

INFLATION, INFLATION UNCERTAINTY, AND A COMMON EUROPEAN MONETARY POLICY

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June 2003

Abstract

The relationship between inflation and inflation uncertainty is investigated in six European Union countries for the period 1960 to 1999. EGARCH models are used to generate a measure of inflation uncertainty and then Granger methods are employed to test for causality between average inflation and inflation uncertainty. In all the European countries, except Germany, inflation significantly raises inflation uncertainty as predicted by Friedman. However, in all countries except the UK, inflation uncertainty does not cause negative output effects, implying that a common European monetary policy applied by the ECB might not lead to asymmetric real effects via the inflation uncertainty channel. Less robust evidence is found regarding the direction of the impact of a change in inflation uncertainty on inflation. In Germany and the Netherlands, increased inflation uncertainty lowers inflation, while in Italy, Spain, and to a lesser extent France, increased inflation uncertainty raises inflation. These results are generally consistent with the existing rankings of Central Bank Independence.

Keywords: EMU, Exponential GARCH, Inflation, Inflation Uncertainty.
JEL Classification: C22, C32, E31, E58.

We are indebted to two anonymous referees for very useful comments and suggestions.

We also thank Alex Cukierman, Soren Johansen, Marika Karanassou, Paul Mizen, Iannis Mourmouras and participants in the 5th Annual Conference on Macroeconomic Analysis and International Finance (Crete, 2001), the conference on EMU Institutions and Macroeconomic Policies (Milan, 2001) and the Irish Economic Association annual conference (Mullingar, 2002) for helpful comments and suggestions. The usual disclaimer applies.

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1 INTRODUCTION

The importance of inflation uncertainty as a distinct channel in explaining the real effects of inflation has recently been given considerable empirical support (Grier and Tullock, 1989, Grier and Perry, 2000, Judson and Orphanides, 2000). This channel was first highlighted in Friedman's (1977) Nobel lecture. Friedman supplied an informal argument that an increase in the average inflation rate would lead to more inflation uncertainty, thus creating distortions in the workings of the price mechanism in allocating resources efficiently. Subsequent theoretical research focused on the opposite type of causation, which runs from inflation uncertainty to inflation. For example, Cukierman and Meltzer (1986) employ the Barro-Gordon set up and show that an increase in uncertainty about money growth and inflation will increase the optimal average inflation rate because it provides an incentive to the policymaker to create an inflation surprise in order to stimulate output growth. Holland (1995) argues that more inflation uncertainty can lead to a lower average inflation rate if the Central Bank tries to minimise the welfare losses arising from more inflation uncertainty. In addition, the evidence on the direction of the effect of inflation uncertainty on inflation can be compared with the existing measures of Central Bank Independence (Grier and Perry, 1998). These authors do find that the most independent Central Banks are in countries where inflation declines as inflation uncertainty rises, thus contradicting the Cukierman-Meltzer hypothesis.

The issue of the relationship between inflation, inflation uncertainty, and output growth acquires great importance for the member countries of the Euro zone. First, evidence that higher inflation causes more inflation uncertainty and, therefore, possible negative output effects would strengthen the case for the choice of price stability by the European Central Bank (ECB) as one of the primary objectives of monetary policy. Second, if the effects of inflation on output that take place via changes in inflation uncertainty differ across the Euro zone, it is possible that a common monetary policy that results in similar inflation rates across countries will have asymmetric real effects. In other words, a reduction in inflation arising from a contractionary monetary policy applied by the ECB could reduce output in some countries but increase output in others, depending on the combination of two effects: (a) The Friedman hypothesis, i.e., the effect of inflation on inflation uncertainty and (b) the effect of inflation uncertainty on output growth. Therefore, lack of uniform evidence supporting the effect of inflation on output via the inflation uncertainty channel across the Euro-zone countries would have important policy implications as it would make a common monetary policy a less effective stabilization policy tool in dealing with national disparities.

Autoregressive Conditional Heteroskedasticity (ARCH) and Generalized ARCH (GARCH) techniques represent a commonly-used approach to proxy uncertainty using the conditional variance of unpredictable shocks to the inflation rate¹. These techniques have recently been employed by Grier and Perry (1998) to investigate the direction of causality in the inflation-inflation uncertainty relationship for the G7². Similarly, Grier and Perry

¹ Alternative measures of uncertainty include survey-based forecasts and a moving standard deviation of inflation.

² We differ from this study in several respects: the GARCH model employed, the sample period, the data frequency, the country group, and the consideration of output growth and its relationship with

(2000) aim to examine the inflation-output uncertainty nexus in the US. The empirical evidence to date on the Friedman and the Cukierman-Meltzer hypotheses provided by Grier and Perry (1998) and a few other recent studies summarised below is rather mixed. Grier and Perry (1998)³ use a GARCH model to estimate inflation uncertainty and run Granger causality tests. We employ an exponential GARCH (EGARCH) model for two reasons: First, we find evidence for asymmetries in the inflation uncertainty-inflation relationship and, second, we follow Brunner and Hess (1993) in testing Friedman's hypothesis.

Our paper contributes to the empirical relationship between inflation and inflation uncertainty in several ways: First, we use an EGARCH model instead of a GARCH model, as discussed above. Second, we examine the relationship between inflation and inflation uncertainty for several EU countries in order to examine whether a case could be made against a common monetary policy, along the lines discussed above. Third, we examine whether inflation is costly, a much-debated issue in monetary economics. Our approach allows us to distinguish between the direct costs of inflation, and those that arise via the inflation uncertainty channel, as predicted by Friedman (1977). The rest of the paper is structured as follows: In section 2 our theoretical econometric model is presented. In section 3 we summarise our empirical results. In section 4 we interpret these results and relate them to the predictions of economic theory and other recent empirical studies. Finally, section 5 concludes.

2 THE EGARCH MODEL

2.1 THE AR(p)-EGARCH(1,1) PROCESS

One of the principal empirical tools used to model inflation uncertainty has been the ARCH class of models. Following Engle's (1982) pathbreaking idea, several formulations of conditionally heteroscedastic models (e.g. GARCH, Fractional Integrated GARCH, Switching GARCH, Component GARCH) have been introduced in the literature, forming an immense ARCH family. However, as Brunner and Hess (1993, p. 187) argue, "The GARCH model places a symmetric restriction on the conditional variance. Since the variance is a function of squared residuals, agents become more uncertain about future inflation whether inflation unexpectedly falls or unexpectedly rises. The essence of Friedman's hypothesis is inconsistent with such a symmetry restriction, since new information suggesting that inflation is lower should reduce, rather than raise, uncertainty about future inflation".

