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"THE COMPLEX RESPONSE OF MONETARY POLICY TO THE EXCHANGE RATE"

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The Complex Response of Monetary Policy to the Exchange Rate

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Abstract

We estimate a flexible non-linear monetary policy rule for the UK to examine the response of policymakers to the real exchange rate. We have three main findings. First, policymakers respond to real exchange rate misalignment rather than to the real exchange rate itself. Second, policymakers ignore small deviations of the exchange rate; they only respond to real exchange under-valuations of more than 4% and over-valuations of more than 5%. Third, the response of policymakers to inflation is smaller when the exchange rate is over-valued and larger when it is under-valued. None of these responses is allowed for in the widely-used Taylor rule, suggesting that monetary policy is better analysed using a more sophisticated model, such as the one suggested in this paper.

JEL: C51; C52; E52; E58

Keywords: monetary policy, asset prices, nonlinearity

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The Complex Response of Monetary Policy to the Exchange Rate

1) Introduction

The importance of the exchange rate to monetary policy is reflected in large academic and policy-related literatures on the topic. We contribute to this literature by addressing three issues. First, although empirical models of open-economy monetary policy rules assume that interest rates respond to the exchange rate, policymakers and economic commentators often focus on exchange rate misalignment rather than the exchange rate itself. We therefore investigate whether interest rates respond to exchange rate misalignments rather than to the exchange rate itself. Second, existing models assume that policymakers respond to all movements in the real exchange rate. This may not be the case. As a consequence of a desire to avoid frequent small adjustments of the interest rate and difficulties in measuring exchange rate misalignment with precision, policymakers may only respond to larger real exchange rate misalignments. We investigate the evidence for this. Third, since the exchange rate influences inflation, we might expect the response of policymakers to inflation to depend on the exchange rate. For example, we might expect a less vigorous response to inflation when the exchange rate is over-valued and thus exerting downward pressure on inflation. We assess evidence for this.

We proceed as follows. Considering the issue of whether policymakers respond to exchange rates or to misalignments, the academic literature has tested the significance of the real exchange rate in monetary policy rules by estimating augmented Taylor rules which relate interest rates to inflation, the output gap and the exchange rate. However contributions by policymakers suggest another approach. For example, Nickell (2005), in discussing the appreciation of sterling that began in 1996 comments that "the dramatic rise in 1996/7.. led people to refer to unsustainability, misalignment and even bubbles… However as time passed and sterling [did not depreciate], talk of unsustainability and misalignment died away". This suggests that policymakers may have responded to real exchange rate misalignments rather than the real exchange rate itself. This implies that existing models may be mispecified. We test whether policymakers respond to the real exchange rate itself or to exchange rate misalignments by comparing estimates of an augmented Taylor rule that includes the exchange rate against one that includes exchange rate misalignment.

We then consider whether the response of monetary policy to the real exchange rate is more sophisticated than allowed for in the simple monetary policy rules that have been used thus far in the literature. These monetary policy rules assume a constant proportional response to the exchange rate. However this may be too simplistic. As quoted in Adam et al (2005), the minutes of the March 1999 meeting of the Monetary Policy Committee (MPC) state "it would not be sensible for policy to react to high frequency movements in the exchange rate as this could lead to a more volatile path for interest rates..[which might].. make it more difficult for others to understand the motives for interest rate changes". Taken together with the difficulty in accurately measuring exchange rate misalignment, this suggests that policymakers may respond more vigorously to larger exchange rate misalignments. Indeed the MPC minutes suggest that policymakers may only respond to large exchange rate misalignments.

We also consider whether the real exchange rate affects the response of policymakers to the inflation rate. Exchange rate misalignments affect the inflation rate; a large over-valuation, for example, places downward pressure on inflation. One might then expect the response of policymakers to inflation to depend on the exchange rate, so that the response of policymakers to the inflation rate might be smaller when the exchange rate is substantially over-valued.

