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THE MISSING LINK BETWEEN INFLATION UNCERTAINTY AND INTEREST RATES

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Abstract

In the literature, there is no consensus about the direction of the effects of inflation uncertainty on interest rates. This paper states that such a result may stem from differentiation in the sources of the uncertainties and analyzes the effects of different types of inflation uncertainties on a set of interest rates for the UK within an interest rate rule framework. Three types of inflation uncertainties – impulse uncertainty, structural uncertainty and steady-state uncertainty – are derived by using a time-varying parameter model with a Generalized Autoregressive Conditional Heteroskedasticity specification. It is shown that the impulse uncertainty is positively and the structural uncertainty is negatively correlated with the interest rates. Moreover, these two uncertainties are important to explain short-term interest rates for the period of inflation targeting era. However, this time, the impulse uncertainty is negatively and the structural uncertainty is positively correlated with the overnight interbank interest rates, which is consistent with the general characteristic of the inflation targeting regimes. Lastly, the evidence concerning the effect of the steady-state inflation uncertainty on interest rates is not conclusive.

I Introduction

There has been a keen interest on the part of both policymakers and academicians in understanding the effects of inflation uncertainty on economic performance. Considerable literature is devoted to the analysis of the effects of inflation uncertainty on inflation, employment and output.[1] Especially, after price stability has emerged as the primary goal for monetary policy, it has often been argued that a credible monetary policy is associated with lower inflation uncertainty as mentioned in Clarida *et al.* (1999) and Johnson (2002).

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[1] For the effects of inflation uncertainty on inflation, Ball (1992), Ball and Cecchetti (1990), Cukierman and Meltzer (1986), Cukierman and Wachtel (1979), Evans (1991), Evans and Wachtel (1993) and Holland (1993 and 1995) find a positive relationship. For negative effects of inflation uncertainty on employment, see Hafer (1986) and Holland (1986). Friedman (1977), Froyen and Waud (1987) and Holland (1988) report a negative relationship between inflation uncertainty and output.

The literature regarding the relationship between inflation and interest rates has intensified further in the last decade, especially after the emergence of price stability as the overriding goal of monetary policy. Along with the dominance of price stability, interest rates have become the main policy instrument during the policymaking process. More importantly, this period witnessed the implementation of inflation targeting regimes in many industrialized economics, where inflation uncertainty as well as inflation itself became more critical issues for the policymakers. Surprisingly, despite the extensive literature concerning monetary policy rules in an inflation targeting framework, there have been only a limited number of studies, such as Johnson (2002) and Kontonikas (2004), which analyze inflation uncertainty in an inflation targeting regime. While Johnson (2002) studies four industrialized countries and finds that the decrease in expected inflation during the inflation targeting period does not coincide with an equal decrease in inflation uncertainty, Kontonikas (2004) reports that there has been an improvement in inflation uncertainty for the UK during the inflation targeting period.

In the transmission mechanism of inflation uncertainty on economic performance, interest rates play a key role. Higher interest rates depress output further by decreasing consumption and investment. More importantly, for many emerging economies, where debt sustainability is still a critical issue, higher interest rates deepen the debt burden and threaten the stability of the financial system by leading to massive capital outflows, as stressed in Blanchard (2003). On the other hand, finance theory suggests that risk is priced. Therefore, there should be a positive relationship between inflation risk and return. Other specifications, such as the asset pricing and term structure of interest rate models, also suggest a positive relationship between inflation risk and interest rates. Berument (1999), Chan (1994), Kandel *et al.* (1996), Fama (1975), Fama and Gibbons (1982), Fama and Schwert (1977) and Mishkin (1981) provide empirical evidence for this by using different specifications.

Although various studies find a positive relationship between interest rates and inflation uncertainty, there are some important expectations. Hahn (1970) reports a negative relationship between inflation uncertainty and interest rates by employing the loanable funds theory. Furthermore, Juster and Wachtel (1972a, b) and Juster and Taylor (1975) provide a negative relationship by claiming that consumers seek to protect themselves against inflation and if the variability of money income does not match inflation volatility, then the latter will effect the real income variability because of loss of consumer confidence. Thus, consumers will increase their savings, and this will cause consumption and interest rates to decrease. Cukierman and Meltzer (1986), on the other hand, argue that unanticipated inflation can be generated by governments in order to stimulate their economies by decreasing interest rates.

Another line of literature, initiated by the theoretical works of Fischer (1975), Merton (1975) and Malliaris and Malliaris (1991), argues that there is a positive relationship between inflation uncertainty and real interest rates. When the inflation rate is stochastic, the nominal interest rate is equal to the real interest rate plus the sum of the expected inflation rate plus the covariance between the nominal rate and the inflation rate minus the variance of the rate of inflation. Their specification suggests that there is a negative relationship between inflation uncertainty and nominal interest rates.

After elaborating on the literature devoted to the effects of inflation uncertainty on interest rates, it can be claimed that the overall impact is not known *a priori*. The reason for this differentiation in the literature may stem from the identification of different types of inflation uncertainties. Evans (1991) defines three types of uncertainties and claims that their effects on the inflation rate are different. Following his lead, we define three types of inflation uncertainty: (1) the impulse uncertainty that is measured by the conditional variance of inflation to capture the inflation risk, which could be induced for the future by the information content of past inflation;[2] (2) the structural uncertainty, which captures the instability on the predictive power of past inflation for the future; and (3) the steady-state uncertainty, which captures the instability in the long run steady-state inflation rate.

In particular, we identify these three types of inflation uncertainties within a time-varying parameter model with a Generalized Autoregressive Conditional Heteroskedasticity (GARCH) specification. Next, in order to assess the effects of these uncertainties on interest rates, we regress these three uncertainty variables along with the expected inflation and output gap on a set of interest rates for the UK. Then, we analyze their role in the monetary policymaking process. The results are promising both from the perspective of the inflation targeting and the role of inflation uncertainty in the policymaking process. The empirical evidence provided in this paper suggests that there is a positive relationship between impulse uncertainty and interest rates, and that there is a negative relationship between structural inflation uncertainty and interest rates for the period between 1962:06 and 2002:01. The evidence on the negative relationship between steady-state inflation uncertainty and interest rates is weak. However, once the era of inflation targeting is considered, then we could find a statistically significant negative relationship between the overnight interbank interest rates and impulse uncertainty.[3] On the other hand, the relationship with structural inflation uncertainty turns out to be positive.