Many of the proposed GARCH models include a term that can capture correlation between the inflation rate and inflation uncertainty. Models with this feature are often termed asymmetric or leverage volatility models. One of the earliest asymmetric GARCH models is the EGARCH model of Nelson (1991). In contrast to the conventional GARCH specification which requires nonnegative coefficients, the EGARCH model, by modeling

inflation uncertainty.

³The authors estimate both asymmetric and symmetric GARCH models. However, they cannot reject the null hypothesis of symmetry. They, therefore, proceed to perform the Granger-causality tests using the estimated conditional variance from the GARCH model of each country.

the logarithm of the conditional variance, does not impose the nonnegativity constraints on the parameter space. Of the many different functional forms, the EGARCH model has become perhaps the most common. In particular, various cases of the EGARCH model have been applied by many researchers. For example, Brunner and Hess (1993), using EGARCH models, find that estimates of the conditional variance of U.S. inflation are very similar to those obtained using state-dependent models.

We model the conditional mean of inflation as

$$\phi(L)y_t = \phi + \varepsilon_t, \quad (1a)$$

with

$$\phi(L) = \sum_{l=1}^p (1 - \phi_l L), \quad (1b)$$

where y_t denotes the rate of inflation. Equation (1) is simply an AR(p) process.

In addition, we model the time-varying residual variance as an EGARCH(1,1) process. This can be written as

$$\varepsilon_t = e_t h_t^{1/2}, \quad (2a)$$

$$(1 - \beta L) \ln(h_t) = \omega + d \frac{\varepsilon_{t-1}}{h_{t-1}} + c \frac{\varepsilon_{t-1}^2}{h_{t-1}}, \quad (2b)$$

where e_t is a sequence of independent, normally distributed random variables with mean zero and variance 1. In the empirical work reported below, we estimate AR(p)-EGARCH(1,1) models for inflation and then use the conditional variance h_t as a measure of inflation uncertainty.

3 EMPIRICAL ANALYSIS

3.1 METHODOLOGICAL ISSUES

The relationship between inflation and inflation uncertainty could be estimated in a simultaneous approach as in a GARCH-in-mean (GARCH-M) model that includes a function of the lagged inflation rate in the conditional variance equation or a two-step approach where an estimate of the conditional variance is first obtained from a GARCH-type model and then causality tests are run to test for bidirectional effects. Examples of the former approach include Brunner and Hess (1993), Grier and Perry (1998), Baillie et al (1996) and Fountas et al (2000)⁴. The latter approach was followed in Grier and Perry (1998).

⁴Grier and Perry (1998) use a Component GARCH-M model of US inflation that includes lagged inflation in the conditional variance, whereas Brunner and Hess (1993) use a state-dependent model

The simultaneous approach suffers from the disadvantage that it does not allow the testing of a lagged effect of inflation uncertainty on inflation, which would be expected in a study that employs monthly or quarterly data. As Grier and Perry (1998) mention, the impact of a change in inflation uncertainty on average inflation, via a change in the stabilization policy of the monetary authority, takes time to materialize and cannot be fairly tested in a model that restricts the effect to being contemporaneous.

3.2 The EMPIRICAL EVIDENCE TO DATE

The inflation-inflation uncertainty relationship has been analysed extensively in the empirical literature. Holland (1993) and Davis and Kanago (2000) survey this literature. Inflation uncertainty is measured either using survey-based forecasts of inflation or the GARCH approach. In the recent literature that employs the GARCH approach, the U.S. evidence in favour of the Friedman hypothesis is mixed. Brunner and Hess (1993), Grier and Perry (1998, 2000) and Fountas et al (2000) find evidence in favour, whereas Baillie et al (1996) find evidence against it. The US evidence on the Cukierman-Meltzer hypothesis is rather negative. Only Fountas et al (2000) find evidence in favour of the hypothesis. There are a limited number of studies using international data that employ the GARCH approach. They are Baillie et al (1996) and Grier and Perry (1998). Grier and Perry (1998) find evidence supporting the Friedman hypothesis in the rest of the G7 countries but Baillie et al (1996) find mixed evidence. Grier and Perry (1998) find evidence supporting the Cukierman-Meltzer hypothesis in Japan and France and Baillie et al (1996) in the UK and three high-inflation economies, Argentina, Brazil and Israel.

This study aims to fill the gaps arising from the methodological shortcomings of the previous studies and the lack of interest in the European case, where the results would have interesting implications for the successful implementation of common European monetary policy.

3.3 UK RESULTS

3.3.1 DESCRIPTION OF THE UK DATA AND ESTIMATION RESULTS

We first test for the relationship between inflation and inflation uncertainty using UK data. Even though the UK is not presently a member of the Euro zone, it is likely that it will participate in the European monetary union (EMU) in the future. In our empirical application we use non-seasonally adjusted time series data on Consumer Price Index obtained from the OECD Main Economic Indicators Database. Our sample includes quarterly data from 1960:Q1 through 1999:Q2. Figure 1 plots the inflation rate (π_t) series constructed as the first difference of the log of CPI. To establish that the inflation data series is stationary we use both the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests presented in Table 1(a) below. Using the second lagged difference terms in

where the standard deviation of inflation is included in the mean equation and the lagged value of the squared deviation of inflation from a parameter is included in the variance equation. Baillie et al (1996) model inflation as a fractionally-integrated process and include lagged inflation in the conditional variance equation and the standard deviation in the mean equation. Fountas et al (2000) use a GARCH-M model that includes the lagged inflation rate in the variance equation.

the ADF test and setting the truncation lag at four in the PP test, we find that both tests reject the null hypothesis of a unit root at 0.01 significance level. Hence, we have evidence in this sample that the UK inflation rate is stationary. We choose an AR(6) plus 2 seasonal dummy variables⁵ model for the mean inflation rate and an EGARCH(1,1) model for the variance equation, according to the minimum Akaike Information Criterion (AIC) and Schwarz criterion (SC).