These latter two issues cannot be addressed using a conventional linear monetary policy rule, as this assumes a constant proportional response to inflation and the exchange rate and assumes that the marginal response to one variable is independent of the values of other variables. These issues require a model in which the response to the exchange rate can differ depending on whether this is under-valued, over-valued or close to fundamentals. It also requires a model in which the response to inflation depends on the real exchange rate. We therefore use a model which allows for these effects.

We address these issues using data for the UK since 1992, so our sample comprises the period of inflation targeting. We have a number of interesting findings. First, we find that Taylor rule models that include measures of real exchange rate misalignments outperform models that include the exchange rate. This suggests that the latter type of model is mispecified and that policymakers respond to real exchange rate misalignment rather than the real exchange rate itself. Second, we find that policymakers only respond to larger misalignments of the real exchange rate. Our estimates suggest that there is no response to the real exchange rate if exchange rates are under-valued by less than 4.4% or over-valued by less than 5.1%. As we discuss, these estimates imply that policymakers raised interest rates in response to under-valuations of the exchange rate in 1992-1993, 1995-1996 and reduced interest rates in response to an over-valuation in 1996-1998, but did not respond to the exchange rate at other times. Third, we find that the response of policymakers to inflation does depend on the exchange rate. The response is strongest when the exchange rate is significantly under-valued and weakest when it is over-valued. This implies that the increase in interest rates in response to excessive inflation is stronger in periods when exchange rate under-valuation intensifies inflationary pressures. To illustrate, although inflation was excessively high in 1995-1996 and in 1997-1998, the response to inflation was stronger in the first period when the exchange was under-valued and weaker in the latter when the exchange rate was over-valued.

The remainder of the paper is structured as follows. Section 2) addresses the issue of whether policymakers respond to exchange rates or to misalignment, explaining our methodology and presenting estimates that suggest that the response is to misalignments. Section 3) addresses the remaining issues, explaining the multiple-regime model and presenting estimates. Section 4) summarises and concludes.

2) Monetary policy and real exchange rate misalignment

We assume that policymakers' preferences are given by

(1) $$\sum_{j=0}^{\infty} \delta^j L_{t+j}$$

where δ is the discount rate and L is the per-period loss function, given by

(2) $$L_t = \frac{1}{2}(\pi_t - \pi^T)^2 + \frac{\lambda}{2} y_t^2 + \frac{\mu}{2}(i_t - i^*)^2 + \frac{\gamma}{2} F_t^2$$

The loss function depends on the divergence of the inflation rate (π) from the inflation target (π^T), the output gap (y), on the divergence of the nominal interest rate (i) from its' equilibrium value (i*) and on potentially destabilising capital flows (F).

The aggregate demand curve is

(3) $$y_t = \bar{y}_t - \omega\left(i_{t-1} - \pi_t\right) + \varepsilon_t^d$$

where $\bar{y}$ captures other determinants of aggregate demand and ε_t^d is an i.i.d demand shock. This is a standard forward-looking demand relationship. Aggregate supply is the familiar New-Keynesian Philips curve

(4) $$\pi_t = ky_t + \theta E_t \pi_{t+1} + \varepsilon_t^s$$

where ε_t^s is an i.i.d supply shock. Capital flows depend on the differential between domestic and foreign interest rates and on the deviation of the real exchange rate (defined as the real price of domestic currency in terms of foreign currency) from its' fundamental value:

(5) $$F_t = \beta_1(i_t - i^f{}_t) - \beta_2(e_t - e^*{}_t)$$

where i^f is the foreign interest rate, e is the real exchange rate and e^* is the fundamental value of the real exchange rate.

