Uncertainty and UK Monetary Policy*

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Abstract

This paper provides empirical evidence on the response of monetary policymakers to uncertainty. Using data for the UK since the introduction of inflation targets in October 1992, we find that the impact of inflation on interest rates is lower when inflation is more uncertain and is larger when the output gap is more uncertain. These findings are consistent with the predictions of the theoretical literature. We also find that uncertainty has reduced the volatility but has not affected the average value of interest rates and argue that monetary policy would have been less passive in the absence of uncertainty.

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1) Introduction

The importance of uncertainty for monetary policy is widely accepted by both academics and practitioners (prominent examples include Goodhart, 1999, and Greenspan, 2003). However, although the impact of uncertainty on monetary policy has been extensively discussed in the theoretical literature, there is very little empirical evidence on how uncertainty has actually affected the behaviour of policymakers. This paper attempts to provide some evidence on this by estimating monetary policy rules that incorporate uncertainty, using data for the UK since the introduction of inflation targets in October 1992.

Our empirical model draws on the theoretical literature on optimal monetary policy rules under uncertainty. This literature considers the behaviour of policymakers who seek to stabilise inflation, the output gap and interest rates where output and inflation are determined by the interaction of aggregate demand and a New Keynesian supply curve. This literature has three main predictions. First, uncertainty affects the response of interest rates to inflation and the output gap but does not affect interest rates directly. Second, policymakers should respond less vigorously to variables that are more uncertain (Brainard, 1967). In the context of Taylor (1993) monetary policy rules in which interest rates respond to inflation and the output gap, this implies that the weight on inflation should be smaller when inflation is more uncertain. Similarly, the weight on the output gap should be smaller when the output gap is less certain (Peersman and Smets, 1999, Smets, 1999, Soderstrom, 2000, Rudebusch, 2001, Srour, 2003, Walsh, 2003 and Swanson, 2004). Third, uncertainty about one variable may strengthen the response to the other variable, so the weight on the output gap may be larger when inflation is less certain, and vice versa (Peersman and Smets, 1999, and Swanson, 2004).

Our empirical model consists of a Taylor rule in which the coefficients are functions of the volatility of inflation and the output gap. This model allows us to assess the main propositions of the theoretical literature. We can assess the

proposition that uncertainty should only affect the response of interest rates to inflation and the output gap by testing our model against a more general model in which uncertainty can also affect monetary policy independently. The propositions that policymakers should respond less vigorously to variables that are more uncertain and that uncertainty about one variable may strengthen the response to variables both imply restrictions that are easily testable using our model.

We estimate our model using data for the UK since the introduction of inflation targets in October 1992. We find that the response of monetary policy uncertainty is consistent with the predictions of the theoretical literature. Uncertainty affects the response of interest rates to inflation and the output gap but has no further independent effect on monetary policy. The estimates show that the response of policymakers to inflation is smaller when inflation is more uncertain. This is consistent with the Brainard principle. We also find that the response of policymakers to inflation is larger when the output gap is more uncertain.

We use our estimates to correct the observed interest rate for the effects of uncertainty, producing a measure of what the interest rate would have been had there been no uncertainty. This is more volatile than the actual interest rate but has a similar mean. We use the uncertainty-corrected interest rate to estimate a counterfactual monetary policy rule describing what monetary policy would have been under certainty. We find that the weight on inflation is substantially larger and the weight on the lagged interest rate is substantially smaller in the counterfactual model. Taken together, our evidence suggests that uncertainty has smoothed the path of monetary policy but has not affected the average stance of monetary policy over the longer term.

The remained of the paper is structured as follows. Section 2 explains our methodology and describes the two models of monetary policy that we estimate. Section 3 presents our estimates. Section 4 summarises our findings and offers some conclusions.

2) Methodology

Most recent models of monetary policy have used the Taylor rule (Taylor, 1993). In the context of the inflation targeting regime that has operated in the UK since October 1992, the Taylor rule can be expressed as

(1) $$i_t = i^* + \rho_\pi (E_t \pi_{t+1} - \pi^T) + \rho_y y_t$$

where i is the nominal interest rate, i^* is a constant, $E_t \pi_{t+1}$ is the inflation rate that at time t is expected for time (t+1), π^T is the inflation target, y is the output gap, ρ_π is the weight on inflation and ρ_y is the weight on output. In (1), interest rates are adjusted to keep expected inflation close to the target and minimize the output gap; the importance of each objective is captured by the relative size of the relevant coefficient of the Taylor rule.

