2k} \cos(2\pi kt/T) + \sum_{j=1}^{p+d} \beta_{1,1j}\, INF_{t-j} + \sum_{j=1}^{p+d} \beta_{1,2j}\, INFU_{t-j} + \varepsilon_{1,t}$

(18) $INFU_t = \alpha_{2,0} + \sum_{k=1}^{n} \delta_{2,1k} \sin(2\pi kt/T) + \sum_{k=1}^{n} \delta_{2,2k} \cos(2\pi kt/T) + \sum_{j=1}^{p+d} \beta_{2,1j}\, INF_{t-j} + \sum_{j=1}^{p+d} \beta_{2,2j}\, INFU_{t-j} + \varepsilon_{2,t}$

In the above equations, $INF$ denotes inflation and $INFU$ denotes inflation uncertainty. The null hypothesis of no causality from inflation uncertainty to inflation is tested by setting $\beta_{1,2j} = 0$, and no causality from inflation to inflation uncertainty by $\beta_{2,1j} = 0$.

In this study, the causal relationship between inflation and inflation uncertainty is examined using inflation data (i.e., percentage change in the consumer price index of Iranian households at constant 2021 prices). The time frame spans April 2013 to September 2024. Data were obtained from the Statistical Center of Iran. Inflation uncertainty was calculated using EViews, and other estimations were performed in Shazam software.

## 3. Findings and Results

In ARCH and GARCH modeling, the first essential step is to perform a unit root test and examine the data structure for stationarity. Therefore, the Enders and Lee (2012) unit root test was conducted, and the results are presented in Table 1. As shown, the null hypothesis of a unit root cannot be rejected for the level of the inflation variable, while for the first difference of the inflation variable, the null hypothesis is rejected at the 1% significance level.

**Table 1. Stationarity Test Results for the Inflation Variable**

| Variable | Optimal k | Test Statistic | Critical Value (5%) |
|---|---|---|---|
| Inflation (INF) | 3 | 1.39 | -3.78 |
| First Difference of INF (DINF) | 2 | -4.21 | -3.27 |

*Significance levels: *, **, and *** denote significance at 10%, 5%, and 1% respectively

The second step is selecting the appropriate ARIMA structure. In this study, the Akaike Information Criterion (AIC) was used, and ARIMA(1,1,1) was selected as the optimal model due to its lowest AIC value. Table 2 presents the model coefficients and results of the heteroskedasticity tests. Based on the results, the null hypothesis of no ARCH effects is rejected at the 1% level, indicating that the variance of inflation can be modeled using the ARCH-GARCH process (Apergis et al., 2021). Moreover, tests for serial correlation and normality of residuals were conducted, indicating no serial correlation and normally distributed residuals.

**Table 2. ARIMA(1,1,1) Model and Heteroskedasticity Test Results**

| Variable | Coefficient | Std. Error | t-Statistic |
|---|---|---|---|
| Intercept | 30.97 | 14.05 | 2.20 |
| AR(1) | *0.99* | 0.01 | 92.68 |
| MA(1) | *0.92* | 0.05 | 19.13 |
| ARCH Test | 53.00 | – | – |

*Significance levels: *, **, and *** denote significance at 10%, 5%, and 1% respectively

Given the significance of the coefficients and the AIC value, the ARCH-GARCH structures were further examined, and ARCH-GARCH(2,1) was selected. Table 3 presents the coefficients of this model. In the next step, inflation uncertainty was calculated using the conditional variance of inflation derived from the ARCH-GARCH(2,1) model.

**Table 3. Results of the ARCH-GARCH(2,1) Model**

| Variable | Coefficient | Std. Error | Z-Statistic |
|---|---|---|---|
| Intercept | *31.79* | 5.31 | 6.11 |
| AR(1) | *1.01* | 0.005 | 203.82 |
| MA(1) | *0.89* | 0.023 | 38.17 |
| Variance Equation | | | |
| Intercept | 0.20 | 0.096 | 2.09 |
| u(t-1)^2 | *0.29* | 0.086 | 3.43 |
| u(t-2)^2 | *0.47* | 0.121 | 3.90 |
| σ(t-1)^2 | -0.35 | 0.160 | -2.19 |
| sin(2πkt/T) | 0.11 | 0.049 | 2.34 |
| cos(2πkt/T) | -0.12 | 0.098 | -1.17 |

*Significance levels: *, **, and *** denote significance at 10%, 5%, and 1% respectively

Figure 1 illustrates inflation uncertainty over the period from May 2013 to September 2024. Based on the figure, uncertainty increased following the U.S. withdrawal from the JCPOA in May 2018, then declined temporarily before rising again.