Assuming that policymakers choose the nominal interest rate at the start of period t using information available up to the end of period $(t-1)$, the first-order condition is

(6) $$E_{t-1}(\pi-\pi^T)_{t+1}\frac{d\pi_{t+1}}{dy_{t+1}}\frac{dy_{t+1}}{di_t}+\lambda E_{t-1}y_{t+1}\frac{dy_{t+1}}{di_t}+\mu(i_t\ \text{-i*})+\gamma E_{t-1}F_t\frac{dF_t}{di_t}=0$$

Using (3)-(5) this can be written as

(7) $$-k\omega E_{t-1}(\pi-\pi^T)_{t+1}-\lambda\omega E_{t-1}y_{t+1}+\mu(i_t\ \text{-i*})+\gamma_1(\beta_1(i_t-i^f{}_t)-\beta_2(e_t-e*_t))=0$$

where $\gamma_1=\gamma(\beta_1-\beta_2\phi)$ and $\phi=\frac{de_t}{di_t}$ ($\gamma_1>0$ since $\phi<0$). Solving this, we can express the optimal monetary policy rule as

(8) $$\hat{i}_t=\tilde{i}+\rho_\pi E_{t-1}(\pi-\pi^T)_{t+1}+\rho_y E_{t-1}y_{t+1}+\rho_f E_{t-1}i_t^f+\rho_e E_{t-1}(e_t-e*_t)$$

where $\tilde{i}=\frac{\mu i*}{\mu+\beta_1\gamma_1}$, $\rho_\pi=\frac{k\omega}{\mu+\beta_1\gamma_1}$, $\rho_y=\frac{\lambda\omega}{\mu+\beta_1\gamma_1}$, $\rho_f=\frac{\beta_1\gamma_1}{\mu+\beta_1\gamma_1}$ and $\rho_e=\frac{\beta_2\gamma_1}{\mu+\beta_1\gamma_1}$. Equation (8) is an open-economy Taylor rule. It differs from models estimated in the literature in that interest rates respond to real exchange rate misalignment rather than to the real exchange rate itself. In the remainder of this section we present empirical evidence on the superiority of the policy rule in (8) and argue that the existing model is mispecified.

Allowing for interest rate smoothing (which possibly arises for the reasons discussed in Woodford, 2003) by assuming that the actual nominal interest rate adjusts towards the desired rate by

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

and invoking rational expectations, the policy rule can be expressed as

(10) $$i_t = \rho_i i_{t-1} + (1-\rho_i)\{\tilde{i} + \rho_\pi(\pi - \pi^T)_{t+1} + \rho_y y_{t+1} + \rho_f i_t^f + \rho_e(e_t - e^*_t)\} + \varepsilon_t$$

where ε is an error term that contains the errors generated by replacing expected values of variables with actual values.

Estimates of this model are presented in column (i) of Table 1. We use UK data for the period 1992Q4-2005Q4. We measure i using the 3-month Treasury Bill Rate, π as the year-on-year proportional change in the retail price index, y as the proportional deviation of output from its underlying (Hodrick-Prescott, 1997) trend, i^f is the US 3-month effective funds rate and e is the log of the real effective exchange rate. These definitions are similar to the existing literature, although Adam et al (2005) use both US and German interest rates (we also present estimates that use this rate), while Chadha et al (2004) measure the output gap using the share of labour in national income (Gali et al, 2001). Since 1997Q2 (when the Bank of England was given operational independence), the inflation target, π^T, is equal to 2.5 percent. Prior to that date, we construct the target as the centred two-year moving average of actual inflation (see also the discussion in Kesriyeli et al, 2006). Figure 1 plots the UK interest rate, UK inflation rate, UK output gap, the US interest rate and the German (Euro after 1999) interest rate.