In practice, interest rate smoothing slows the adjustment of interest rates. This is normally modeled (Judd and Rudebusch, 1998, Rudebusch, 2002 and Castelnuovo, 2003) using the simple partial adjustment mechanism

(2) $$i_t = \rho_i i_{t-1} + (1 - \rho_i)\hat{i}_t$$

where $\hat{i}_t$ is given by (1). The resulting model is

(3) $$i_t = \rho_0 + \rho_i i_{t-1} + (1 - \rho_i)\{\rho_\pi (E_t \pi_{t+1} - \pi^T) + \rho_y y_t\}$$

where $\rho_0 = (1 - \rho_i) i^*$.

In order to capture the effects of uncertainty we extend the Taylor rule as

(4) $$i_t = \rho_0 + \rho_{it} i_{t-1} + (1 - \rho_{it})\{\rho_{\pi t} (E_t \pi_{t+1} - \pi^T) + \rho_{yt} y_t\}$$

where $\rho_{it} = \rho_i + \rho_i^{\pi}\sigma_{\pi t} + \rho_i^{y}\sigma_{yt}$, $\rho_{\pi t} = \rho_{\pi} + \rho_{\pi}^{\pi}\sigma_{\pi t} + \rho_{\pi}^{y}\sigma_{yt}$, $\rho_{yt} = \rho_y + \rho_y^{\pi}\sigma_{\pi t} + \rho_y^{y}\sigma_{yt}$ and $\sigma_{\pi t}$ and σ_{yt} are measures of uncertainty over inflation and the output gap respectively. In equation (4), the Taylor rule coefficients vary over time in responses to changes in uncertainty. This model can be used to test whether the predictions of the literature on optimal responses to uncertainty are reflected in the behaviour of policymakers. If, as the theoretical literature suggests, increased uncertainty leads to a more passive response to a variable[1], then $\rho_{\pi}^{\pi} < 0$ and $\rho_y^{y} < 0$. If increased uncertainty about one variable strengthens the response to other variables, then $\rho_{\pi}^{y} > 0$ and $\rho_y^{\pi} > 0$. We also expect $\rho_i^{\pi} > 0$ and $\rho_i^{y} > 0$.

We assess the adequacy of our model by comparing estimates of (4) with estimates of the augmented model

$$i_t = \rho_0 + \rho_{it} i_{t-1} + (1 - \rho_{it})\{\rho_{\pi t}(E_t \pi_{t+1} - \pi^T) + \rho_{yt} y_t\} + \rho_{\sigma_\pi}\sigma_{\pi t} + \rho_{\sigma_y}\sigma_{yt} \tag{5}$$

This equation adds measures of inflation and output gap uncertainty to (4) to allow for an additional direct effect of uncertainty on monetary policy[2]. The proposition that uncertainty should only affect the response of interest rates to inflation and the output gap implies that $\rho_{\sigma_\pi} = \rho_{\sigma_y} = 0$ in (5).

We can use estimates of our model of monetary policy under uncertainty to infer what interest rates would have been if there had been no uncertainty by constructing the counterfactual interest rate

[1] Greenspan (2003) and Yellen (2003) discuss instances where monetary policy responded more strongly to uncertainty. Occasional departures from the Brainard principle can be rationalised in some cases (Soderstrom, 2000).

[2] A simplified version of (5) in which $\rho_{\pi t}$ and ρ_{yt} are constants has been used by Dolado et al. (2002), who find that inflation uncertainty had a negative impact on US interest rates for 1970-79 but has had a positive effect since 1983.

(6) $$i_t^c = \hat{\rho}_0 + \hat{\rho}_i i_{t-1} + (1-\hat{\rho}_i)\{\hat{\rho}_\pi (E_t \pi_{t+1} - \pi^T) + \hat{\rho}_y y_t\}$$

where $\hat{\rho}_0$, $\hat{\rho}_i$, $\hat{\rho}_\pi$ and $\hat{\rho}_y$ are estimates of the corresponding parameters in (4). Equation (6) is simply the fitted value of (4) but where $\sigma_{\pi t} = \sigma_{yt} = 0$ for all t. We can then estimate the counterfactual monetary policy rule

(7) $$i^c{}_t = \rho_0^c + \rho_i^c i^c{}_{t-1} + (1-\rho_i^c)\{\rho_\pi^c (E_t \pi_{t+1} - \pi^T) + \rho_y^c y_t\}$$

This is the monetary policy rule that our estimates of (4) suggest would have been followed had inflation and the output gap been known with certainty.

3) Empirical Results

We use quarterly UK data for 1992Q3-2003Q3. We focus on this period because there is evidence of frequent changes in monetary policy behaviour before the introduction of inflation targets in October 1992 (Nelson, 2003). We use the 3-month treasury bill rate as the nominal interest rate (this has a close relationship with the various interest rate instruments used over this period; see Nelson, 2003), inflation is the annual change in the retail price index and output is GDP. We model the output gap as the difference between output and a Hodrick and Prescott (1997) trend. Unit root tests show that the interest rate, inflation and the output gap are all stationary.

