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# Inflation and inflation uncertainty in the G-7 countries

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**Abstract**

This study examines the relationship between inflation and inflation uncertainty in the G-7 countries for the period from 1957 to 2001. The causality between the inflation and inflation uncertainty is tested by using the *Full Information Maximum Likelihood Method* with extended lags. Our results suggest that inflation causes inflation uncertainty for all the G-7 countries, while inflation uncertainty causes inflation for Canada, France, Japan, the UK and the US. Furthermore, we find that in four countries (Canada, France, the UK and the US) increased uncertainty lowers inflation, and in only one country (Japan), increased uncertainty raises inflation.


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*Keywords:* Inflation uncertainty; GARCH models; Monetary policy

## 1. Introduction

The relationship between inflation and inflation uncertainty has always been of interest among economists. As the cost of inflation and inflation uncertainty on

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growth and welfare are significant, it is beneficial to determine the direction of the causality between inflation and uncertainty.

In his Nobel lecture, Friedman [1] points out the potential of increased inflation to create nominal uncertainty, which lowers welfare and output growth. Ball [2] formalizes and supports Friedman's hypothesis in a game theoretical framework. Hence, Friedman and Ball argue that high inflation creates higher inflation uncertainty. Cukierman and Meltzer [3] and Cukierman [4], on the other hand, argue that increases in inflation uncertainty raise the optimal inflation rate by increasing the incentive for the policy maker to create inflation surprises in a game theoretical framework. Hence, the causality runs from inflation uncertainty to inflation.

On the empirical side of the inflation uncertainty literature, Baillie et al. [5] consider the application of long-memory processes to the description of inflation for ten countries using the auto-regressive fractionally integrated moving average (ARFIMA) and generalized auto-regressive conditional hetero-skedasticity (GARCH) processes. For three high inflation countries, they find that inflation and volatility of inflation interact in a way that is consistent with the Friedman hypothesis. Grier and Perry [6] analyze the real effect of inflation on the dispersion of real prices in the economy, while Grier and Perry [7] perform the Granger method to test the direction between average inflation and uncertainty. On the other hand, Grier and Perry [8] test four hypotheses about the effects of real and nominal uncertainty on the inflation and output growth in the United States, while Kontonikas [9] examines the relationship between inflation and inflation uncertainty using British data. However, the results are mixed at best.

Although the empirical studies discussed above used the GARCH type of specifications as their common method to assess the relationship between inflation and inflation uncertainty, some studies make use of a two-step procedure. For example, Grier and Perry [7] estimate the conditional variance of inflation by GARCH and Component GARCH methods, and then perform the Granger causality tests between these generated conditional variance measures and the inflation series. However, Pagan [10] criticizes this two-step procedure for its misspecifications due to the use of generated variables from the first stage as regressors in the second stage. Pagan and Ullah [11] suggest using the *Full Information Maximum Likelihood* (FIML) method to address these issues. If the inflation affects the inflation uncertainty, then the inflation variable should be included in the GARCH specification in the first step. Similarly, if the inflation uncertainty affects the inflation, then the inflation uncertainty measure must be present in the first step of the inflation specification. Thus, the inflation and inflation uncertainty specifications should be estimated jointly as a one-step procedure rather than a two-step procedure. Other studies, like Baillie et al. [5] and Kontonikas [9], address these issues. However, they included just one lag of inflation variable in the GARCH specification and the current value of the conditional variance in the inflation specifications. These inflation and inflation uncertainty measures will probably be persistent and highly correlated with each other. Thus, further lags of inflation and inflation uncertainty should be included in each other's specifications. Failure to do this is likely to lead to biased estimates.

The aim of this paper is to assess the causality between inflation and inflation uncertainty for the G-7 countries by addressing the misspecification problems elaborated on above. The estimates we gathered with the modified specifications suggest that inflation causes inflation uncertainty for all the G-7 countries. However, inflation uncertainty causes inflation for Canada, France, Japan, the UK and the US. Furthermore, we find that in four countries (Canada, France, the UK and the US) increased uncertainty lowers inflation, while in only one country (Japan) increased uncertainty raises inflation. The paper proceeds as follows. Section 2 presents the general method that is used in previous empirical studies to analyze the relationship between inflation and inflation uncertainty. Section 3 introduces the specification that overcomes the problems of the previous studies. In Section 4, the estimates are discussed and the conclusions are given in Section 5.