We calculate the equilibrium real exchange rate as the Hodrick-Prescott filtered value (Hodrick and Prescott, 1997) of the real exchange rate and calculate exchange rate misalignment as the difference between the real exchange rate and its trend value. The resultant series is plotted in Figure 2, alongside the exchange rate. The narrative in Cobham (2006) provides a detailed description of movements in the exchange rate over this period and the concerns of policymakers about this, while Batini and Nelson (2005) provide a broader historical perspective. The exchange rate was under-valued between 1993-1996, over-valued from 1996-2000 and close to equilibrium thereafter. The effects of the appreciation that began in 1996 are initially marked but fall away quite rapidly. This is consistent with the comments of Nickell (2005) cited above. Although a more satisfactory measure of real exchange rate misalignment might be derived from a more structural model, we would argue that the measure depicted in Figure 2 is plausible and will serve as a satisfactory first approximation.

We estimate ρ_π=1.76 and ρ_y=0.91 (these are similar to other studies, eg Martin and Milas, 2003, and Mihailov, 2005), ρ_f=0.38 (this is also similar to previous studies, see Adam et al, 2005, Table 1) and ρ_e=0.10 (Chadha et al, 2004 report an estimate of 0.06 from a model using the exchange rate rather than misalignment). We test for a structural break (in 1997Q2 following the transfer of responsibility for interest rate decisions to the newly-formed monetary policy committee) but find none. Column (ii) presents estimates that use the German (Euro) rather than the US interest rate. The estimates are similar, although the model fits the data less well

As mentioned above, the existing literature on empirical open economy monetary policy rules typically uses a different model of the optimal policy rule, which can be summarised as

(11) $$i_t = \rho_i i_{t-1} + (1-\rho_i)\{\tilde{i} + \rho_\pi(\pi - \pi^T)_{t+1} + \rho_y y_{t+1} + \rho_f i_t^f + \rho_e e_t\} + \varepsilon_t$$

Adam et al (2005) use a specification similar to (11) but without the real exchange rate, while Chadha et al (2004) do not include the foreign interest rate. Equation (11) differs from the optimal rule in (10) in that interest rates respond to the exchange rate rather than to exchange rate misalignment.

Column (iii) of Table 1) presents estimates of (11) using the US interest rate to measure i_t^f. Although the estimates are broadly similar to those of (10) (although the coefficient on the exchange rate is now insignificant); it is clear that the fit of the model is worse. The model also fails the test of structural stability. Column (iv) reports estimates that use the German (Euro) interest rate; the fit of the model is worse than the corresponding estimates of (10) in column (ii). In summary, our estimates show that an open economy Taylor rule that includes real exchange rate misalignment is superior to one that includes the exchange rate. This suggests that the existing model is mispecified.

3) A more complex model

In this section we turn to the issues of whether policymakers only respond to larger exchange misalignments and whether the response to inflation depends on the exchange rate. Neither issue can be addressed using an augmented Taylor rule like (10). In that, interest rates respond to all exchange misalignments irrespective of their size, while the marginal response of interest rates to inflation is not affected by the exchange rate.

We therefore generalise (10) by using the time-varying parameter model

(12) $$i_t = \rho_i i_{t-1} + (1-\rho_i)\{\tilde{i} + \rho_{\pi t}(\pi - \pi^T)_{t+1} + \rho_{yt} y_{t+1} + \rho_f i_t^f + \rho_{et}(e_t - e*_t)\} + \varepsilon_t$$

If the behaviour of policymakers depends on whether the exchange rate is significantly over-valued or under-valued, the economy will have three distinct exchange rate “regimes”. The economy is in the over-valued regime if the degree of over-valuation exceeds a value of ϕ^O, while it is in the under-valued regime if the degree of under-valuation exceeds a value of ϕ^U. However there is also evidence that the behaviour of policymakers differs according to whether or not inflation is close to the inflation target (eg Martin and Milas, 2004; Srinivasan et al, 2006, Taylor and Davradakis, 2007). To allow for this, we also allow for two inflation regimes, depending on the divergence of inflation from the target. The economy is in the outer inflation regime if inflation exceeds the target by more than a value of τ^U or if it is below the target by more than τ^L. Since policymakers choose interest rates before the value of inflation, output and exchange rates are known, we can express the time-varying parameters in (12) in terms of the probabilities of the economy being in a particular regime, so