We use the implied volatility of inflation and the output gap from GARCH models to measure uncertainty (for a similar approach, see Grier and Perry, 2000). We experimented with different GARCH representations and our preferred specifications are reported in Table 1. For inflation, we report a Phillips curve with an ARCH(1) component, whereas for the output gap we report a univariate model with an ARCH(1) component. Notice, that the conditional variance for inflation and output are generated regressors that measure with noise the true but unobserved regressors (see e.g. Pagan, 1984 and Pagan and

Ullah, 1988). The estimates can be biased and inconsistent if the ARCH-type models employed are misspecified. To check this, we follow Pagan and Ullah (1988) in testing the squared residuals of the estimated ARCH models for neglected serial correlation of up to order 4. The Lagrange Multiplier (LM) F-test statistics for the ARCH model of inflation and the output gap reported at the bottom of Table 1 suggest no evidence of misspecification. Therefore, our ARCH models capture adequately the conditional heteroscedasticity present in the inflation and output data for the UK. We estimated a variety of other GARCH models to assess the robustness of our estimates. These alternative models had similar patterns of volatility, so we are confident that our measures of uncertainty are robust. The volatility of inflation and the output gap are presented in figures 1 and 2. Uncertainty about inflation is most marked in early 1994, after the general election of mid-1997, in late 2001 and in late 2002 and early 2003. Uncertainty about the output gap is greater from early 2000 to late 2001 and is also high in early 1995.

Estimates of the simple Taylor rule model of monetary policy in (3) are presented in column (i) of Table 2. We treat inflation and the output gap as endogenous, replacing expected future inflation with actual future inflation and using lagged variables as instruments for inflation and the output gap. The estimates indicate that interest rates increase by 1.65 percentage points in response to a 1 percentage point excess of inflation over the inflation target and increase by 0.54 percentage points in response to a 1 percentage point excess of output over equilibrium output (the output gap is not statistically significant). The estimated residuals appear to be white noise. However the model does fail the parameter stability test. We also note that the residuals are relatively large in late 1999 and after 2002Q1, which are periods of greater uncertainty.

Estimates of the augmented Taylor rule model in (4) are presented in column (ii) of Table 2. After removing insignificant effects, we obtained a simplified model whose estimates are presented in column (iii). The inclusion of measures of uncertainty improves the fit of the model and the estimates in

columns (ii) and (iii) pass the parameter stability test[3]. We find that $\rho_\pi^\pi < 0$ and $\rho_\pi^y > 0$. The response of interest rates to inflation is therefore weaker when inflation is more uncertain and stronger when the output gap is more uncertain (although this latter effect is not statistically significant). These effects are consistent with the predictions of the theoretical literature. The smaller response to inflation when inflation is less certain is consistent with the Brainard principle, while the larger response to inflation when output is less certain is consistent with the predictions of Peersman and Smets (1999) and Swanson (2004). We also note that the average value of $\rho_{\pi t} = \rho_\pi + \rho_\pi^\pi \sigma_{\pi t} + \rho_\pi^y \sigma_{yt}$ is 1.55 for the estimates in column (ii) and 1.64 for the estimates in column (iii). These are similar to the estimate of ρ_π in column (i), showing that introducing uncertainty does not affect the average estimated response to inflation.

We estimated a variety of alternative models in order to assess the robustness of our findings (these and other estimates that are not reported are available on request). We estimated the model of column (iii) of table 2) using three alternative volatility measures. These were (i) derived from recursive estimates of our GARCH and ARCH models, (ii) based on simultaneous estimates of GARCH and ARCH models and the policy rule in (4)[4] and (iii) measured as a four quarter backward-looking moving average of the measures derived from the estimates of table 1). In each case the estimates of ρ_i, ρ_i^π and ρ_i^y had the same sign and a similar magnitude to those reported in column (iii) of table 2). The average values of $\rho_{\pi t}$ were also similar to the value implied by the estimates of column (iii) of table 2). We also experimented with three alternative measures of the output gap, derived from (i) the Kalman Filter, (ii) the band pass

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[3] We also estimated models that imposed $\rho_\pi^y = 0$ and both $\rho_\pi^y = 0$ and $\rho_y = 0$. These models explained the data less well than the estimates presented in Table 2.