The next section introduces the model, the data set and the motivation behind the model selection. The third section reports the empirical evidence for the model estimates, their interpretation and implications from a monetary policy perspective. The final section concludes the paper.

II THE MODEL

Interest rate equation

The original Fisher equation is specified as the relationship between interest rates and expected inflation. However, especially for overnight interest rates,

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[2] Such an uncertainty can also be seen to arise from the unforeseen shocks that hit the economy.

[3] The level of significance is at the 10% unless otherwise mentioned.

which are viewed to be the main policy instruments for central banks, there are other factors that they respond to. The first of these is the aggregate demand pressure. It is well documented that output gap, which shows the pressure of aggregate demand on price level, is a key variable in this context. Secondly, interest rate smoothing could be another concept. As mentioned by Clarida *et al.* (1999), central bankers avoid large changes in interest rates in short periods of time. Instead, they adjust the interest rates slowly. Therefore, the original Fisher equation can be modified with an interest rate rule such as

$$R_t = \alpha_0 + \alpha_1 \pi^{\mathrm{e}}_{t+1} + \alpha_2 gap_t + \sum_{i=1}^{p} \alpha_{3,i} R_{t-i} + w_t, \tag{1}$$

where R_t is the nominal interest rate at time t, π^{e}_{t+1} is the expected inflation for time $t+1$, gap_t is the output gap at time t, w_t is the residual term and p is the lag order. The Fisher equation suggests that there is a positive relationship between expected inflation and interest rates. Moreover, when actual output exceeds potential level, the monetary authority will most likely increase interest rates since the positive output gap, as a measure of excess aggregate demand, will put extra pressure on inflation. When the output gap is negative, in order to stimulate output, the Central Bank can follow in an accommodative way and ease monetary policy.

In this paper, we consider another set of interest rates in addition to overnight rates. These interest rates vary in terms of liquidity, maturity, tax treatment and their responsiveness to the market conditions. We also allow that these interest rates are subject to changes in expected inflation and business cycle conditions.

Modeling inflation uncertainty

One obvious method for measuring inflation uncertainty is the survey-based approach as employed by Hafer (1986) and Davis and Kanogo (1996). Such an approach measures uncertainty by the standard deviation of inflation forecasts. Recently, Johnson (2002) employed absolute value of inflation forecast errors to measure inflation uncertainty. However, Bomberger (1996) claims that using the dispersion of the survey forecast does not provide a mean of measuring uncertainty, rather it provides a way to measure disagreement. Furthermore, he claims that some forecasters may try to avoid deviating from other's forecasts, which causes the value of expected inflation to be biased. Finally, Mankiw *et al.* (2003) provides further support for the disagreement about survey results.

Another method would be to employ the Kalman Filter, which can be used to measure the uncertainty regarding the structural variability of the parameters of an equation. In other words, this method is capable of measuring inflation uncertainty by estimating the time-varying parameters of an inflation specification.

Finally, one can use the Autoregressive Conditional Heteroskedasticity (ARCH) or the GARCH processes, which measure the uncertainty concerning the inflation shocks by using the conditional variance of residuals.[4] Grier and Perry (1998) and Kontonikas (2004) are two recent examples adopting such a methodology.

In this study, similar to Evans (1991), we combine the last two methods to measure the three types of inflation uncertainty within a time-varying parameter model with a GARCH specification. Formally, inflation uncertainty is modeled as:

$$\pi_{t+1} = X_t \beta_{t+1} + \varepsilon_{t+1}, \quad \text{where} \quad \varepsilon_{t+1} \sim N(0, h_t), \tag{2}$$

$$h_t = h + \sum_{i=0}^{m} \phi_i \varepsilon_{t-i}^2 + \sum_{i=1}^{n} \gamma_i h_{t-i}, \tag{3}$$

$$\beta_{t+1} = \beta_t + v_{t+1}, \quad \text{where} \quad v_{t+1} \sim N(0, Q), \tag{4}$$

where X_t is the set of explanatory variables for inflation, ε_t is a normally distributed error term with a time-varying conditional variance of h_t and stands for describing the shocks that hit the economy, β_{t+1} is the parameter vector, which is normally distributed with a homoskedastic covariance matrix of Q and v_{t+1} is the vector of shocks to β_{t+1}. Here, equation (3) is very important because it implies that if past forecasts of inflation deviate substantially from the observed inflation, uncertainty will increase.

In the model, the inflation equation is specified as a kth order time-varying autoregressive process and the residuals of the inflation equation follow a GARCH process. In such a setting, the Kalman Filter enters into the process for two reasons. Firstly, in a time-varying parameter framework, the Kalman Filter emerges as an efficient estimation method. Secondly, and more importantly, the updating equations regarding the Kalman Filter enable us to decompose different types of inflation uncertainties. These updating equations are:

$$\pi_{t+1} = X_t E_t \beta_{t+1} + \eta_{t+1}, \tag{5}$$

$$H_t = X_t \Omega_{t+1|t} X_t^T + h_t, \tag{6}$$

$$E_{t+1}\beta_{t+2} = E_t \beta_{t+1} + [\Omega_{t+1|t} X_t^T H_t^{-1}]\eta_{t+1}, \tag{7}$$

$$\Omega_{t+2|t+1} = [I - \Omega_{t+1|t} X_t^T H_t^{-1} X_t]\Omega_{t+1|t} + Q. \tag{8}$$

In the Kalman Filter updating equations, equation (6) clearly shows that two types of 'variability', which cause two types of uncertainties, can be decomposed. Equations (7) and (8) show how past forecast errors are built into new estimates about inflation, which provides a link from inflation uncertainty to inflation. The conditional covariance matrix of β_{t+1}, which represents the role of the structural uncertainty in the inflation process, is denoted by $\Omega_{t+1|t}$. Equation (7) shows the innovations in updating the estimates of β_{t+1}, which are used for forecasting future inflation. The updating of the conditional distribution of β_{t+1}

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[4] The ARCH model was first introduced by Engle (1982) and the GARCH model is provided by Bollerslev (1986).

over time in response to new information is also shown in equations (7) and (8). Thus, this model enables us to evaluate the uncertainties that originate from both inflation shocks (ε_{t+1}) and the structure of the inflation (v_{t+1}).