Table 1(b) presents the estimates of an AR(6)-EGARCH(1,1) model for the UK inflation rate with two seasonal dummies. The model was estimated under quasi-maximum likelihood estimation using the consistent variance-covariance estimator of Bollerslev and Wooldridge (1992). Residual diagnostics for this model are also reported in Table 1(b), and include Ljung-Box (Q) tests for residual correlation, and Ljung-Box diagnostics for serial dependence in the squared residuals. As reported, the Ljung-Box tests for serial correlation in the levels and squares of the standardized residuals do not reject the hypothesis of no autocorrelation. Thus, the Ljung-Box tests indicate that the estimated model fits the data very well. The persistence of volatility implied by the EGARCH equation is measured by the size of β , which is highly significant. Asymmetry in inflation uncertainty is conveniently quantified by examining the sign of d . In the present case, the positive and significant value of the coefficient implies that periods of positive inflation shocks are accompanied by high inflation uncertainty and periods of negative inflation shocks are accompanied by lower uncertainty about inflation. In summary, the AR(6)-EGARCH(1,1) model seems to fit both the mean and variance of the UK inflation rate quite well.

3.3.2 GRANGER-CAUSALITY TESTS

Next we employ Granger methods to test for bidirectional causality between inflation and inflation uncertainty. In particular, we test the null hypotheses that inflation does not Granger-cause inflation uncertainty, and that inflation uncertainty does not Granger-cause inflation using two, four, six, and eight lags⁶. The F statistics are reported in Table 2. These statistics have been obtained following correction for serial correlation and/or heteroskedasticity in the unrestricted regression in each case. The first null hypothesis is rejected at 0.01 level for all lags, while the second is also rejected at 0.10 or better. The sum of the coefficients on lagged uncertainty in the inflation equation (at lags 2 and 6) and on lagged inflation in the inflation uncertainty equation are positive. We thus provide strong empirical confirmation of Friedman's hypothesis. We also find some evidence that increased inflation uncertainty increases inflation, confirming the theoretical predictions made by Cukierman and Meltzer (1986).

Inflation uncertainty has real effects only if it leads to output losses. To test for such effects we have used the index of industrial production to construct the growth rate of output. Our Granger-causality results in Table 2 (fourth column) indicate that higher inflation uncertainty causes a negative output growth effect, thus supporting the argument

⁵The seasonal dummy variables are included to seasonally adjust the inflation series. We find that 2 of these dummies are jointly statistically significant.

⁶It is possible to test for the relationship between inflation and its uncertainty simultaneously, as argued in Appendix A.

that higher inflation uncertainty is part of the welfare costs of inflation⁷. Finally, in the last column of Table 2, we report the F statistics on the causal effect of inflation uncertainty on output growth, where the regression includes in addition lagged inflation rates. The rationale for this choice is to control for possible effects of inflation uncertainty on output that take place via changes in inflation⁸. The reported results indicate that inflation uncertainty still affects output negatively, even though the effect is perhaps somewhat weaker (i.e., it applies for two and four lags only).

3.3.3 PREDICTABILITY OF HIGHER LEVELS OF UK INFLATION

Several researchers, such as Engle (1983) and Cosimano and Jansen (1988), have failed to find strong evidence that higher rates of inflation are less predictable. Using the EGARCH model, we compare our results with theirs. The inflation and inflation uncertainty series for the AR(6)-EGARCH(1,1) model are shown in Figure 2, which plots the inflation rate and its corresponding conditional standard deviation in dual scale.

In contrast to the conclusion of the above-mentioned studies, Figure 2 provides evidence that higher levels of inflation are less predictable. According to our estimates, the conditional standard deviation average (annual rate) in the low-inflation 1960s is about 2.4%. In the high-inflation 1970s, the conditional standard deviation average (annual rate) is about 4.3%. Finally, in the low-inflation environment of the 1990s, the average of the conditional standard deviation is only 2.4%. Brunner and Hess (1993) argue that it is the relaxation of the symmetry restriction in conditional volatility models which enables them to find that higher levels of inflation are less predictable. We reach the same conclusion by using an EGARCH model. To compare our results to theirs we also use an asymmetric GARCH process. The AIC and SC were -6.979647 and -6.759845 respectively, much worse than those of the EGARCH model. The estimates of the conditional standard deviation were quite unsatisfactory as well. Figure 3 shows that the volatility of inflation for the GARCH model is unreasonably high during the relatively low and stable inflation years of the late 1980s and 1990s.

3.4 EVIDENCE FOR THE EURO-ZONE COUNTRIES

3.4.1 DESCRIPTION OF THE DATA AND ESTIMATION RESULTS

We apply the above empirical approach to five European countries (France, Germany, Italy, the Netherlands, and Spain) that are presently members of the Euro zone. Our group of countries includes the largest four EMU countries. We use quarterly non-seasonally adjusted time series on CPI obtained from the OECD main economic indicators database from 1960:Q1 to 1999:Q3⁹. To adjust the time series for seasonality, we use 3 seasonal dummy variables in each country, provided they are jointly significant¹⁰.

⁷This result is identical if we use GDP to measure real output.

⁸We are grateful to an anonymous referee for this point.

⁹The time series for France ends in 1999:Q2, for Germany in 1999:Q2, for Italy in 1999:Q3, for the Netherlands in 1999:Q2, and for Spain in 1999:Q2.

¹⁰The seasonal dummy variables are jointly significant in all the examined countries except for the Netherlands and Spain.

Table 3 presents ADF and PP tests of the unit root hypothesis for each country. The PP tests reject the null hypothesis of a unit root for all six countries at 0.01 (0.05 for France) significance level. The ADF tests for France, Germany, and Italy fail to reject the null hypothesis of a unit root, but we will consider their inflation series stationary in our analysis, taking into consideration the Phillips-Perron results.

The best fitted model is chosen according to the minimum values of the AIC and SC. We choose an EGARCH(1,1) specification for the conditional variance and an AR(3) model for France, an AR(7) for Germany, an AR(4) for Italy, and an AR(8) for the Netherlands and Spain. Table 4 shows the estimated results for each country for the models specified above. In all countries, except Germany, the estimated coefficient d is statistically significant and positive, indicating evidence of asymmetry in the conditional variance. This implies that negative and positive shocks to the inflation process have a different impact on inflation uncertainty. More specifically, positive (negative) inflation surprises lead to more (less) inflation uncertainty. For Germany, the estimated coefficient of asymmetry is negative, implying that a positive inflation shock leads to less uncertainty about inflation. This finding can be attributed to the strong commitment of the German monetary authority towards anti-inflationary policies. We also perform the same specification tests for the adequacy of the models as we did for the UK above. For all the estimated models, residuals diagnostics (not reported) yield no evidence of mis-specification.