[4] simultaneous estimation of the full system proved to be computationally difficult. We therefore fixed initial values for the GARCH parameters and estimated equation (4) and the mean components of the inflation and output gap models by 3SLS. We then used these estimates to obtain updated estimates of the GARCH parameters and iterated the process until we achieved convergence.

filter of Christiano and Fitzgerald (1999) and (iii) a regression of output on a quadratic trend. The estimates were again similar to those reported in Table 2, although the effect of output gap uncertainty is less well determined. On balance, it appears that our estimates are robust.

We also estimated policy rules that used RPIX inflation rather than RPI inflation. RPIX inflation was insignificant in estimates of the baseline Taylor rule in (3). In addition, the standard error was much larger than that reported in column (i) of table 2) and the estimates suffered from serial correlation. Estimates of (4) had the same sign as those reported in columns (ii) and (iii) of table 2) but all estimated parameters were insignificant and the models had a higher standard error. Other estimates that used the Bank of England's published measures of uncertainty over RPIX inflation were equally unsuccessful.

Column (iv) of Table 2 reports estimates of the alternative model of monetary policy under uncertainty in (5) using the specification in column (iii) of Table 2. The effects of uncertainty are insignificant, their inclusion does not affect estimates of the other parameters and this model has a higher standard error than other models and also fails the parameter stability test. We also estimated (5) with the specification in column (ii) of Table 2. The estimates were less well determined and the standard error was higher than any reported in Table 2. Also neither ρ_{σ_π} nor ρ_{σ_y} were significant when uncertainty measures were added to the simple Taylor rule in (3), this model also had a high standard error. We therefore conclude that the model in (4) provides a better explanation of UK monetary policy and that uncertainty only affects monetary policy by changing the response of interest rates to inflation and the output gap.

We then used the estimates in column (iii) of Table 2 to construct estimates of the counterfactual interest rate i_t^c. Figure 3 plots the two series. As shown in Table 3, we cannot reject the hypothesis that i_t^c has the same mean as i_t, but can reject the hypothesis that the series have the same standard deviation. This implies that uncertainty has not affected the average level of

interest rates but has made interest rates less volatile. We note that the largest gaps between actual and counterfactual interest rates occur in early 1995 (when output uncertainty was high), in late 1997 (possibly reflecting the South East Asian crisis that began in July 1997), in early 1999 (possibly reflecting the Russian crisis of mid-late 1998 or the introduction of the Euro in January 1999) and in late 2001 (reflecting the events of September 11 2001 or the uncertain economic environment in the US).

The counterfactual monetary policy rule was estimated as (standard errors in parentheses)

$$i^c{}_t = \underset{(0.252)}{3.756} + \underset{(0.044)}{0.308}\, i^c{}_{t-1} + \underset{(-)}{(1-0.308)}\ \{\underset{(0.171)}{3.398}(E_t\pi_{t+1} - \pi^T) + \underset{(0.189)}{0.256}\, y_t\} \tag{8}$$

We note that the weight on the lagged interest rate in estimates of the Taylor rule in (3) is 0.76, but only 0.31 in the counterfactual Taylor rule. By contrast the weight on inflation in (3) is 1.65 but rises to 3.40 in the counterfactual rule. The output gap is insignificant in both. It appears therefore that uncertainty has led to a more passive monetary policy. This is consistent with Goodhart's (1999) discussion of the impact of uncertainty on UK monetary policy. It is also consistent with more indirect evidence in Martin and Salmon (1999) and Sack (2000), who use estimates of VAR models to find the optimal response of policymakers to uncertainty. They find that optimal monetary policy rules give less weight to inflation and greater weight to the output gap when uncertainty is higher (see also, Hall et al, 1999, Goodhart, 1999, Martin, 1999 and Rudebusch, 2001).

4) Conclusions

This paper has estimated the impact of uncertainty on monetary policy using data for the UK since the introduction of inflation targets in October 1992. We have proposed an empirical model in which uncertainty affects the response

of policymakers to inflation and the output gap in an otherwise standard monetary policy rule. We have found clear evidence that monetary policy has been affected by uncertainty. The response of policymakers to inflation is smaller when inflation is more uncertain but is larger when the output gap is more uncertain. We have used estimates of our model of monetary policy to construct counterfactual measures of what the interest rate would have been had there been no uncertainty. The mean value of the counterfactual interest rate is similar to that observed in the data, but is more volatile, suggesting that uncertainty has not affected the average value of interest rates but has led to less volatile policy. We also estimated a counterfactual monetary policy rule to show what monetary policy would have been if there had been no uncertainty. The weight on inflation is considerably larger and the weight on the lagged interest rate is considerably lower in the counterfactual monetary policy rule, suggesting that monetary policy would have been less passive in the absence of uncertainty.