(13)
$$\begin{aligned}\rho_{jt} &= \theta_t^{\pi}\theta_t^{eO}\rho_{j1} + \theta_t^{\pi}\theta_t^{eU}\rho_{j2} + \theta_t^{\pi}(1-\theta_t^{eO} - \theta_t^{eU})\rho_{j3} \\ &+ (1-\theta_t^{\pi})\theta_t^{eO}\rho_{j4} + (1-\theta_t^{\pi})\theta_t^{eU}\rho_{j5} + (1-\theta_t^{\pi})(1-\theta_t^{eO} - \theta_t^{eU})\rho_{j6}\end{aligned}$$

for $j = \pi, y, e$ (initial experiments suggested constant parameters on the foreign interest rate and lagged interest rate). θ_t^{eO} is the probability that the real exchange rate in period t will be in the over-valued "regime" , θ_t^{eU} is the probability it will be in the under-valued regime and θ_t^{π} is the probability that inflation will not significantly diverge from the target.

This model is sophisticated enough to allow us to address the issues we are concerned with. If $\rho_{e3} = \rho_{e6} = 0$, then interest rates do not respond to the exchange rate when misalignments are small, as some commentators have suggested. If $\rho_{\pi 1}$ differs from $\rho_{\pi 2}$ and $\rho_{\pi 3}$, and $\rho_{\pi 4}$ differs from $\rho_{\pi 5}$ and $\rho_{\pi 6}$, then the response to inflation depends on exchange rate misalignment, as has been suggested. Clearly, estimating such a model on a relatively limited span of data is challenging. Fortunately, we were able to impose a series of restrictions that simplified estimation greatly. These were (i) interest rates only respond to output in the inner inflation and exchange rate regimes (this implies $\rho_{y1} = \rho_{y2} = \rho_{y4} = \rho_{y5} = \rho_{y6} = 0$); (ii) there is no response to inflation in the inner inflation regime ($\rho_{\pi 1} = \rho_{\pi 2} = \rho_{\pi 3} = 0$); (iii) there is no response to the exchange rate in the inner exchange rate regime ($\rho_{e3} = \rho_{e6} = 0$) and (iv) the response of interest rates to the real exchange rate is independent of the rate of inflation ($\rho_{e1} = \rho_{e2}$ and $\rho_{e4} = \rho_{e5}$).

We make the model operational by assuming

(14) $$\theta_t^{\pi} = \Pr\{\tau^L \le (\pi - \pi^T)_{t+1} \le \tau^U\} = 1 - \frac{1}{1 + e^{-\gamma^{\pi}(\pi_{t+1} - \pi_{t+1}^T - \tau^L)(\pi_{t+1} - \pi_{t+1}^T - \tau^U)/\sigma^2_{(\pi_{t+1} - \pi_{t+1}^T)}}}$$

(15) $$\theta_t^{eO} = \Pr\{(e_t - e_t^*) < \phi^O\} = 1 - \frac{1}{1 + e^{-\gamma^{eO}(e_t - e_t^* - \phi^O)/\sigma_{(e_t - e_t^*)}}}$$

(16) $$\theta_t^{eU} = \Pr\{\phi^U < (e_t - e_t^*)\} = \frac{1}{1 + e^{-\gamma^{eU}(e_t - e_t^* - \phi^U)/\sigma_{(e_t - e_t^*)}}}$$

Equation (14) models the probability that inflation is no less than τ^L percentage points below the target or no more than τ^U percentage points above (where we note that these regime boundaries may be asymmetric) using a quadratic logistic function, following Jansen and Teräsvirta (1996). Equations (15) and (16) model the probability that the economy is in the over-valued or under-valued exchange rate regimes using logistic functions. These functions use smoothness parameters γ^π, γ^{eO} and γ^{eU} that determine the smoothness of the transition regimes. We follow Granger and Teräsvirta (1993) and Teräsvirta (1994) in making γ^π dimension-free by dividing it by the variance of $\pi_{t+1} - \pi^T{}_{t+1}$ and making γ^{eO} and γ^{eU} dimension-free by dividing them by the standard deviation of $e_t - e_t^*$.