3.4.2 GRANGER-CAUSALITY TESTS

Table 5 reports the Granger-causality test results for the above five countries. The null hypothesis that inflation does not Granger-cause inflation uncertainty is rejected for all the examined countries at the 0.05 level and for each lag length, except Germany. These results are similar to those of the UK, supporting the Friedman hypothesis. The null hypothesis that inflation uncertainty does not Granger-cause inflation is rejected in all countries. However, only in the case of Italy, France (2 lags) and Spain (6 and 8 lags) is the effect positive, supporting the Cukierman - Meltzer hypothesis. For Germany and the Netherlands, where the effect is negative, we find evidence in favour of Holland's (1995) stabilisation hypothesis discussed below.

Finally, the fourth column of Table 5 indicates that inflation uncertainty does not Granger cause output growth in all countries, except perhaps Italy, where we find a significant and negative impact on real output growth at the 10% level and the Netherlands and Spain, where the effect is positive. Somewhat similar results apply in the last column of Table 5, which adds the inflation rate in the right-hand side of the regression. The only differences are the insignificance of inflation uncertainty in Italy and the slight evidence for a positive impact in France. These results are discussed further below¹¹.

¹¹ The choice of the industrial production index in measuring real output is dictated by the unavailability of quarterly national accounts (and hence GDP) for the full sample period for several countries in our sample.

3.4.3 PREDICTABILITY OF INFLATION

As in the case of UK inflation, there is evidence that higher rates of inflation are less predictable for each of the other European countries. This conclusion is derived from an examination of the plots (not reported) of the inflation rate and its corresponding conditional standard deviation for each country. This result is in agreement with the conclusion of Brunner and Hess (1993) for the US. According to our estimated model for France, the average of the conditional standard deviation (annual rate) in the high-inflation 1970s is 2% and in the low-inflation environment of the 1990s only 0.9%. Similarly, according to our estimated model for Spain, the average value of the conditional standard deviation (annual rate) in the 1970s is 4% whereas in the stable inflationary environment of the 1990s the average figure is 1.6%. Similar results apply for the rest of the countries in our sample.

3.5 ROBUSTNESS

Our sample period 1960-99 includes various exchange rate and monetary policy regimes. For example, the UK operated under a managed float regime, following the collapse of the Bretton Woods system, for most of our sample, except for the brief period of ERM participation. In addition, from 1979 to 1990, Thatcher's government emphasised a strong anti-inflation objective. Hence, we repeat the above analysis for the UK for two periods: 1973-99 (the managed float regime) and 1979-90 (the Thatcher years). The results are presented in Table 6. Overall, these results are in broad agreement with those reported in Table 2. It is interesting to note that during the Thatcher years inflation uncertainty had no impact on output growth, a result that is very robust to the presence or absence of lagged inflation in the regression equation. Moreover, there is some evidence, in both periods under consideration, that inflation uncertainty lowers inflation, in agreement with the stabilisation hypothesis.

For the rest of our sample, countries that were ERM members for most of our original sample period 1960-99, we repeat the above analysis for the period 1983-99¹². The choice of this period is based on the widely accepted notion that the ERM entered a calmer phase in 1983 following the turbulent early years (Gros and Thygesen, 1992). Following the estimation of GARCH models for each country (results not reported), we perform Granger-causality tests as previously and report the results in Table 7. These results support those reported for the full sample period (see Table 5) in many respects. First, we find strong support for the Friedman hypothesis regarding the positive impact of inflation on inflation uncertainty in most countries (see column 2). Second, as was the case in the analysis of the full period, we find that inflation uncertainty does not seem to lead to lower output, with a single exception (last two columns of Table 7). Finally, significant difference obtains between the full sample and the post-1983 period on the significance of the causal effect of inflation uncertainty on inflation. We find (column 3) that in most countries, there is no causal effect. This result squares with the loss of

¹²For all 6 countries, we have re-estimated the GARCH model using the new sample periods and obtained new values for the conditional variances. These values have then been used in performing the Granger-causality tests.

monetary policy independence in the ERM period, as monetary policy was constrained by the exchange-rate peg objective.

4 DISCUSSION

Our full sample period includes considerable inflation diversity both across countries and across time. The high-inflation 1970s was followed by the low-inflation 1980s and 1990s. This was the case for two reasons: First, the global reduction in inflationary pressures. Second, some European countries, France, Italy, and Spain in our sample, joined the European Monetary System (EMS) in 1979 in order to borrow Germany's anti-inflation reputation. This is less so for the Netherlands, which has traditionally aligned its monetary policy stance to Germany's. The reduction in inflation for France, Italy, and Spain was more prevalent during the last stage of the EMS, starting in 1987. During most of the 1990s, inflation remained low and relatively stable. The significant variability in the level of inflation and the uncertainty about it during our sample period provides the testing ground to examine the bidirectional relationship between inflation and inflation uncertainty.

We discuss first the Granger-causality results on the effect of inflation on inflation uncertainty. Our results indicate strong evidence in support of the Friedman hypothesis for all countries, except Germany¹³. The lack of evidence for Germany is not surprising, as it is consistent with Ball's (1992) theory, which formalised Friedman's prediction¹⁴. Using Ball's (1992) argument, an increase in German inflation would not lead to more inflation uncertainty as the Bundesbank had a strong anti-inflation reputation, and, therefore, was willing to bear the costs of disinflation. Our result on the Friedman hypothesis for France, Italy, and the UK is consistent with the Grier and Perry (1998) study of the G7. However, in contrast to our study, Grier and Perry (1998), using a different methodology (GARCH model), sample size (1948-93), and data frequency (monthly, as opposed to quarterly) find support for Friedman's hypothesis for Germany. Our finding of a non causal effect of inflation on inflation uncertainty for this country indicates that inflation uncertainty in Germany is not caused by rising inflation rates.

Regarding the causality from inflation uncertainty to output growth, our Granger-causality tests indicate that only in the UK does inflation uncertainty have a negative effect on output growth (when the full period is used). In the EMU countries during the more relevant 1983-1999 period such an effect does not apply. This is according to the last column of Table 7 which allows us to separate the effects of inflation uncertainty on output. Hence, we conclude that the welfare costs of inflation do not seem to be significant, with the exception of the UK¹⁵. This finding has important implications for the ECB's policymaking strategy. In particular, it supports those claiming that the objective

¹³No evidence in favour of the Friedman hypothesis applies for the Netherlands and Spain when the 1983-99 period is used.