In the model presented above, 'ε' can be viewed as describing the shocks that hit the economy. Then, the time-varying parameter β will show how these shocks are propagated through the economy. Such terminology leads us to Frisch and Slutsky's distinction between impulses and propagation.[5] As a result, we can refer to inflation uncertainty associated with randomness in β as 'structural uncertainty', which we measure by $X_t\Omega_{t+1|t}X_t^T$, while the uncertainty associated with randomness in 'ε' can be called 'impulse uncertainty', which is measured by the conditional variance of $\varepsilon_{t+1}(h_t)$.

In addition to structural and impulse uncertainties, we employ the steady-state inflation uncertainty as the third type of inflation uncertainty measure. We believe that this might capture the credibility of central banks in their long-term commitment to control inflation. In particular, the inflation equation is defined as an AR(2) process:[6]

$$\pi_{t+1} = \beta_{1,t+1} + \beta_{2,t+2}\pi_t + \beta_{3,t+3}\pi_{t-1} + \varepsilon_{t+1}. \tag{9}$$

Therefore, the steady-state inflation is defined as

$$\pi^*_{t+1} = (1 - \beta_{2,t+1} - \beta_{3,t+1})^{-1}\beta_{1,t+1} \tag{10}$$

and the conditional variance of steady-state inflation is

$$\nabla_t^2(\pi^*_{t+1}) = \nabla E_t\beta_{t+1}\Omega_{t+1}\nabla E_t\beta'_{t+1}, \tag{11}$$

where

$$\nabla(E_t\beta_{t+1})' = \begin{bmatrix} [1 - E_t\beta_{2,t+1} - E_t\beta_{3,t+1}]^{-1} \\ E_t\beta_{1,t+1}[1 - E_t\beta_{2,t+1} - E_t\beta_{3,t+1}]^{-2} \\ E_t\beta_{1,t+1}[1 - E_t\beta_{2,t+1} - E_t\beta_{3,t+1}]^{-2} \end{bmatrix}. \tag{12}$$

Finally, after defining the three sources of inflation uncertainty, we can modify the interest rate specification (equation (1)). The positive relationship between interest rate and inflation uncertainty, as suggested by Berument (1999), Chan (1994), Fama (1975), Fama and Gibbons (1982), Fama and Schwert (1977) and Mishkin (1981), can be elaborated further now. In particular, we extended Berument (1999) by allowing the output gap to enter the interest rate specification and using three different types of inflation uncertainty. Thus, we estimate the following specification:[7]

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[5] For a detailed discussion, see Blanchard and Fischer (1989, p. 277).

[6] Following Engle (1982), we also estimated a version of the Phillips curve, which also includes real wages in the inflation specification. However, in those specifications, the real wage variable could not explain the behavior of prices in a statistically significant fashion. This finding is parallel to Berument (1999). Therefore, in order to avoid over-parameterization, we drop the real wage variable from the inflation specification and model the inflation as an AR process.

[7] We plot the impulse, structural and steady-state uncertainty of inflation variables in Figures 1–3, then briefly discuss these plots in the Appendix.

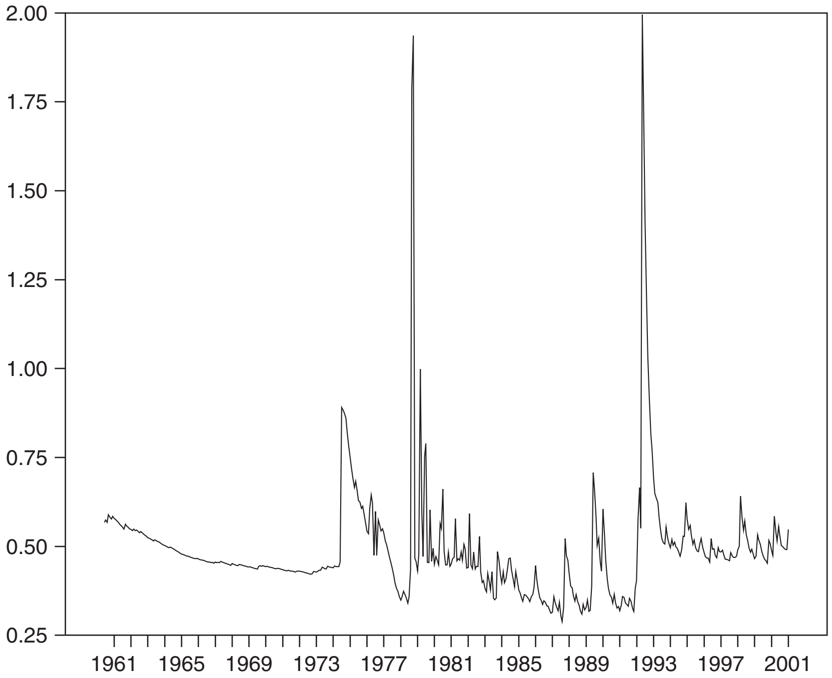

Figure 1. Impulse inflation uncertainty.