## 2. The general method

The GARCH specification, which is generally used for inflation and time-varying residual variance as a measure of inflation uncertainty, is as follows:

$$\pi_t = \beta_0 + \sum_{i=1}^{n} \beta_i \pi_{t-i} + \varepsilon_t \, , \tag{1}$$

$$\sigma^2_{\varepsilon_t} = \alpha_0 + \alpha_1 \varepsilon^2_{t-1} + \alpha_2 \sigma^2_{\varepsilon_{t-1}} \, , \tag{2}$$

where $\pi_t$ is the inflation, $\varepsilon_t$ is the residual of Eq. (1), $\sigma^2_{\varepsilon_t}$ is the conditional variance of the residual term taken as inflation uncertainty at time $t$, and $n$ is the lag length. Eq. (1) is an autoregressive representation of inflation. Eq. (2) is a GARCH (1,1) representation of the conditional variance [6–8].

If inflation affects inflation uncertainty and inflation uncertainty affects inflation then the inflation and inflation uncertainty measures should appear in the inflation uncertainty and inflation specifications, respectively. Thus, an alternative specification that is generally used is the Component GARCH model [7–9]:[1]

$$\pi_t = \beta_0 + \sum_{i=1}^{n} \beta_i \pi_{t-i} + \gamma \sigma^2_{\varepsilon_t} + \varepsilon_t \, , \tag{3}$$

$$\sigma^2_{\varepsilon_t} = q_1 + \alpha_1 (\varepsilon^2_{t-1} - q_{t-1}) + \alpha_2 (\sigma^2_{\varepsilon_{t-1}} - q_{t-1}) + \lambda \pi_{t-1} \, , \tag{4}$$

where

$$q_1 = \alpha_0 + \rho q_{t-1} + \alpha_3 (\varepsilon^2_{t-1} - \sigma^2_{\varepsilon_{t-1}}) \, . \tag{5}$$

[1] Although the GARCH-in-means specification allows that the inflation uncertainty affects the inflation rate, we skip this in the discussion because the extension of the specification is elaborated later on in the text.

However, assuming that just the current value of uncertainty measure affects the level of inflation and just the first lagged value of inflation affects the inflation uncertainty measure might be too restrictive. Both of these series are persistent and highly correlated. Therefore, excluding further lags would lead to biased estimated parameters.

## 3. The full information maximum likelihood specification with extended lags

In this section, we included further lags of inflation and inflation uncertainty in the inflation uncertainty and inflation specifications, respectively. When we tested the joint significance of these lags, following Baillie et al. [5], we called them Granger causality tests. To be specific, we estimated Eqs. (1′) and (2)′[2] to see whether all $\delta_i$'s are jointly statistically significant (to test if inflation uncertainty Granger causes inflation) and all $\mu_i$'s are jointly statistically significant (to test if inflation Granger causes inflation uncertainty).

$$\pi_t = \beta_0 + \sum_{i=1}^{n} \beta_i \pi_{t-i} + \sum_{i=0}^{n-1} \delta_i \sigma^2_{\varepsilon_{t-1}} + \varepsilon_t \,, \tag{1'}$$

$$\sigma^2_{\varepsilon_t} = \alpha_0 + \alpha_1 \varepsilon^2_{t-1} + \alpha_2 \sigma^2_{\varepsilon_{t-1}} + \sum_{i=1}^{n} \mu_i \pi_{t-i} \,. \tag{2'}$$

In order to assess the Granger causality test within the component GARCH specification, we estimate the following equations:

$$\pi_t = \beta_0 + \sum_{i=1}^{n} \beta_i \pi_{t-i} + \sum_{i=0}^{n-1} \gamma_i \sigma^2_{\varepsilon_{t-1}} \,, \tag{3'}$$

$$\sigma^2_{\varepsilon_t} = q_1 + \alpha_1 (\varepsilon^2_{t-1} - q_{t-1}) + \alpha_2 (\sigma^2_{\varepsilon_{t-1}} - q_{t-1}) + \sum_{i=1}^{n} \lambda_i \pi_{t-i} \,. \tag{4'}$$

Moreover, following Pagan and Ullah [11], we estimate Eqs. (1′) and (2′) jointly and Eqs. (3′), (4′) and (5) jointly using the full information maximum likelihood method and considering various lag values: $n$.