¹⁴Ball (1992) uses an asymmetric information game where two policymakers with different preferences towards inflation alternate stochastically in office. Therefore, a higher current inflation rate raises inflation uncertainty as it is not known which policymaker will be in office in the next period.

¹⁵For the UK, the welfare cost of inflation was contained by the adoption of inflation targeting in 1992, following the country's brief participation in the EMS.

of price stability has been overemphasised by the ECB. The second implication of these output growth Granger-causality results concerns the application of a common monetary policy by the ECB following the launch of the Euro zone in 1999. As we saw earlier, inflation uncertainty does not seem to cause negative real effects across all countries in our sample, except in the UK. Hence, a common European monetary policy would have relatively symmetrical real effects (=zero), which work through the inflation uncertainty channel, across the EMU countries¹⁶.

Our evidence on the Cukierman-Meltzer hypothesis is rather mixed. For Germany and the Netherlands, we found evidence against this hypothesis. This evidence partially favours the "stabilization hypothesis" put forward by Holland (1995). He claims that for countries where inflation leads to inflation uncertainty and real costs, we would expect the Central Bank to stabilize inflation, hence a negative effect of inflation uncertainty on inflation. Our evidence is in part¹⁷ consistent with this argument for Germany and the Netherlands. In contrast, for Italy, France (2 lags) and Spain (not robust across the various lags considered) we found evidence in favour of the Cukierman-Meltzer hypothesis. Hence, these countries would be expected to gain significantly from EMU as the surrender of their monetary policy to the ECB would eliminate the policymakers' incentive to create inflation surprises. Finally, our evidence for the UK is rather mixed. At 2 and 6 lags, we found evidence supporting the Cukierman-Meltzer hypothesis and at 4 and 8 lags evidence against the hypothesis. Our evidence for France (lag 2) and the UK (2 and 6 lags) squares with the findings of Grier and Perry (1998) and Baillie et al (1996), respectively.

More independent Central Banks would have stronger anti-inflation preferences than the government and hence lead to a lower optimal inflation rate (Rogoff, 1985). Moreover, if inflation uncertainty is costly, i.e., it implies real output effects, and inflation can affect inflation uncertainty (the Friedman hypothesis), an independent Central Bank will have a greater incentive (and freedom) to reduce inflation in response to more uncertainty. This is because in doing so (and hence keeping inflation uncertainty lower), the Central Bank can attain both lower inflation and higher output, i.e., a higher welfare level. The predictions of this analysis are borne out by the empirical evidence. Alesina and Summers (1993) show that more independent Central Banks are indeed associated with both lower inflation and inflation uncertainty.

Our results for the impact of inflation uncertainty on inflation are generally consistent with the existing literature on the rankings of Central Bank Independence (see Alesina and Summers, 1993). Countries like France, Italy and Spain have less independent Central Banks than Germany and the Netherlands, at least using the measures of Central Bank Independence that refer to the pre-1990 period, which is more in line with our sample period. Hence, we would expect that less independent Central Banks would be more likely to cause inflation surprises in response to higher inflation uncertainty, a result consistent

¹⁶For the Netherlands, Spain, and possibly France, we found evidence that inflation uncertainty raises output growth, in particular when the full sample period 1960-99 is used. This, seemingly, surprising result may arise under the assumption of risk averse agents and a precautionary motive for savings, as Dotsey and Sarte (2000) have shown in their theoretical model. According to their argument, when inflation uncertainty rises, savings increase and this boosts investment and growth.

¹⁷Our partial support arises from a lack of evidence for a negative impact of inflation uncertainty on output growth for these two countries and a lack of evidence for the Friedman hypothesis for Germany.

with the Cukierman-Meltzer hypothesis. Our empirical analysis generally supports this prediction. Our conclusion on France and Germany also agrees with Grier and Perry (1998).

5 CONCLUSIONS

The relationship between inflation and inflation uncertainty has been investigated in six European Union countries for the period 1960 to 1999. EGARCH models were used to generate a measure of inflation uncertainty and then Granger methods were employed to test for causality between average inflation and inflation uncertainty. In all the European countries of our sample, except Germany, inflation significantly raises inflation uncertainty, as predicted by Friedman. However, in all countries, except the UK, inflation uncertainty does not cause negative output effects, implying that a common European monetary policy applied by the ECB might not lead to asymmetric real effects via the inflation uncertainty channel.

Less robust evidence is found regarding the direction of the impact of a change in inflation uncertainty on inflation. In Germany and the Netherlands, increased inflation uncertainty lowers inflation, while in Italy, Spain, and to a lesser extent France, increased inflation uncertainty raises inflation. These results are generally consistent with the existing rankings of Central Bank Independence.

The reported differences in the results between this study and related studies, such as Grier and Perry (1998), can be attributed to the different methodologies, sample periods, and data frequency. These differences highlight the need for further empirical work in search of more robust evidence on the relationship between inflation, inflation uncertainty and output growth. This work will provide an additional testing ground for the empirical relevance of economic theories and at the same time will be rather informative for the authorities in charge of monetary policymaking.

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APPENDIX A

This appendix reports the estimation results of an Exponential GARCH-in-mean model of inflation in six countries with lagged inflation included in the conditional variance. As in the text, the estimation period is 1960-1999 and the data frequency quarterly. We simultaneously estimate a system of equations that allows only the current value of either the conditional variance or standard deviation of inflation¹⁸ to affect average inflation and also allows up to the twelfth lag of average inflation to influence the conditional variance. The model includes the inflation equation which adds the inflation variance to the equation reported in the text

$$\pi_t = \alpha_{t-1} + \delta h_t + \varepsilon_t,$$

with

$$\varepsilon_t = e_t h_t^{\frac{1}{2}},$$

and the conditional variance equation:

$$(1 - \beta L)\ln(h_t) = \omega + c \sum_{i=1}^j e_{t-i} + d e_{t-1} + k_i \pi_{t-i}$$

In the mean equation, α_{t-1} stands for the part of the regression that includes the intercept and lagged inflation rates. In the variance equation, various lags of inflation (from 1 to 12) were considered with the best model chosen on the basis of the minimum value of the Akaike information criterion.