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\begin{aligned}
R_t = {} & \alpha_0 + \alpha_1 \pi^{\mathrm{e}}_{t+1} + \alpha_2 gap_t + \sum_{i=1}^{p} \alpha_{3,i} R_{t-i} + \alpha_4 h_t + \alpha_5 S_t \\
& + \alpha_6 \nabla_t^2 (\pi^*_{t+1}) + w_t,
\end{aligned}
\tag{13}
$$

where S_t is the structural uncertainty, which denotes $X_t \Omega_{t+1|t} X_t^T$. h_t and $\nabla_t^2(\pi^*_{t+1})$ stand for the impulse uncertainty and steady-state uncertainty, respectively. Furthermore, π^{e}_{t+1} is the forecast value of inflation (from equation (9)), gap_t is the deviation of output from its long-run trend, which is calculated with the HP filter. In addition, α_0 is the constant term, α_1 is the coefficient for the expected inflation, α_2 is the coefficient for the output gap, $\alpha_{3,i}$ is the coefficient of the ith lagged value of the interest rate, α_4 is the coefficient for the impulse uncertainty, α_5 is the coefficient for the structural uncertainty and α_6 is the coefficient for the steady-state uncertainty. Equation (13) can also be regarded as 'Enriched Taylor-Type' rule, where there is room for adding the inflation uncertainty, other than the response of interest rate to price stability and output stability together with its lagged values.

Instead of estimating the inflation specification and interest rate equations jointly, we estimate the inflation equation with the rolling regression method by using all the sample data that is known at a given time for the estimation of the parameters. If we estimated the inflation and the interest rate specifications jointly, then we would be implicitly assuming that agents know the inflation

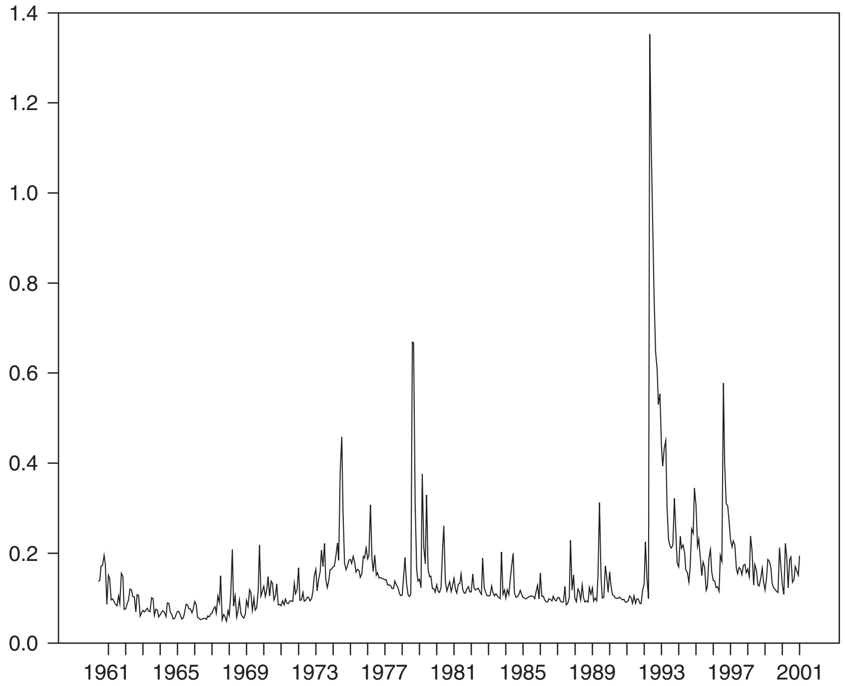

Figure 2. Structural inflation uncertainty.

rates for the full sample to estimate β_{t+1} for each $t+1$. In particular, by using rolling regressions; first, we estimate equations (5)–(8) and (11) for each t. Then we use these estimates to calculate the expected inflation and three uncertainty measures for time $(t+1)$th observation. Finally, we include these derived series in the interest rate specification.

Data Set

We use monthly UK data from 1961:06 to 2002:2. The main reason for choosing the UK to assess the effects of different types of inflation uncertainty on interest rates is the vast amount of literature devoted to inflation uncertainty for the UK, pioneered by Engle (1982). The inflation series is obtained by taking the logarithmic first difference of the seasonally adjusted CPI series. For robustness purposes, we consider several types of interest rates, which vary in terms of liquidity, maturity, tax treatment and their responsiveness to market conditions: the Overnight minimum interbank interest rate, the Treasury bill rate, the Treasury bill rate bond equivalent, the Deposit rate, the Lending rate (clearing banks) and the Government bond yields (both short- and long-term). It is important to note that all of these series are not available for the full sample size: the data for the Overnight interbank interest rate is available after 1972:01; the Treasury bill rate data is available after 1964:01; Treasury bill rate bond

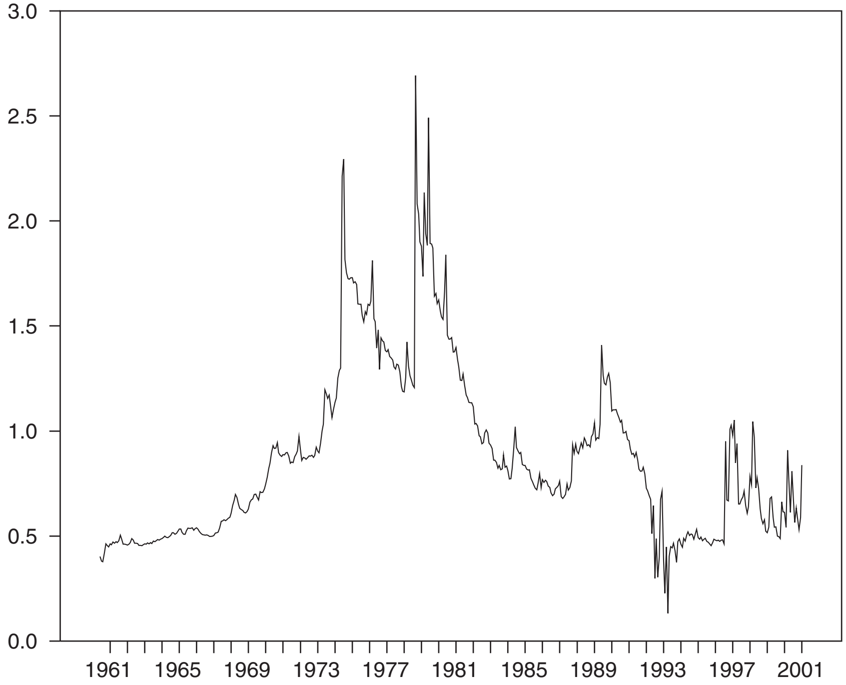

Figure 3. Steady-state inflation uncertainty.

equivalent data is available after 1974:06; the Deposit rate data is available after 1961:01; the Lending rate data is available after 1966:06; Government bond yields (short-term) data is available after 1966:01; and Government bond yields (long-term) data is available after 1961:06.