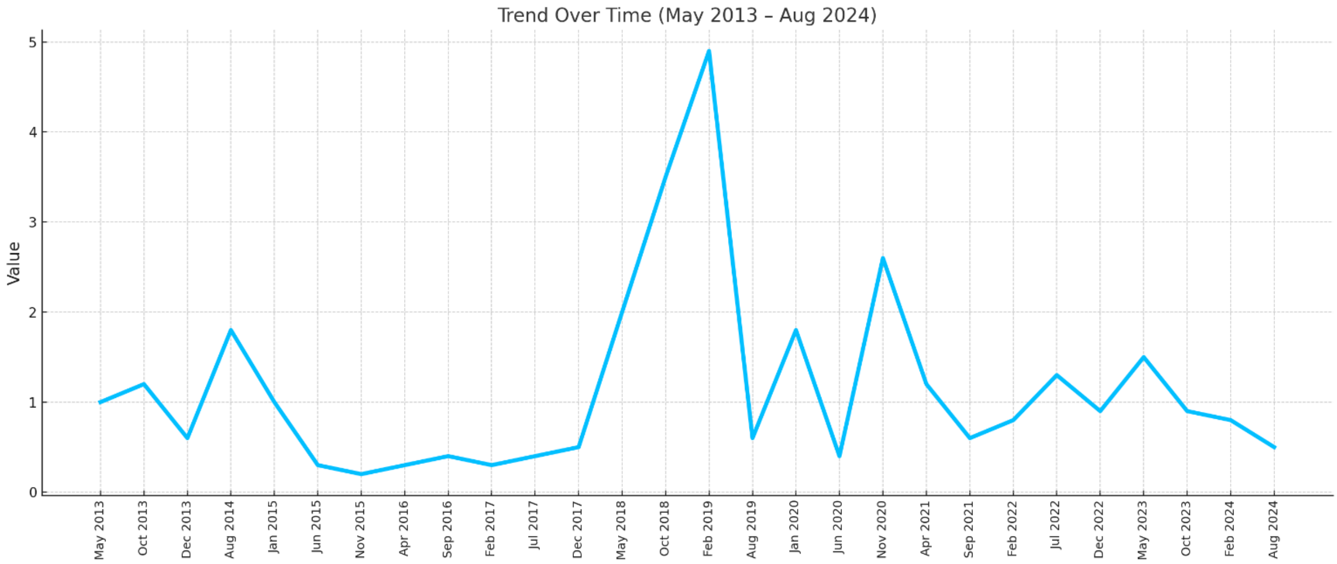


**Figure 1. Inflation Uncertainty**

Before performing the causality test, the stationarity of the inflation uncertainty variable was assessed using the Enders and Lee (2012) unit root test. The results are presented in Table 4, indicating that the inflation uncertainty variable does not have a unit root.

**Table 4. Stationarity Test Results for Inflation Uncertainty**

| Variable | Optimal k | Test Statistic | Critical Value (5%) |
|---|---|---|---|
| Inflation Uncertainty (UINF) | 2 | *-4.30* | -3.27 |

*Significance levels: *, **, and *** denote significance at 10%, 5%, and 1% respectively

Following the stationarity test, the Fourier cointegration test was used to examine the long-run relationship between inflation and inflation uncertainty. Table 5 presents the results of the Fourier cointegration test. The null hypothesis of no cointegration is rejected, indicating a long-term relationship between inflation and inflation uncertainty.