Our work can be extended in a number of ways. This approach can be applied to other countries in order to see whether there is a clear pattern in the response of monetary policy to uncertainty. Monetary policy can also be allowed to respond to other influences. It would be interesting to analyse the response of monetary policy to uncertainty over the exchange rate and asset prices, especially house prices. We intend to address these issues in future work.

Table 1

Implied volatility models

Inflation model: $\pi_t = \pi_{t-1} + \gamma_0 y_t + \varepsilon_t \,, \sigma_{\pi t}^2 = \omega_0 + \omega_1 \varepsilon_{t-1}^2$

Output gap model: $y_t = \delta_0 + \delta_1 y_{t-1} + \delta_2 y_{t-2} + \delta_3 y_{t-3} + \delta_4 y_{t-4} + \eta_t \,, \sigma_{yt}^2 = \phi_0 + \phi_1 \eta_{t-1}^2$

	Inflation	Output gap
γ_0	0.197 (0.083)	
ω_0	0.291 (0.079)	
ω_1	0.253 (0.130)	
δ_0		-0.026 (0.034)
δ_1		1.325 (0.168)
δ_2		-0.592 (0.264)
δ_3		0.551 (0.207)
δ_4		-0.420 (0.112)
ϕ_0		0.047 (0.015)
ϕ_1		0.622 (0.310)
Neglected ARCH	1.14 [0.35]	0.82 [0.52]

Notes: Numbers in parentheses are the standard errors of the estimates. Neglected ARCH is the Lagrange Multiplier F test on the squared residuals for remaining serial correlation of order 4. Numbers in square brackets are the probability values of the test statistics.

Table 2
Estimates of Augmented Taylor Rules

$$
\begin{aligned}
i_t &= \rho_0 + (\rho_i + \rho_i^{\pi}\sigma_{\pi t} + \rho_i^{y}\sigma_{yt})i_{t-1} \\
&+(1 - \rho_i - \rho_i^{\pi}\sigma_{\pi t} - \rho_i^{y}\sigma_{yt}) \\
&\{(\rho_\pi + \rho_\pi^{\pi}\sigma_{\pi t} + \rho_\pi^{y}\sigma_{yt})(E_t\pi_{t+1} - \pi^T) \\
&+(\rho_y + \rho_y^{\pi}\sigma_{\pi t} + \rho_y^{y}\sigma_{yt})y_t\}
\end{aligned}
$$

Sample: 1992Q4-2003Q3
IV Estimates

	(i)	(ii)	(iii)	(iv)
ρ_0	1.244 (0.323)	1.150 (0.313)	1.143 (0.293)	1.765 (0.670)
ρ_i	0.762 (0.056)	0.865 (0.115)	0.773 (0.051)	0.769 (0.052)
ρ_i^{π}		-0.156 (0.195)		
ρ_i^{y}		0.020 (0.149)		
ρ_π	1.646 (0.484)	9.532 (4.082)	11.700 (4.431)	9.960 (3.871)
ρ_π^{π}		-16.869 (7.257)	-19.660 (7.949)	-17.295 (7.056)
ρ_π^{y}		7.036 (3.983)	5.950 (3.890)	6.373 (3.526)
ρ_y	0.540 (0.466)	3.152 (4.756)	0.540 (0.453)	0.732 (0.463)
ρ_y^{π}		-2.216 (7.237)		
ρ_y^{y}		-3.883 (5.317)		
$\rho_{\sigma\pi}$				-0.887 (1.001)
$\rho_{\sigma y}$				-0.220 (0.683)
Adjust. R^2	0.873	0.886	0.906	0.891
s.e.	0.380	0.360	0.351	0.363
AIC	0.987	0.999	0.862	0.920
AR	2.08 [0.09]	0.61 [0.69]	1.97 [0.85]	2.16 [0.07]
Het	1.18 [0.34]	0.49 [0.92]	0.83 [0.61]	0.85 [0.58]
ARCH	0.56 [0.68]	2.03 [0.12]	1.86 [0.14]	2.23 [0.08]
Norm	0.05 [0.97]	1.53 [0.46]	0.19 [0.91]	0.23 [0.89]
Parameter stability	5.63 [0.00]	1.81 [0.11]	2.44 [0.06]	2.99 [0.02]

Notes: Numbers in parentheses are the standard errors of the estimates. s.e. is the regression standard error. AIC is the Akaike information criterion. AR is the Lagrange Multiplier F test for residual serial correlation of up to fourth order. Het is an F test for heteroscedasticity. ARCH is the fourth order Autoregressive Conditional Heteroscedasticity F test. Norm is a Chi-square test for normality. Parameter stability is an F test of parameter stability (see Lin and Teräsvirta, 1994, and Eitrheim and Teräsvirta, 1996). Numbers in square brackets are the probability values of the test statistics.