An important remark about the estimation process is that while estimating the inflation, we did not include the conditional variance to the inflation specification. There is considerable literature regarding the positive relationship between inflation and inflation uncertainty. However, the direction of this relationship is a subject of debate. Following, Grier and Perry (1998), we did not include inflation uncertainty in the inflation specification.[8] We also included two intercept dummy variables, which characterize the institutional developments that the Bank of England pursued during the sample period. These dummies stand for the adoption of an inflation targeting regime for the post October 1992 era and the change in the independence of the Bank of England for the post May 1997 era. Several studies including Johnson (2002), Kontonikas (2004) and

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[8] The positive relationship between inflation and inflation uncertainty is often elaborated in the literature. However, the direction of the effect is still an unsettled issue: whether inflation uncertainty causes inflation or inflation causes inflation uncertainty. Grier and Perry (1998) argue that for the UK inflation causes inflation uncertainty, the evidence for the reverse is weak. This is similar to our experiments – not reported in the text. Thus, we did not include the inflation risk in the inflation specification.

Nelson (2000) report that the nature of monetary policy changed significantly after the implementation of inflation targeting. Communicating more clearly the goals of monetary policy and creating accountability for the achievement of goals led to a decline in expected inflation. Granting more independence to Bank of England further strengthened the positive aspects of the inflation targeting framework. Therefore, two dummies about these two institutional features are included in the regressor matrix.

Justification of the Model

The purpose of this sub-section is to justify the selection of the GARCH–Kalman Filter specification that is used in this paper. Parallel to Berument (1999) and Grier and Perry (2000), we model the inflation equation as an AR process which is enriched with two types of level dummies. The lag order is selected by the Final Prediction Error Criteria (FPE), which selects the optimal lag length such that residuals of the inflation equation are no longer autocorrelated. This is important because ARCH-LM tests of autocorrelated residuals wrongly suggest the presence of an ARCH effect, even when there is no ARCH effect (see, Jansen and Cosimona (1988)). The FPE criteria suggests the lag order of two. Next, we estimate the inflation equation as an AR(2) process and apply the ARCH-LM test for the 1, 6 and 12 lags, respectively. The ARCH-LM test statistics are 64.142*,* 79.617 and 85.544 for these three lags. These test statistics clearly suggest the presence of an ARCH effect. Various specifications of GARCH are considered next. GARCH(1,1) is selected as the process to assess the conditional variance.

Time-varying parameter models give superior estimates to many other estimation techniques since the time-varying parameter β will show how the shocks hitting the inflation dynamics are propagated through the system over time. Different specifications for the evolution of the parameters are also estimated. These specifications include models with a return-to-normality assumption, which can be written as:

$$(\beta_{t+1} - \bar{\beta}) = F(\beta_t - \bar{\beta}) + v_{t+1}$$

and models with constant mean, which take the form:

$$\beta_{t+1} = F\bar{\beta} + v_{t+1}.$$

However, the evidence from Table 1 suggests that the random walk assumption used in this study outperforms its alternatives, both in terms of Schwarz Information Criteria and Akaike Information Criteria.

III EMPIRICAL EVIDENCE

Table 2 reports a set of unit root tests with a constant term for the inflation rate and seven interest rates. The first three tests – Dickey-Fuller, Augmented Dickey-Fuller and Phillips and Perron – take the presence of unit root as their

Table 1
Model selection criteria

	AIC	SIC
Our model	3.15	3.68
Model with return-To normality assumption	3.96	3.99
Model with constant mean	4.18	4.21

AIC, Akaike Information Criteria; SIC, Schwarz Information Criteria.

Table 2
Unit root tests

	DF	ADF	PP	KPSS
Inflation	– 12.212*	– 4.570*	– 12.491*	1.761*
Ovenight minimum interbank rate	– 3.067	– 2.034	– 2.446	1.110*
Treasury bill rate	– 1.836	– 2.524	– 2.379	1.418
Treasury bill rate bond equivalent	– 1.196	– 1.911	– 1.788	3.103*
Deposit rate	– 2.106	– 2.408	– 2.407	2.011*
Lending rate (clearing banks)	– 1.594	– 1.848	– 1.781	1.500*
Government bond yields (short-term)	– 1.710	– 2.078	– 2.133	2.252*
Government bond yields (long-term)	– 1.016	– 1.285	– 1.268	2.160*

Note:
*indicates rejecting the null at the 5% level.
DF, Dickey-Fuller; ADF, Augmented Dickey-Fuller; PP, Phillips and Perron; KPSS, Kwiatowski, Phillips, Schmidt and Shin.

null hypothesis. Except for inflation, we cannot reject the null hypothesis for the variables in interest. This is similar to Berument and Froyen (1998). However, failing to reject the null hypothesis does not mean that one can accept the alternative. Thus, we also report the Kwiatowski, Phillips, Schmidt and Shin test in the last column and with this test, we can reject the null hypothesis of stationarity for all of the variables. Therefore, we assume all the variables of interest have unit roots.