**Table 5. Fourier Cointegration Test Results**

| Optimal k | Cointegration Test Statistic | Critical Value (5%) |
|---|---|---|
| 2 | -4.02 | -3.75 |

*Significance levels: *, **, and *** denote significance at 10%, 5%, and 1% respectively

Table 6 presents the results of the Fourier causality test. The results indicate that the null hypothesis of no causality from inflation to inflation uncertainty can be rejected. However, the null hypothesis of no causality from inflation uncertainty to inflation cannot be rejected. In other words, a unidirectional causal relationship from inflation to inflation uncertainty is confirmed, which aligns with the findings of Latan and Galag (2020) and Apergis et al. (2021).

**Table 6. Fourier Causality Test Results**

| Null Hypothesis | Wald Statistic | Optimal k | P + d |
|---|---|---|---|
| No causality from inflation to uncertainty | *15.50* | 2 | 2 |
| No causality from uncertainty to inflation | 1.05 | 2 | 2 |

*Significance levels: *, **, and *** denote significance at 10%, 5%, and 1% respectively

## 4. Discussion and Conclusion

The primary objective of this study was to examine the causal relationship between inflation and inflation uncertainty in Iran over the period from April 2013 to September 2024, using advanced econometric techniques that consider both sharp and smooth structural breaks. The findings provide several important insights into the behavior of inflation and its associated uncertainty under economic shocks and policy changes.

The results of the Enders and Lee (2012) unit root test confirmed that the inflation series is non-stationary at levels but becomes stationary after first differencing, while the inflation uncertainty variable was found to be stationary in levels. These results align with the stochastic properties observed in other macroeconomic time series and are consistent with the findings of [9], who demonstrated that incorporating Fourier terms in unit root testing significantly improves the power of stationarity diagnostics under structural changes. This preliminary step confirmed the appropriateness of further modeling techniques applied in this study.

In the modeling phase, the ARIMA(1,1,1) model was selected as the optimal structure based on the Akaike Information Criterion. The significant results of the ARCH test confirmed the presence of autoregressive conditional heteroskedasticity in the inflation series, justifying the use of the ARCH-GARCH framework for modeling time-varying volatility. The selected ARCH-GARCH(2,1) model, augmented with Fourier terms to capture cyclical and structural shifts, successfully estimated the conditional variance of inflation, which was then interpreted as inflation uncertainty. This approach is in line with the methodology recommended by [19] and [21], who emphasized the effectiveness of GARCH-type models in modeling volatility in non-linear and uncertain environments.

The results of the Fourier-based cointegration test provided evidence of a long-term equilibrium relationship between inflation and inflation uncertainty. This supports the hypothesis that inflation and its uncertainty are not independent in the long run and that shocks in one can have persistent effects on the other. This finding is consistent with the works of [6] and [22], who also documented a cointegrating relationship between these two variables in the Iranian and OIC contexts, respectively. The presence of cointegration further implies the need for policy interventions that simultaneously address both inflation levels and volatility.

The most significant finding emerged from the Fourier-based Toda–Yamamoto causality test. The results showed a unidirectional causal relationship from inflation to inflation uncertainty, while no evidence was found to support the reverse causality. This is an important outcome as it suggests that inflation is a key driver of inflation uncertainty in Iran. These findings are strongly supported by [5], who reported similar unidirectional causality for Turkey using conditional variance modeling under structural breaks. Additionally, this result is in harmony with the theoretical proposition made by [1] and [3], which argues that higher inflation introduces greater uncertainty in future price levels due to the increased difficulty in forecasting monetary policy responses and macroeconomic performance.

The study also provides empirical confirmation of the Friedman-Ball hypothesis, which posits that higher inflation leads to greater inflation uncertainty. This theory has found empirical support across both developed and emerging economies. In particular, [20] documented similar time-varying effects of inflation uncertainty in Turkey, indicating that periods of rising inflation tend to be accompanied by increased uncertainty. This pattern was observable in the Iranian context as well, particularly following key events such as the U.S. withdrawal from the JCPOA and the onset of the COVID-19 pandemic, which corresponded to significant surges in both inflation and its conditional variance.

Furthermore, the findings highlight the importance of accounting for structural breaks in econometric modeling. By applying Fourier approximations, this study has captured both abrupt and gradual regime shifts, improving the robustness and reliability of the test results. This methodological refinement echoes the work of [8] and [12], who emphasized the superiority of Fourier-based approaches in capturing the complex dynamics of macroeconomic variables. Without these adjustments, the underlying relationship between inflation and uncertainty might have been misrepresented or rendered statistically insignificant.