## 4. Estimates

In our estimates, we used the monthly consumer price index inflation taken from the *International Monetary Fund-International Financial Statistic* tape for the

[2]We included not only the lag values of inflation uncertainty but the current value of the uncertainty measure in the inflation equation. The reason for this is that the contemporaneous value of the conditional variance is the deterministic function of squared lag values of residuals and conditional variances; hence, the contemporaneous value of the conditional variance is exogenous.

January 1957–December 2001 period. We report the test statistics of the Granger causality tests for Canada, France, Germany, Italy, Japan, the UK and the US in Table 1. In the first column, we tested the null hypothesis that inflation does not Granger-cause inflation uncertainty, whereas the second column represents the results of the analysis with the null hypothesis that inflation uncertainty does not

Table 1
Granger causality tests between inflation and inflation uncertainty after the specification issues are addressed

| | $H_0$: Inflation does not Granger-cause inflation uncertainty | | $H_0$: Inflation uncertainty does not Granger-cause inflation | |
|---|---|---|---|---|
| | GARCH(1,1) | Component | GARCH(1,1) | Component |
| (A) Canada | | | | |
| Four lags | 13.12**(+) | 15.64***(+) | 5.01 | 7.47 |
| Eight lags | 30.87***(+) | 30.82***(+) | 17.38**(−) | 17.33**(−) |
| Twelve lags | 38.49***(+) | 32.30***(+) | 50.04***(−) | 28.48***(−) |
| (B) France | | | | |
| Four lags | 14.41***(−) | 32.41***(−) | 16.33***(−) | 46.21***(−) |
| Eight lags | 29.66***(+) | 34.31***(+) | 22.09***(−) | 27.94***(−) |
| Twelve lags | 68.80***(+) | 68.19***(+) | 40.70***(−) | 25.29**(−) |
| (C) Germany | | | | |
| Four lags | 8.87 | 12.84***(−) | 6.56 | 1.86 |
| Eight lags | 28.44***(−) | 27.82***(−) | 12.28 | 11.70 |
| Twelve lags | 42.79***(+) | 38.90***(+) | 11.18 | 13.69 |
| (D) Italy | | | | |
| Four lags | 15.04***(−) | 182.21***(−) | 3.87 | 4.00 |
| Eight lags | 18.61**(+) | 21.34**(+) | 9.71 | 12.44 |
| Twelve lags | 32.71***(+) | 19.12 | 16.48 | 27.91***(+) |
| (E) Japan | | | | |
| Four lags | 39.98***(+) | 39.64***(+) | 25.92***(+) | 25.58***(+) |
| Eight lags | 76.71***(+) | 73.34***(+) | 30.61***(+) | 35.30***(+) |
| Twelve lags | 51.01***(+) | 50.34***(+) | 9.97 | 12.77 |
| (F) UK | | | | |
| Four lags | 24.19***(+) | 34.65***(+) | 6.47 | 12.83**(−) |
| Eight lags | 58.42***(+) | 53.54***(+) | 29.85***(−) | 0.04 |
| Twelve lags | 91.04***(+) | 60.57***(+) | 63.12***(−) | 29.91***(−) |
| (G) US | | | | |
| Four lags | 13.40***(+) | 58.26***(+) | 4.82 | 5.86 |
| Eight lags | 44.25***(+) | 44.67***(+) | 20.29***(−) | 17.46**(−) |
| Twelve lags | 33.24***(+) | 34.26***(+) | 23.78**(−) | 22.59**(−) |

*Note*: ***, ** and * indicate significance at the 0.01, 0.05 and 0.10 levels, respectively. A (+) indicates that the sum of the coefficients is positive and significant. A (−) indicates that the sum of the coefficients is negative and significant.