Table 3 reports the parameter estimates of equation (1) when the expected inflation is gathered from the predicted value of equation (9) for the whole sample by using the OLS method. The estimated coefficients for the expected inflation and the output gap are always positive, which is consistent with the economic priors. These coefficients are statistically significant only when the interest rate is taken as the overnight minimum interbank rate and the lending rate. The last three columns report the estimated coefficients of lag dependent variables up to three lags, where the lag order is determined by the FPE for the largest lag length among seven interest rates. The positive coefficient for the output gap suggests that interest rate increases when there is an inflation pressure. Note that we include three lagged values of the dependent variables on the right-hand side; therefore, we cannot interpret the coefficients of the expected inflation to see the interest rates increase more or less than the expected

Table 3
Estimates of the Fisher equation: 1961:06–2000:02

	Constant	π^{e}_{t+1}	gap_t	R_{t-1}	R_{t-2}	R_{t-3}
Overnight minimum interbank rate	– 0.002 (– 0.133)	0.034* (1.760)	0.074* (1.796)	0.583** (5.599)	0.142 (1.453)	0.247** (2.561)
Treasury bill rate	0.015** (2.952)	0.007 (1.265)	0.020 (1.456)	1.351** (17.421)	– 0.422** (– 3.707)	0.045 (0.807)
Treasury bill rate bond equivalent	0.014** (2.392)	0.006 (0.990)	0.019 (1.010)	1.408** (17.851)	– 0.513** (– 4.375)	0.081 (1.340)
Deposit rate	0.014** (2.896)	0.008 (1.167)	0.036 (1.610)	1.146** (18.181)	– 0.181** (– 2.244)	0.003 (0.073)
Lending Rate (clearing banks)	0.013** (2.471)	0.010** (2.515)	0.035** (2.163)	1.092** (18.372)	– 0.149* (– 1.804)	0.033 (0.555)
Government Bond yields (short-term)	0.016** (2.283)	0.004 (0.721)	0.004 (0.335)	1.318** (20.526)	– 0.413** (– 4.563)	0.071 (1.412)
Government Bond yields (long-term)	0.005 (1.224)	0.001 (0.348)	0.006 (0.646)	1.340** (22.978)	– 0.482** (– 5.312)	0.134** (2.294)

Note:
t-statistics are reported in parentheses next to the corresponding coefficients where standard errors are calculated with the Newey–West's heteroskedastic consistent formula.
*Significance at the 5% level; **Significance at the 10% level.

inflation. In order to observe the long-run effect of inflation on interest rates, one needs to estimate $(1-\alpha_{31}-\alpha_{32}-\alpha_{33})^{-1}\alpha_1$. If this coefficient is observed to be greater than one, then this suggests that interest rates increase more than the expected inflation. Alternatively, the estimated $(1-\alpha_{31}-\alpha_{32}-\alpha_{33})^{-1}\alpha_1$ being less than one would suggest that interest rate increases are less than the expected inflation. The estimates are always less than one for all of the interest rates except the overnight minimum interbank interest rate (not reported here). This is quite important, since the Bank of England can control the overnight minimum interbank rate and affect the other types of interest rates. The Bank of England's increasing the short-term interest rate more than expected inflation indicates a tight monetary policy. The estimate of $(1-\alpha_{31}-\alpha_{32}-\alpha_{33})^{-1}\alpha_1$ is 1.21, and this suggests that as expected inflation increases by 1%, the Bank of England increases the nominal interest rate by 1.21% or the expected real interest rate by .21%.

Next, in order to evaluate whether the derived inflation uncertainty series play any role in the interest rate rule for the monetary authority, three types of uncertainties are added to the regression equation presented in Table 3. A brief elaboration of these three inflation uncertainty measures are provided in the Appendix. The estimates are reported in Table 4.[9]

The estimates of the coefficient for the impulse uncertainty, h_t, are always positive for all of the interest rates, and the estimated coefficients for the structural uncertainty, S_t, are always negative, but these estimates are not statistically significant for the overnight minimum interbank rate. The estimates for the coefficients of impulse uncertainty are parallel with Berument (1999), Chan (1994) and Fama (1975). Interest rates increase with higher impulse uncertainty. The negative coefficients of the structural uncertainty are parallel with Hahn (1970), Juster and Wachtel (1972a, b) and Juster and Taylor (1975). The estimated coefficients for the expected inflation and output gap are always positive, and these coefficients are statistically significant when the interest rate is taken as the overnight interest rate and the lending rate. The positive coefficient for the output gap parallels the economic priors mentioned in the 'Interest Rate Equation'. Lastly, the estimate of $(1-\alpha_{31}-\alpha_{32}-\alpha_{33})^{-1}\alpha_1$ is greater than one only for the overnight interest rate, but it is not statistically significant. This

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[9] As a robustness test, we report the inflation and conditional variance specification for the full sample (standard errors are reported in parentheses under the corresponding estimated coefficients.) where D_{1t} is the dummy variable for the post-October 1992 era and D_{2t} is the dummy variable for the pre-May 1997 era. Here, the estimates of the GARCH(1,1) specification is of interest. Estimated coefficients of GARCH(1,1) specification are all positive and statistically significant. This satisfies the non-negativity condition of the variance. Moreover, the estimate of the sum of $(\phi_1+\gamma_1)$ is less than one, which satisfies the non-explosiveness of the estimated conditional variances. Thus, the robustness tests provide support for our specification.

$$\pi_{t+1} = \underset{(29.83)}{0.4219} - \underset{(-11.57)}{0.1636}\pi_t - \underset{(-23.84)}{0.2384}\pi_{t-1} - \underset{(-5.98)}{0.274}D_{1t} + \underset{(1.88)}{0.0702}D_{2t} + \varepsilon_{t+1}$$

$$h_t = \underset{(1.98)}{0.028} + \underset{(3.51)}{0.238}\varepsilon_t^2 + \underset{(5.68)}{0.632}h_{t-1}$$

Table 4
Estimates of the interest rate specification – Whole Sample (1961:06–2002:01)