The Table below reports only the estimated parameters of interest:

	EGARCH	EGARCH	EGARCH	
	Level	In-Mean	Level	In-Mean
	k_i	δ	k_i	δ
UK	$k_4 = 23.67$ (0.03)	17.28 (0.32)	$k_4 = 25.20$ (0.03)	7.92 (0.72)
FRANCE	$k_6 = 6.26$ (0.00)	177.18 (0.00)	$k_4 = 15.82$ (0.05)	80.39 (0.00)
GERMANY	$k_4 = 18.63$ (0.16)	$\delta = 46.85$ (0.74)	$k_2 = 8.05$ (0.36)	$\delta = 46.21$ (0.65)
ITALY	$k_4 = 8.42$ (0.06)	$\delta = 15.28$ (0.40)	$k_6 = 3.40$ (0.08)	$\delta = 12.94$ (0.44)
NETH/NDS	$k_6 = 3.21$ (0.76)	2.50 (0.79)	$k_{12} = 0.37$ (0.97)	$\delta = 3.20$ (0.81)
SPAIN	$k_6 = 20.74$ (0.04)	13.87 (0.60)	$k_6 = 20.92$ (0.03)	$\delta = 3.99$ (0.60)

Notes: (1) Probability values are given in parentheses.

(2) k_i indicates the estimated coefficient that corresponds to the i th lag in the inflation rate.

Note that when we estimate the model for the UK without the in-mean effect ($\delta = 0$), the coefficient for the effect of the 4th lag of inflation is 23.67 and is statistically significant.

¹⁸According to the information criteria, the models with the variance of inflation were preferred to those with the standard deviation.

When we estimate the model without the level effect ($k_i = 0$), the in-mean coefficient is insignificant (the probability value is 0.32). When we estimate the model with the simultaneous feedback between the conditional variance and the conditional mean (last two columns in the Table), the above results imply a positive association between lagged inflation and uncertainty similar to that found using the two-step method in the text. We do not find a significant effect of uncertainty on average inflation. However, as we emphasize in the text, such a result is plausible, as any relationship where uncertainty influences average inflation takes time to materialize and cannot be fairly tested in a model that restricts the effect to being contemporaneous.

A comparison of the results of the simultaneous estimation (last two columns in Table) with the Granger causality results reported in the text for the rest of the countries indicates that, in general, there is consistency between the two approaches. In particular, as far as the Friedman hypothesis (significance of k_i) is concerned, we find the two approaches to be in agreement, except in the case of the Netherlands. However, a comparison of the significance of the causal effect of inflation uncertainty on the inflation rate is not valid due to the contemporaneous nature of the effect under the simultaneous approach. As expected, the simultaneous approach does not detect such an effect in the majority of countries considered.

Table 1:
(a) Inflation unit root tests

Country	ADF t-statistic	Phillips-Perron t-statistic
UK	-2.620***	-8.040***

Notes: (1) In the ADF tests, we use two lagged differenced terms. In the Phillips-Perron tests, the truncation lag is set at four.

(2) *** indicates rejection of the unit root null at the 0.01 level.

(b) The estimated AR(6)-EGARCH(1,1) Model for the UK inflation rate

$$\pi_t = \frac{0.003}{(0.00)} + \frac{0.566}{(0.00)} \pi_{t-1} + \frac{0.178}{(0.00)} \pi_{t-4} + \frac{0.169}{(0.01)} \pi_{t-5} + \frac{0.188}{(0.00)} \pi_{t-6} + \frac{0.009}{(0.00)} d_{2t} + \frac{0.007}{(0.00)} d_{3t} + \varepsilon_t$$

$$\ln(h_t) = \frac{-3.196}{(0.01)} + \frac{0.697}{(0.00)} \ln(h_{t-1}) + \frac{0.242}{(0.18)} |e_{t-1}| + \frac{0.437}{(0.02)} e_{t-1}$$

$$Q(12) = 8.789[0.721], Q(24) = 24.810[0.416], Q(36) = 38.650[0.351]$$

$$Q^2(12) = 12.957[0.372], Q^2(24) = 22.579[0.545], Q^2(36) = 26.794[0.867]$$

Notes: (1) The first equation represents the estimated conditional mean of the autoregressive model. d_{2t} and d_{3t} are seasonal dummies. The figures in parentheses under the coefficients and inside the square brackets show the probability values.

Table 2: Granger-Causality tests: UK (1960-1999)

	$H_0: \pi_t \nrightarrow h_{\pi t}$	$H_0: h_{\pi t} \nrightarrow \pi_t$	$H_0: h_{\pi t} \nrightarrow y_t$	$H_0: h_{\pi t} \nrightarrow y_t$
Two Lags	4.741 ^{***} (+)	3.070 ^{***} (+)	8.775 ^{***} (-)	6.770 ^{***} (-)
Four Lags	4.721 ^{***} (+)	8.343 ^{***} (-)	6.410 ^{***} (-)	3.589 ^{***} (-)
Six Lags	9.202 ^{***} (+)	6.864 ^{**} (+)	5.410 ^{***} (-)	1.610
Eight Lags	5.294 ^{***} (+)	5.568 ^{**} (-)	3.345 ^{**} (-)	0.966

Notes: (1) The figures are F statistics. (2) $\pi_t \nrightarrow h_{\pi t}$: Inflation does not Granger-cause inflation uncertainty; $h_{\pi t} \nrightarrow \pi_t$: Inflation uncertainty does not Granger-cause inflation; $h_{\pi t} \nrightarrow y_t$: Inflation uncertainty does not Granger-cause output growth. (3) superscript (a) means that lagged inflation has been added to the regression. (4) the positive or negative sign in parentheses indicates the sign of the sum of the lagged coefficients in the respective equation. (5) ***, ** and * indicate rejection of the null hypothesis at the 0.01, 0.05 and 0.10 levels of significance, respectively.

Table 3: Inflation unit root tests

Country	ADF t-statistic	Phillips-Perron t-statistic
France	-1.910	-3.110**
Germany	-2.150	-5.420***
Italy	-2.340	-3.880***
Netherlands	-4.840***	-11.150***
Spain	-2.720*	-6.550***

Notes: (1) In the ADF tests we use two lagged differenced terms. In the Phillips-Perron tests the truncation lag is set at four, (2) ***, ** and * indicate rejection of the unit root null at the 0.01, 0.05 and 0.10 levels of significance, respectively.