From a policy perspective, the confirmation of inflation's causal influence on uncertainty underscores the necessity of adopting inflation-targeting strategies that not only aim to reduce the inflation rate but also stabilize expectations. As [2] and [15] noted, inflation uncertainty can severely distort household and firm behavior, delaying consumption and investment decisions and undermining overall economic performance. Therefore, any credible monetary framework must target both price stability and the volatility of inflation to ensure sustained macroeconomic resilience.

Another dimension worth highlighting is the consistency of these findings with those obtained from alternative modeling strategies. For instance, studies employing nonparametric regression techniques, such as [4], arrived at similar conclusions regarding the dominant direction of causality. Likewise, [13] used Markov-switching regression to account for regime shifts and confirmed the persistent impact of inflation shocks on future uncertainty levels in Iran. These converging lines of evidence strengthen the validity of the present study's results and reinforce the call for adopting robust modeling tools in macroeconomic research.

Moreover, the use of Fourier-based causality tests, as proposed by [10], has proven effective in accommodating various types of structural breaks that are typical in unstable economies. This technique provides more accurate inferencing without the need to pre-specify breakpoints, an advantage particularly relevant for Iranian data characterized by frequent policy changes and external shocks. The rejection of the null hypothesis for causality from inflation to uncertainty but not the reverse highlights the asymmetric nature of this relationship and calls for targeted interventions.

Lastly, this study contributes to the global discourse on inflation dynamics by offering insights from a developing country context. While much of the existing literature has focused on developed economies, the specific structural features and policy environments of countries like Iran necessitate localized investigations. The current study, in its methodological rigor and contextual sensitivity, adds empirical depth to this domain and aligns with the broader theoretical framework advanced by scholars such as [18] and [17] on the sources and implications of macroeconomic uncertainty.

While the present study offers several methodological and empirical advancements, it is not without limitations. One major constraint lies in the reliance on consumer price index data as the sole measure of inflation. Although widely used, this index may not fully capture sector-specific or regional inflationary dynamics. Moreover, the use of monthly data, while offering higher frequency insights, may introduce noise and volatility that obscure longer-term trends. Another limitation is the exclusive focus on linear and GARCH-type models. Despite incorporating Fourier terms for non-linearity and break adjustments, the models may still not capture extreme events or structural asymmetries adequately. Lastly, while the study accounts for domestic structural breaks, it does not explicitly integrate global factors such as oil prices, exchange rate volatility, or geopolitical risks that could influence both inflation and its uncertainty in Iran.

Future research should consider expanding the model by incorporating additional macroeconomic variables such as interest rates, exchange rates, or monetary aggregates, which may act as intermediating channels in the inflation–uncertainty nexus. Furthermore, employing alternative approaches like regime-switching GARCH, stochastic volatility models, or machine learning-based volatility predictors could offer deeper insights into non-linear dynamics. Comparative studies across countries with similar economic structures or shared geopolitical vulnerabilities would also help in generalizing the findings. Additionally, exploring forward-looking expectations using survey data or market-based measures could enhance the understanding of inflation uncertainty from the perspective of economic agents. Finally, disaggregating inflation by sectors (e.g., food, energy, housing) might uncover heterogeneous effects masked in aggregate analyses.

Policymakers should prioritize inflation stabilization as a strategic goal not only to achieve price-level targets but also to reduce the unpredictability surrounding future inflation. Central banks must enhance the credibility and transparency of their communication strategies to anchor expectations more effectively. Economic planners should also design fiscal and monetary interventions that are responsive to inflation volatility, particularly during periods of structural transition or geopolitical uncertainty. Institutional frameworks that promote policy consistency, legal autonomy of monetary authorities, and macroprudential oversight are crucial for mitigating the adverse effects of inflation uncertainty. Lastly, improving the accuracy and frequency of inflation-related data collection can empower decision-makers to respond more proactively to emerging inflationary pressures.

### Authors' Contributions

Authors equally contributed to this article.

### Ethical Considerations

All procedures performed in this study were under the ethical standards.

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### Conflict of Interest

The authors report no conflict of interest.

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