Table 3

The Actual and Counterfactual Interest Rates

	Mean	Standard deviation
Actual interest rate (i_t)	5.482	1.069
Counterfactual interest rate (i_t^c)	5.325	2.501
	H_0: means are equal F-test=0.09 [0.76]	H_0: standard deviations are equal F-test=5.33 [0.00]

Note: Numbers in square brackets are the probability values of the test statistics.

Figure 1

The volatility of Inflation

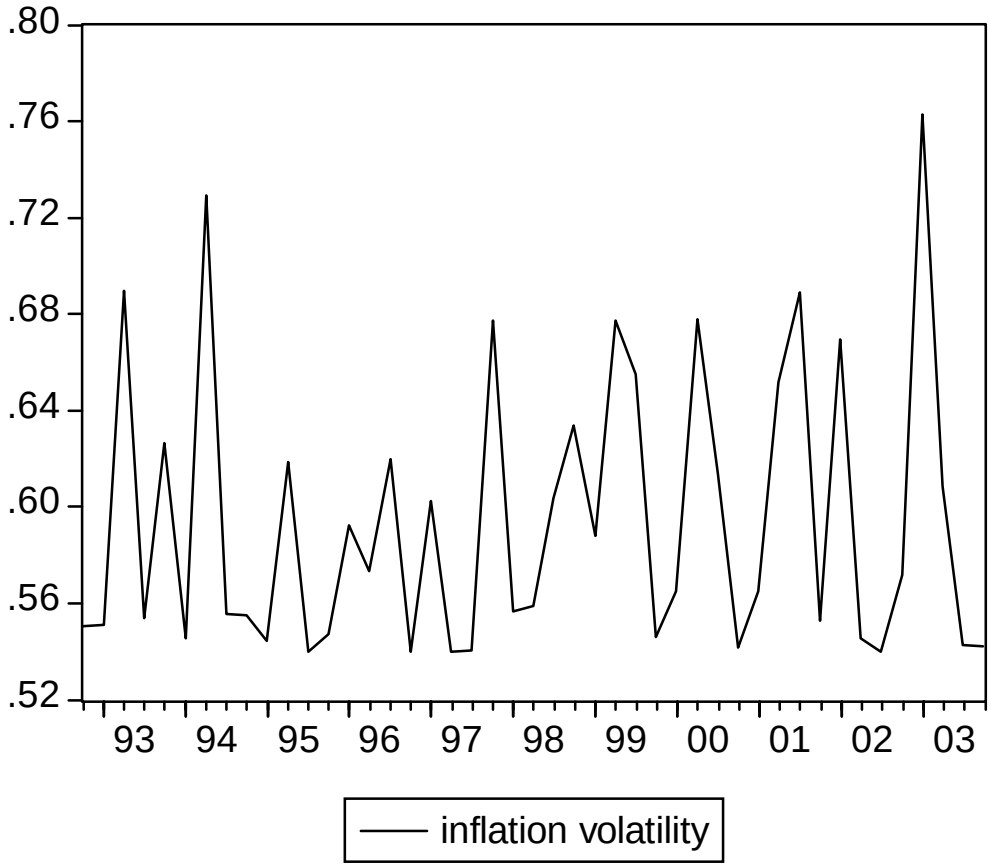


Figure 2

The volatility of the output gap

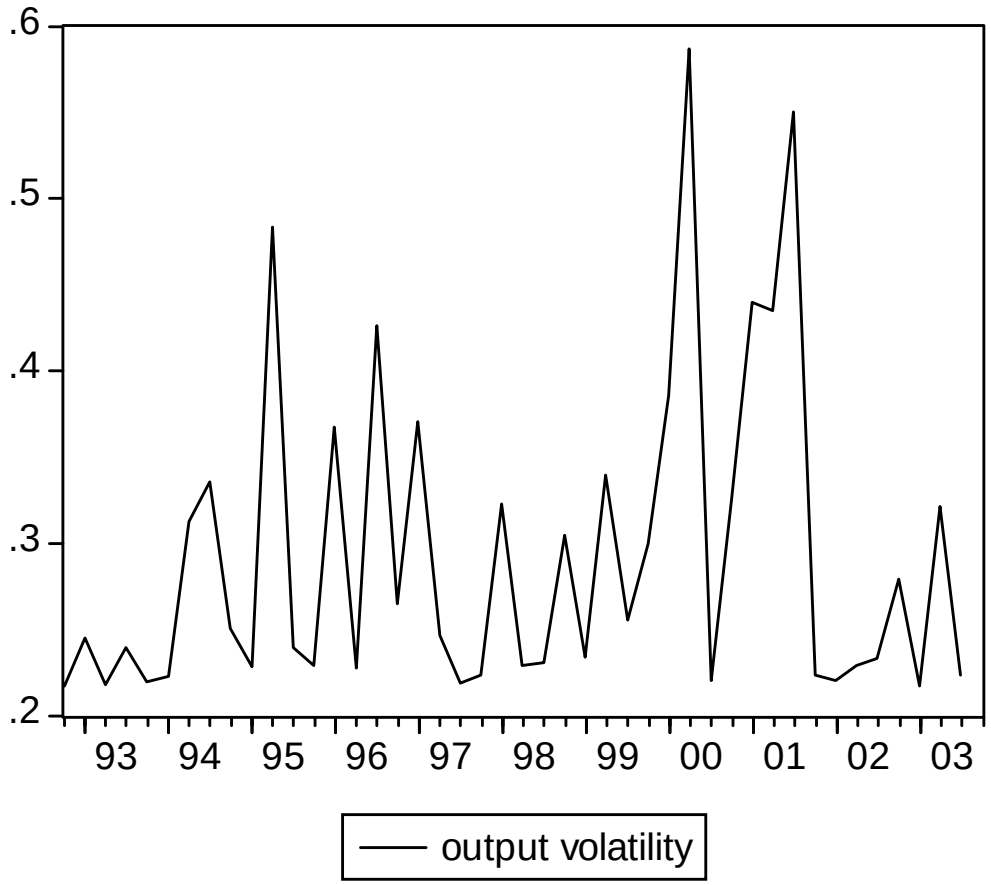
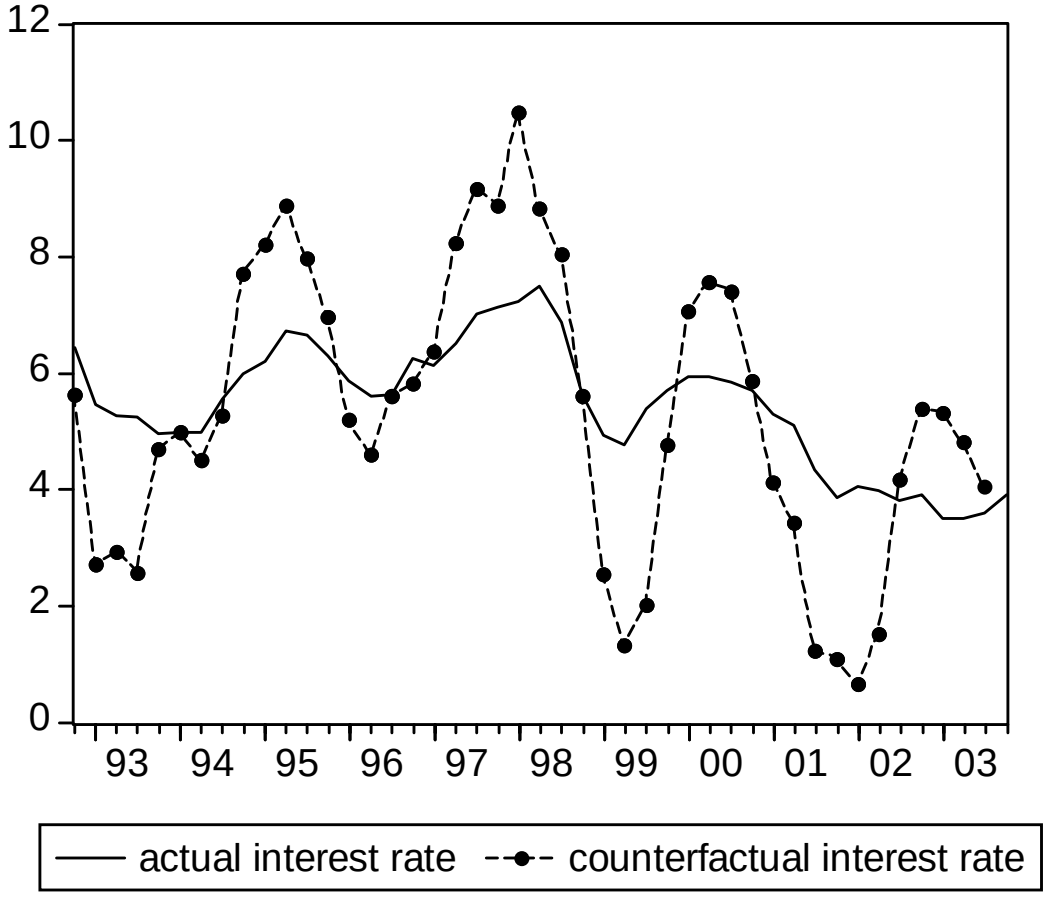


Figure 3

Counterfactual interest rate i_t^c against the actual interest rate i_t



References

Brainard, W. (1967). Uncertainty and the effectiveness of policy, American Economic Review, 57, pp 411-425.