Table 4: The Estimated AR(p)-EGARCH(1,1) Models

Parameter	Country				
	France	Germany	Italy	Neth/nds	Spain
$\pi_{t_i 1}$	0.645[0.000]	0.351[0.000]	0.754[0.000]	0.471[0.000]	0.182[0.006]
$\pi_{t_i 2}$	-0.016[0.837]		0.114[0.240]		0.247[0.001]
$\pi_{t_i 3}$	0.296[0.000]	0.279[0.000]	0.063[0.408]		0.191[0.022]
$\pi_{t_i 4}$		0.361[0.000]	0.039[0.420]	0.337[0.000]	0.232[0.000]
$\pi_{t_i 5}$				-0.195[0.000]	
$\pi_{t_i 6}$				0.115[0.010]	
$\pi_{t_i 7}$		-0.205[0.003]			-0.193[0.003]
$\pi_{t_i 8}$				0.218[0.000]	0.253[0.000]
d	0.223[0.000]	-0.032[0.736]	0.422[0.000]	0.347[0.050]	0.126[0.001]
c	-0.215[0.013]	0.319[0.070]	-0.194[0.000]	0.912[0.000]	-0.163[0.048]
β	0.942[0.000]	0.680[0.011]	0.942[0.000]	0.745[0.000]	0.969[0.000]

Notes: (1) The estimated conditional variance equation has the form:

$$\ln(h_t) = \omega + \beta \ln(h_{t-1}) + c |e_{t-1}| + d e_{t-1}$$

(2) A constant term and seasonal dummies were included but not reported.

(3) Probability values are given in square brackets.

Table 5: Granger causality tests for inflation and inflation uncertainty (1960-1999)

	$H_0: \pi_t \nrightarrow h_{\pi t}$	$H_0: h_{\pi t} \nrightarrow \pi_t$	$H_0: h_{\pi t} \nrightarrow y_t$	$H_0^a: h_{\pi t} \nrightarrow y_t$
(A) France				
Two Lags	46.381 ^{***} (+)	6.319 ^{***} (+)	0.274	1.425
Four Lags	28.570 ^{***} (+)	0.002	0.443	0.657
Six Lags	22.838 ^{***} (+)	0.240	1.128	1.902 ^a (+)
Eight Lags	17.676 ^{***} (+)	0.918	1.003	1.110
(B) Germany				
Two Lags	1.200	0.946	0.850	0.728
Four Lags	0.669	2.780 ^a (-)	0.517	0.528
Six Lags	0.350	3.235 ^{***} (-)	1.151	0.535
Eight Lags	0.407	3.520 ^{***} (-)	0.803	0.409
(C) Italy				
Two Lags	42.552 ^{***} (+)	0.039	2.540 ^a (-)	0.023
Four Lags	39.568 ^{***} (+)	4.559 ^{***} (+)	1.277	0.389
Six Lags	34.108 ^{***} (+)	6.458 ^{***} (+)	0.856	0.853
Eight Lags	38.773 ^{***} (+)	4.334 ^{***} (+)	1.754 ^a (-)	1.016
(D) The Netherlands				
Two Lags	20.394 ^{***} (+)	5.188 ^{***} (-)	8.106 ^{***} (+)	5.978 ^{***} (+)
Four Lags	9.382 ^{***} (+)	5.256 ^{***} (-)	6.889 ^{***} (+)	3.318 ^a (+)
Six Lags	10.114 ^{***} (+)	3.526 ^{***} (-)	3.734 ^{***} (+)	1.806 ^a (+)
Eight Lags	8.280 ^{***} (+)	2.820 ^{***} (-)	7.823 ^{***} (+)	0.606
(E) Spain				
Two Lags	10.021 ^{***} (+)	1.081	3.254 ^a (+)	6.643 ^{***} (+)
Four Lags	8.221 ^{***} (+)	0.454	1.766	3.256 ^{***} (+)
Six Lags	7.142 ^{***} (+)	2.227 ^a (+)	2.113 ^a (+)	4.026 ^{***} (+)
Eight Lags	4.952 ^{***} (+)	2.212 ^a (+)	1.346	3.677 ^{***} (+)

Notes: (1) The figures are F statistics.

(2) $\pi_t \nrightarrow h_{\pi t}$: Inflation does not Granger-cause inflation uncertainty; $h_{\pi t} \nrightarrow \pi_t$: Inflation uncertainty does not Granger-cause inflation; $h_{\pi t} \nrightarrow y_t$: Inflation uncertainty does not Granger-cause output growth.

(3) superscript (a) means that lagged inflation has been added to the regression.

(4) the positive or negative sign in parentheses indicates the sign of the sum of the lagged coefficients in the respective equations.

(5) ***, ** and * indicate rejection of the null at the 0.01, 0.05 and 0.10 levels of significance, respectively.

Table 6: Granger-Causality tests: UK

	$H_0: \pi_t \nrightarrow h_{\pi t}$	$H_0: h_{\pi t} \nrightarrow \pi_t$	$H_0: h_{\pi t} \nrightarrow y_t$	$H_0^a: h_{\pi t} \nrightarrow y_t$
1979-90				
Two Lags	0.350	14.867 ^{***} (-)	0.873	0.360
Four Lags	3.150 ^{***} (+)	6.233 ^{**} (-)	1.375	0.554
Six Lags	2.585 ^{**} (+)	2.785 ^{**} (-)	1.030	0.428
Eight Lags	3.495 ^{**} (-)	2.615 ^{**} (-)	0.909	0.560
1973-99				
Two Lags	38.047 ^{***} (+)	0.722	2.514 [*] (-)	1.061
Four Lags	38.830 ^{***} (+)	2.286 [*] (-)	2.518 ^{**} (-)	0.815
Six Lags	55.507 ^{***} (+)	1.050	5.604 ^{***} (-)	0.896
Eight Lags	39.675 ^{***} (+)	1.118	3.700 ^{***} (-)	1.113

Notes: (1) The figures are F statistics.

(2) $\pi_t \nrightarrow h_{\pi t}$: Inflation does not Granger-cause inflation uncertainty; $h_{\pi t} \nrightarrow \pi_t$: Inflation uncertainty does not Granger-cause inflation; $h_{\pi t} \nrightarrow y_t$: Inflation uncertainty does not Granger-cause output growth.

(3) superscript (a) means that lagged inflation has been added to the regression.

(4) the positive or negative sign in parentheses indicates the sign of the sum of the lagged coefficients in the respective equations.