Granger-cause inflation. Then we further give the results of the two methods used to test the null hypotheses separately for the G-7 countries: GARCH (1,1) and Component GARCH (1,1). For each country, we applied the tests for 4, 8 and 12 lags. The results are given for each country in the rows. The signs in parentheses next to the $F$-statistics are for the direction of effects in the causality tests.

Table 1 suggests overall that inflation Granger-causes inflation uncertainty for all the G-7 countries. However, inflation uncertainty Granger-causes inflation for Canada, France, Japan, the UK and the US. Furthermore, we find that in four countries (Canada, France, the UK and the US) increased uncertainty lowers inflation, while in only one country (Japan) increased uncertainty raises inflation (Table 1).[3]

In sum, our results support the Friedman–Ball hypothesis that inflation increases the inflation uncertainty for all the G-7 countries and the empirical studies on this subject [5,7,9,12]. On the other hand, we find a negative causality from inflation uncertainty to inflation for four countries. These results are similar to the empirical evidence of Grier and Perry [7] and Holland [13] for the US and reject the hypothesis of Cukierman and Meltzer. The intuition behind this result is that increased inflation has real costs through its impact on uncertainty. When uncertainty is high, the central bank reduces those real costs at the margin by reducing inflation. These last two studies explain the institutional reasons why inflation responds to increased uncertainty across countries due to central bank independence. These studies claim that countries with more independent central banks realize a negative causality from inflation uncertainty to inflation. Our results suggest that the only country supporting Cukierman and Meltzer's view is Japan.

We also repeated the analysis of Grier and Perry's [7] two-step estimates for the sake of completeness. The estimates are reported in Table 2. Here the lag lengths are taken as 4, 8 and 12, instead of including the first lag only. A comparison of the two tables suggests that inflation Granger-causes inflation uncertainty for most of the countries in both specifications. In Table 1, inflation uncertainty Granger-causes inflation for Canada, France, Japan, the UK and the US whereas in Table 2 this relationship is valid for France, Germany, Japan and the US. Furthermore, Table 2 suggests that in Germany and the US increased uncertainty lowers inflation, while in France and Japan increased uncertainty raises inflation. In contrast, Table 1 illustrates that for Canada, France, the UK and the US increased uncertainty lowers inflation while in Japan increased uncertainty raises inflation. Thus, our results suggest a further relationship between inflation and inflation uncertainty that Grier and Perry [7] could not find.

Table 3 reports the causality tests with one lag as Baillie et al. [5] and Kontanikas [9] did. The Granger causality of inflation to inflation uncertainty cannot be observed for Canada, France, Germany and Italy (as observed in Table 1 with extended lags). Moreover, the empirical evidence on the Granger causality from

[3]In order to make the VAR specification symmetric, we first increased the lag order in the GARCH and component of GARCH specifications to (4,1), (8,1) and (12,1). Then we increased the lag orders of the inflation variable in the inflation equation ($n$ in Eqs. (1′), (2′), (3′) and (4′)). The results were robust.

Table 2
Granger causality tests between inflation and inflation uncertainty as Grier and Perry (1998) used