	Constant	π^{e}_{t+1}	gap_t	h_t	S_t	$\nabla^2_t(\pi^*_{t+1})$	R_{t-1}	R_{t-2}	R_{t-3}
Overnight minimum interbank rate	− 0.011 (− 0.552)	0.055 (1.609)	0.067* (1.667)	0.022 (0.595)	− 0.024 (− 0.285)	− 0.015 (− 0.960)	0.594** (6.009)	0.132 (1.378)	0.258** (2.665)
Treasury bill rate	0.011 (1.589)	0.006 (0.925)	0.019 (1.373)	0.028* (1.719)	− 0.069** (− 2.029)	− 0.001 (− 0.110)	1.351** (17.323)	− 0.421** (− 3.704)	0.043 (0.778)
Treasury bill rate bond equivalent	0.012 (1.568)	0.006 (0.789)	0.016 (0.855)	0.030* (1.911)	− 0.075** (− 2.285)	− 0.001 (− 0.264)	1.408** (17.741)	− 0.509** (− 4.367)	0.076 (1.280)
Deposit rate	0.007 (0.850)	0.006 (0.702)	0.034 (1.522)	0.041* (1.663)	− 0.095* (− 1.894)	− 0.001 (− 0.100)	1.149** (18.115)	− 0.182** (− 2.248)	0.003 (0.067)
Lending rate (clearing banks)	0.002 (0.211)	0.016** (3.064)	0.029* (1.892)	0.049** (2.250)	− 0.108** (− 2.429)	− 0.007 (− 1.538)	1.106** (18.166)	− 0.158* (− 1.866)	0.035 (0.574)
Government bond yields (short-term)	0.014 (1.535)	0.002 (0.196)	0.005 (0.397)	0.037** (2.518)	− 0.090** (− 2.823)	0.001 (0.212)	1.301** (20.988)	− 0.392** (− 4.393)	0.063 (1.249)
Government bond yields (long-term)	0.001 (0.108)	0.003 (0.462)	0.004 (0.509)	0.025** (3.447)	− 0.068** (− 4.042)	− 0.002 (− 0.592)	1.327** (22.774)	− 0.468** (− 5.106)	0.136** (2.324)

Note:
t-statistics are reported in parentheses next to the corresponding coefficients where standard errors are calculated with the Newey–West's heteroskedastic consistent formula.
*Significance at the 5% level; **Significance at the 10% level.

suggests that the interest rate increases more than expected inflation for overnight rates in the long run, while other interest rates increase less than the increase in inflation.

Inflation Targeting Period

In October 1992, The Bank of England adopted an inflation targeting regime. This policy shift, which could induce structural changes in the macroeconomic environment, could not be addressed simply by the dummy variable in equation (2). Thus, we re-estimate the whole system for the post-inflation targeting regime, for which the results are presented in Table 5. None of the estimated coefficients for the impulse uncertainty and structural uncertainty are statistically significant except the ones for the overnight minimum interbank interest rates. The estimated coefficients for steady-state inflation uncertainty have alternating signs across interest rates, but only for the deposit rate and government bond yields (short-term) are these coefficients statistically significant. The estimates on the overnight interbank rate are important. Bearing in mind that the overnight rate is the main policy instrument for the Bank of England especially after the implementation of inflation targeting, the results imply that the uncertainties related to the structure of the inflation process and the long-run level of inflation induce the Bank of England to increase interest rates, while any uncertainty because of unforeseen shocks leads the monetary authority to ease its policy. The estimates on the overnight rate make sense in terms of an inflation targeting framework. When the monetary authorities announce their inflation targets, they make it explicit (in order to enhance credibility), that any uncertainty that could lead to a permanent change in the structure of the inflation or its long-run level will be eliminated. Therefore, agents in the economy can have a clearer idea about the long-term goals of the monetary authority. The finding that overnight interest rates, as the main policy instrument of the Bank of England, drop because of an increase in impulse uncertainty can be explained within the context of 'escape clauses', which are inherent in an inflation-targeting framework. It should be once again mentioned that impulse uncertainty stems mostly from unforeseen shocks that are viewed to be temporary. If a shock is perceived to be temporally such that it does not affect the long-term goals of central banks, then there is room for central banks to change the short-term interest rates to accommodate temporary shocks. As Bernanke *et al.* (1999, p. 24) states, those escape clauses even permit a central bank to change its medium-term targets in response to unexpected developments, such as supply shocks that cause impulse uncertainty to increase. A similar line of argument is also proposed by Clarida *et al.* (1999). They argue that when central banks are faced with unforeseen shocks, then central banks are allowed to implement accommodative monetary policy, so long as the structure of the inflation path and the long-term inflation targets are not distorted. Finally, the coefficients for the output gap in each equation are positive, implying that the Bank of England increases interest rates to curb any demand pressure that might be inflationary. However, the *t*-statistics for that coefficient

Table 5

Estimates of the interest rate specification for the Post Inflation Targeting Era (1992:10–2002:01)

	Constant	π^{e}_{t+1}	gap_t	h_t	S_t	$\nabla^2_t(\pi^*_{t+1})$	R_{t-1}	R_{t-2}	R_{t-3}
Overnight minimum interbank rate	0.094** (3.818)	0.060** (2.292)	0.060* (1.745)	– 0.113** (– 3.669)	0.222** (3.368)	0.007 (0.414)	0.315** (2.264)	0.375** (2.964)	0.110 (1.328)
Treasury bill rate	0.043* (1.739)	0.004 (0.197)	0.013 (0.842)	– 0.010 (– 0.756)	0.018 (0.624)	– 0.002 (– 0.388)	1.461** (17.422)	– 0.631** (– 2.736)	0.080 (0.544)
Treasury bill rate bond equivalent	0.050* (1.714)	0.004 (0.153)	0.027 (1.339)	– 0.019 (– 1.028)	0.034 (0.902)	– 0.002 (– 0.233)	1.405** (16.439)	– 0.649** (– 3.998)	0.145 (1.478)
Deposit rate	0.048** (3.162)	– 0.009 (– 0.580)	0.076 (1.513)	0.010 (0.493)	– 0.009 (– 0.201)	0.030** (2.546)	1.126** (7.322)	– 0.297 (– 1.167)	– 0.022 (– 0.105)
Lending rate (clearing banks)	0.036** (2.182)	– 0.009 (– 0.569)	0.022 (1.181)	0.003 (0.202)	– 0.005 (– 0.198)	0.001 (0.232)	1.150** (9.455)	0.117 (0.566)	– 0.339** (– 2.343)
Government bond yields (short-term)	0.041** (2.055)	– 0.011 (– 1.134)	0.016 (0.902)	– 0.003 (– 0.181)	0.000 (0.008)	– 0.017* (– 1.668)	1.389** (15.281)	– 0.652** (– 3.352)	0.202 (1.546)
Government bond yields (long-term)	0.009 (0.813)	0.002 (0.249)	0.016 (1.086)	0.001 (0.051)	– 0.016 (– 0.450)	– 0.010 (– 1.342)	1.210** (12.360)	– 0.339** (– 2.212)	0.115 (1.077)