(5) ***, ** and * indicate rejection of the null at the 0.01, 0.05 and 0.10 levels of significance, respectively.

Table 7: Granger causality tests for inflation and inflation uncertainty (1983-1999)

	$H_0: \pi_t \nrightarrow h_{\pi t}$	$H_0: h_{\pi t} \nrightarrow \pi_t$	$H_0: h_{\pi t} \nrightarrow y_t$	$H_0^a: h_{\pi t} \nrightarrow y_t$
(A) France				
Two Lags	4.724 ^{***} (+)	0.001	2.015	2.373 ^{**} (+)
Four Lags	3.432 ^{***} (+)	0.169	1.905	1.766
Six Lags	3.031 ^{***} (+)	0.237	0.552	1.018
Eight Lags	3.111 ^{***} (+)	0.396	0.604	1.269
(B) Germany				
Two Lags	2.762 ^{**} (+)	0.651	1.566	1.410
Four Lags	4.026 ^{***} (+)	0.943	1.670	1.689
Six Lags	2.927 ^{***} (+)	0.845	2.479 ^{***} (-)	1.643
Eight Lags	2.293 ^{***} (+)	0.691	1.937 ^{**} (-)	1.374
(C) Italy				
Two Lags	5.898 ^{***} (+)	3.605 ^{***} (-)	1.127	2.079
Four Lags	5.576 ^{***} (+)	2.038 ^{**} (-)	0.780	1.535
Six Lags	3.015 ^{***} (+)	2.933 ^{***} (-)	1.018	1.778
Eight Lags	1.947 ^{**} (+)	2.608 ^{***} (-)	1.033	0.844
(D) The Netherlands				
Two Lags	3.829 ^{***} (-)	4.492 ^{***} (-)	0.546	0.299
Four Lags	8.285 ^{***} (-)	1.442	2.068 ^{**} (+)	0.124
Six Lags	14.995 ^{***} (-)	0.971	1.585	0.297
Eight Lags	9.717 ^{***} (-)	1.069	0.539	0.686
(E) Spain				
Two Lags	0.890	1.629	0.081	0.074
Four Lags	1.567	1.659	2.594 ^{***} (+)	2.923 ^{***} (+)
Six Lags	0.754	1.483	2.004 ^{**} (+)	1.549
Eight Lags	0.561	1.772	1.626	1.245

Notes: (1) The figures are F statistics.

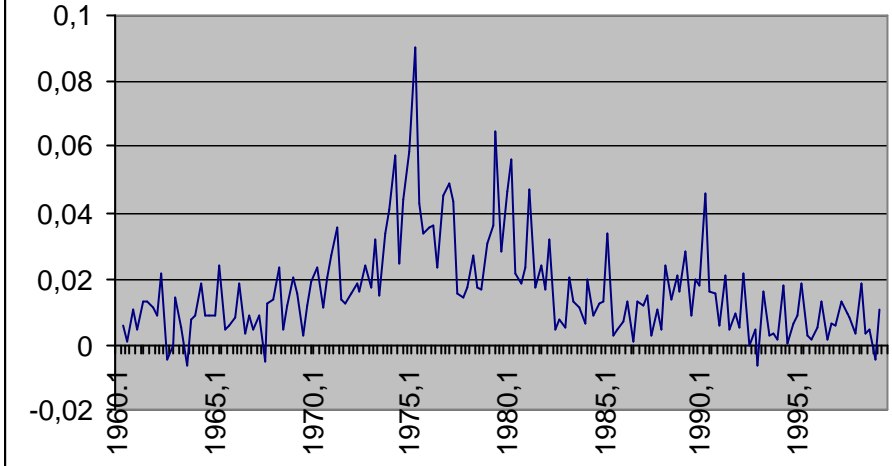
(2) $\pi_t \nrightarrow h_{\pi t}$: Inflation does not Granger-cause inflation uncertainty; $h_{\pi t} \nrightarrow \pi_t$: Inflation uncertainty does not Granger-cause inflation; $h_{\pi t} \nrightarrow y_t$: Inflation uncertainty does not Granger-cause output growth.

(3) superscript (a) means that lagged inflation has been added to the regression.

(4) the positive or negative sign in parentheses indicates the sign of the sum of the lagged coefficients in the respective equations.

(5) ***, ** and * indicate rejection of the null at the 0.01, 0.05 and 0.10 levels of significance, respectively.

**Figure 1: UK inflation rate
1960:Q1-1999:Q2**



**Figure 2: UK inflation rate and
conditional standard deviation,
AR(6)-EGARCH(1,1) model.
Estimation period 1960:Q1-1999:Q2**

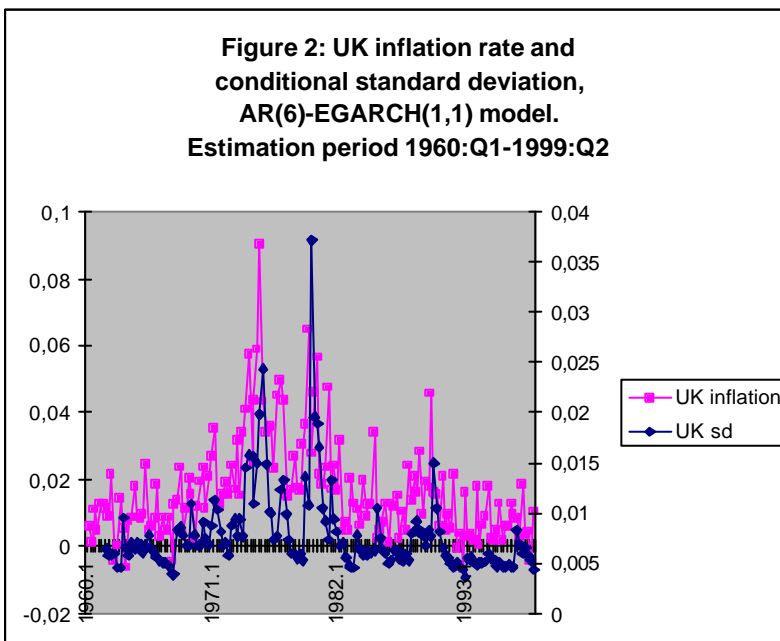


Figure 3: Inflation rate and conditional standard deviation, AR(6)-Asymmetric GARCH(1,1) model. Estimation period 1960:Q1-1999:Q2