| | $H_0$: Inflation does not Granger-cause inflation uncertainty | | $H_0$: Inflation uncertainty does not Granger-cause inflation | |
|---|---|---|---|---|
| | GARCH(1,1) | Component | GARCH(1,1) | Component |
| (A) Canada | | | | |
| Four lags | 9.58***(+) | 16.91***(+) | 1.02 | 1.08 |
| Eight lags | 6.09***(+) | 9.75***(+) | 1.69 | 0.82 |
| Twelve lags | 4.57***(+) | 7.10***(+) | 1.72 | 1.68 |
| (B) France | | | | |
| Four lags | 3.40***(+) | 25.69***(+) | 4.28***(+) | 4.86***(+) |
| Eight lags | 3.43***(+) | 14.32***(+) | 2.39**(+) | 1.99**(+) |
| Twelve lags | 3.87***(+) | 12.68***(+) | 2.95***(−) | 2.38***(+) |
| (C) Germany | | | | |
| Four lags | 1.75 | 1.71 | 2.42**(+) | 1.66 |
| Eight lags | 1.20 | 3.04***(+) | 3.14***(+) | 3.37***(+) |
| Twelve lags | 0.90 | 2.18**(−) | 3.01***(+) | 3.04***(+) |
| (D) Italy | | | | |
| Four lags | 34.07***(+) | 29.97***(+) | 3.99***(+) | 1.72 |
| Eight lags | 19.68***(+) | 15.59***(+) | 1.44 | 1.35 |
| Twelve lags | 14.61***(+) | 11.95***(+) | 0.87 | 0.91 |
| (E) Japan | | | | |
| Four lags | 40.72***(+) | 171.16***(+) | 13.14***(+) | 17.68***(+) |
| Eight lags | 21.92***(+) | 88.82***(+) | 4.47***(+) | 4.59***(+) |
| Twelve lags | 15.23***(+) | 59.64***(+) | 3.27***(+) | 3.33***(+) |
| (F) UK | | | | |
| Four lags | 83.29***(+) | 76.88***(+) | 4.51***(+) | 6.90***(+) |
| Eight lags | 48.52***(+) | 38.04***(+) | 2.33**(+) | 1.89 |
| Twelve lags | 31.92***(+) | 27.67***(+) | 2.14**(+) | 3.47***(−) |
| (G) US | | | | |
| Four lags | 10.61***(+) | 15.49***(+) | 2.45**(+) | 1.95 |
| Eight lags | 5.83***(+) | 7.55***(+) | 1.25 | 0.91 |
| Twelve lags | 4.00***(+) | 5.16***(+) | 1.18 | 0.73 |

*Note*: ***, ** and * indicate significance at the 0.01, 0.05 and 0.10 levels, respectively. A (+) indicates that the sum of the coefficients is positive and significant. A (−) indicates that the sum of the coefficients is negative and significant.

inflation uncertainty to inflation is weaker for some of the countries and cannot even be observed for the US. Thus, increasing the lag length alters the conclusion gathered from the causality tests performed in the literature on the inflation–inflation uncertainty relationship.

Table 3
Granger causality tests between inflation and inflation uncertainty after the specification issues are addressed with 1 lag

| | $H_0$: Inflation does not Granger-cause inflation uncertainty | | $H_0$: Inflation uncertainty does not Granger-cause inflation | |
|---|---|---|---|---|
| | GARCH(1,1) | Component | GARCH(1,1) | Component |
| (A) Canada | 1.90 | 1.54 | 7.58***(−) | 0.44 |
| (B) France | 0.49 | 1.32 | 2.31 | 6.90***(−) |
| (C) Germany | 0.26 | 1.39 | 0.72 | 0.01 |
| (D) Italy | 0.20 | 2.46 | 2.56 | 2.72*(−) |
| (E) Japan | 13.26***(+) | 10.21***(+) | 8.41***(+) | 31.81***(+) |
| (F) UK | 2.10 | 26.94***(+) | 0.03 | 22.89***(+) |
| (G) US | 12.26***(+) | 3.50*(+) | 0.92 | 1.30 |

*Note*: ***, ** and * indicate significance at the 0.01, 0.05 and 0.10 levels, respectively. A (+) indicates that the sum of the coefficients are positive and significant. A (−) indicates that the sum of the coefficients are negative and significant.

## 5. Conclusion

The literature on the causality between inflation and inflation uncertainty either applied a two-step procedure, which uses generated variables as regressors, or made the lag length too narrow to assess this relationship. Both of these issues lead to biased parameter estimates. This paper uses the full information maximum likelihood method with extended lags to overcome these problems. The estimates we gathered with the new set of specifications suggest that inflation Granger-causes inflation uncertainty for all the G-7 countries, supporting the Friedman–Ball hypothesis. However, inflation uncertainty Granger-causes inflation for Canada, France, Japan, the UK and the US. Furthermore, we find that in four countries (Canada, France, the UK and the US) increased uncertainty lowers inflation, while in only one country (Japan) increased uncertainty raises inflation.

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