Note:

t-statistics are reported in parentheses next to the corresponding coefficients where standard errors are calculated with the Newey–West's heteroskedastic consistent formula.
*Significance at the 5% level; **Significance at the 10% level.

are mostly low and the response of interest rates to the output gap is generally lower than the response to expected inflation, which also implies that price stability has become a more dominant factor in the monetary policy making process after the adoption of inflation targeting.

IV Conclusion and Policy Implications

There are conflicting views about the effects of inflation uncertainty on interest rates. While some studies find evidence of a positive effect of inflation uncertainty on interest rates because of an increase in the inflation risk premium, others argue that higher saving incentives under higher inflation uncertainty or political motives to generate surprise inflation may actually lead to a negative relationship between those two variables. However, most of these studies stop short of breaking down inflation uncertainty to its components and analyzing the effects of each type of uncertainty on the interest rates.

This paper analyzes the impact of different types of inflation uncertainties on interest rates for the UK within the context of a time-varying parameter model with GARCH specification. Since the relationship between inflation uncertainty and interest rates may have changed significantly after the implementation of the inflation targeting regime, the role of each type of inflation uncertainty in the monetary policy reaction function is also investigated for the inflation targeting period. It is shown that when the whole sample is considered, the impulse uncertainty is positively, and the structural inflation uncertainty is negatively correlated with interest rates.

When the inflation targeting period is considered alone, the results imply that any uncertainty regarding the structure or the long-run level of the inflation process causes the Bank of England to follow a tight monetary policy and increase the overnight interest rates, which is the main policy instrument for that particular period. On the other hand, if the uncertainty arises because of unforeseen shocks, then monetary policy has an accommodative characteristic.

The results are also promising in terms of policy implications. In an inflation targeting framework, where price stability incentives and long-term goals of monetary policy are explicitly stated, two distinctive characteristics emerge: credibility and accountability. An increase in inflation uncertainty that would change either the structure of inflation dynamics or the long-run level of inflation has the potential to disrupt these two features and undermine the success of the regime. Taking this fact into consideration, the monetary authorities seem to attempt to eliminate such uncertainties. On the other hand, if the uncertainty emerges because of unforeseen shocks that are mostly viewed as temporary, then monetary policy can be accommodative and interest rates may be reduced. Actually, the findings in this paper provide further empirical support to this notion of inflation targeting regimes.

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Appendix

Here we report and briefly elaborate the three inflation uncertainty measures. After 1980, the impulse uncertainty tended to decrease until 1992, after which there was a big jump in impulse uncertainty. After 1993, the level of impulse uncertainty increased but the volatility of impulse uncertainty decreased. One may observe a similar pattern for structural inflation uncertainty. However, after 1997, not only the level but the volatility of the structural uncertainty increased. The steady-state uncertainty shows a different picture. 1992–97 era had a lower inflation uncertainty compared with the pre-1992 era and the post-1997 era.

One may look at these uncertainty measures with the help of β coefficients. Figure 4 plots the estimates of the sum of the autoregressive parts in inflation specifications. After 1995, the estimated sums of the coefficients were negative. This could suggest that there is an error correction mechanism in inflation. As the inflation increases too much, the Bank of England adopts policies to decrease inflation. However, the inflation figures are quite persistent. After 1974 until 1992, inflation was quite persistent as suggested by the estimated coefficients of $\beta_2+\beta_3$. These make the structural uncertainty quite low for this period and put the impulse uncertainty into a decreasing trend.

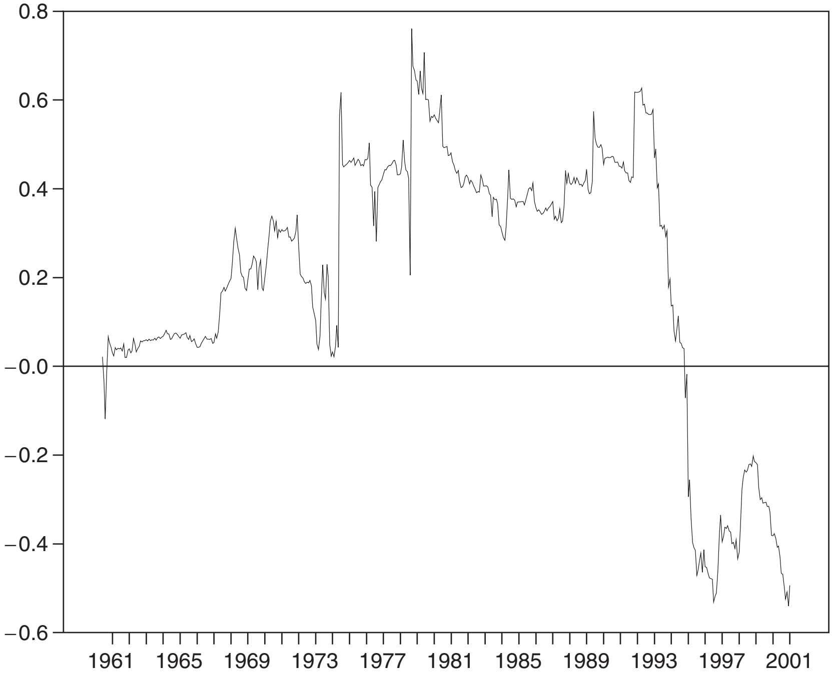

Figure 4. Estimate of $\beta_2+\beta_3$.

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