Castelnuovo, E. (2003). Taylor rules, omitted variables and interest rate smoothing in the US, Economics Letters, 81, pp 55-59.

Christiano, L.J. and T. Fitzgerald, (1999). The Band Pass Filter, NBER Working Paper No. 7257. Forthcoming in the International Economics Review

Dolado, J., R. María Dolores and F.J. Ruge-Murcia (2002). Non-linear monetary policy rules: Some new evidence for the US. Centre for Economic Policy Research Discussion Paper No. 3405.

Eitrheim, Ø. and T. Teräsvirta (1996). Testing the adequacy of smooth transition autoregressive models, Journal of Econometrics, 74, pp 59-75.

Goodhart, C. (1999). Central Bankers and Uncertainty, Bank of England Quarterly Review, February, pp 102-121.

Greenspan, A. (2003). Remarks, in Monetary Policy and Uncertainty: Adapting to a Changing Economy, Federal Reserve Bank of Kansas City.

Grier, K. and M. Perry (2000). The Effects of Real and Nominal Uncertainty on Inflation and Output Growth: Some GARCH-M Evidence, Journal of Applied Econometrics, 15, pp 45-58

Hall, S., C. Salmon, T. Yates and N. Batini (1999). Uncertainty and simple monetary policy rules - An illustration for the United Kingdom, Working Paper 96, Bank of England.

Hodrick, R.J. and E.C. Prescott (1997). Postwar U.S. business cycles: An empirical investigation, Journal of Money, Credit, and Banking, 29, pp 1–16.

Judd, J. and G. Rudebusch (1998). Taylor's rule and the fed: 1970-97, Federal Reserve Bank of San Francisco Economic Review, 3, pp 3-16.

Lin, C-F.J. and T. Teräsvirta (1994). Testing the constancy of regression parameters against continuous structural change, Journal of Econometrics, 62, pp 211-228.

Martin, B. (1999). Caution and gradualism in monetary policy under uncertainty, Working Paper 105, Bank of England.

Martin, B. and C. Salmon (1999), Should Uncertain Monetary Policymakers Do Less?, Working Paper 99, Bank of England.

Nelson, E. (2003). UK Monetary Policy 1972–97: A Guide Using Taylor Rules, in P. Mizen (ed.), Central Banking, Monetary Theory and Practice: Essays in Honour of Charles Goodhart, Volume One. Cheltenham, UK: Edward Elgar, 2003.

Pagan, A. (1984). Econometric issues in the analysis of regressions with generated regressors, International Economic Review, 25, pp 221-247.

Pagan, A. and A. Ullah (1988). The econometric analysis of models with risk terms, Journal of Applied Econometrics, 3, pp 87-105.

Peersman, G. and F. Smets (1999). The Taylor Rule: a useful monetary policy benchmark for the Euro Area? International Finance, 2, pp 85-116.

Rudebusch, G. (2001). Is the Fed too timid? Monetary policy in an uncertain world, Review of Economics and Statistics, 88, pp 203-17.

Rudebusch, G. (2002). Term structure evidence on interest rate smoothing and monetary policy inertia, Journal of Monetary Economics, 49, pp 1161-1187.

Sack, B. (2000). Does the Fed act gradually? A VAR analysis, Journal of Monetary Economics, 46, pp 229-256.

Smets, F. (1999). Output gap uncertainty: does it matter for the Taylor Rule? In B. B. Hunt and A. Orr (eds), Monetary policy under uncertainty, Reserve Bank of New Zealand.

Soderstrom, U. (2000). Monetary policy with uncertain parameters. European Central Bank Working Paper 13.

Srour, G. (2003). Some notes on monetary policy rules with uncertainty, Bank of Canada Working Paper 2003-16.

Swanson, E. (2004). On signal extraction and non-certainty-equivalence in optimal monetary policy rules, Macroeconomic Dynamics, 8, pp 27-50.

Taylor, J. (1993). Discretion versus policy rules in practice, Carnegie-Rochester Conference Series on Public Policy, 39, pp 195-214.

Walsh, C. (2003). Implications of a changing economic structure for the strategy of monetary policy, in Monetary Policy and Uncertainty: Adapting to a Changing Economy, Federal Reserve Bank of Kansas City.

Yellen, J. (2003). Remarks, in Monetary Policy and Uncertainty: Adapting to a Changing Economy, Federal Reserve Bank of Kansas City.