Estimates of the resulting model are presented in column (i) of Table 2. The standard error is substantially lower than for the Taylor rule models reported in Table 1, so this approach gives a much better fit to the data. We estimate the regime boundaries to be –0.522 and 0.261 for the inflation regime and –5.11 and 4.37 for the exchange rate regimes. These imply that the economy is in the inner inflation regime when inflation is expected to fall between $\pi^T{}_{t+1}$-0.522 and $\pi^T{}_{t+1}$+0.261 percent. Since the inflation target was 2.5% from 1997Q2 onwards, the upper boundary of 2.761% to the inner inflation regime is closer to the inflation target than the lower boundary of 1.978%. This implies a deflationary bias to monetary policy, confirming the findings of Martin and Milas (2004). The estimated boundaries to the exchange rate regimes imply that the economy is in the over-valued (resp. under-valued) exchange rate regime when the real exchange rate is over-valued by more than 5.11% (resp under-valued by more than 4.37%). Both inflation and exchange rate boundaries are asymmetric based on the statistical tests reported at the bottom of Table 2. [1]

There is no response of interest rates to the real exchange rate in the inner exchange rate regime. We therefore conclude that policymakers do not respond to the real exchange rate when this is over-valued by less than 5.11% or under-valued by less than 4.37%. We also find that the response to inflation does depend on the exchange rate. Interest rates do not respond to the inflation rate in the inner inflation regime, when inflation is expected to be between the π^T_{t+1}-0.522 and π^T_{t+1}+0.261 percent boundaries (between 1.978% and 2.761% from 1997Q2 onwards). In the outer inflation regime, the response to inflation is stronger when the exchange rate is in the under-valued exchange rate regime (i.e. $\rho_{\pi 5} = 3.047$) and weaker in the over-valued exchange rate regime (i.e. $\rho_{\pi 4} = 1.269$).

[1] The smoothness parameters γ^{π}, γ^{eO} and γ^{eU} reported in Table 2, are imprecisely estimated. Teräsvirta (1994) and van Dijk et al (2002) point out that this should not be interpreted as evidence against the model's validity. Accurate estimation of γ^{π}, γ^{eO} and γ^{eU} is problematic because it requires many observations in the immediate neighbourhood of the regime boundaries. Furthermore, large changes in the smoothness parameters have a small impact on the shape of the functions (14), (15) and (16), which implies that estimates of γ^{π}, γ^{eO} and γ^{eU} do not have to be precise (van Dijk et al, 2002).

Column (ii) of Table 2 reports estimates of the same model but where the German (Euro) is used in place of the US interest rate. These estimates lead to similar conclusions. In this model, policymakers do not respond to the real exchange rate when this is over-valued by less than 5.86% or under-valued by less than 4.96%. Policymakers do not respond to the inflation rate in the inner inflation regime, when inflation is expected to be between ${\pi^T}_{t+1}$-0.66 and ${\pi^T}_{t+1}$+0.194 percent (between 1.84% and 2.694% from 1997Q2 onwards). The response of interest rates to inflation is again stronger when the real exchange rate is under-valued.

The implications of these estimates for the interpretation of recent UK monetary policy are explored in figures 3 and 4. Figure 3) depicts real exchange rate misalignment and the estimated boundaries. Our estimates suggest that policymakers raised interest rates in response to under-valuations of the exchange rate in 1992-1993, 1995-1996 and reduced interest rates in response to an over-valuation in 1996-1998, but did not respond to the exchange rate at other times. Policymakers did not respond to the exchange rate between 1998-2005 as real exchange rate misalignment remained within the regime boundaries. By contrast, a Taylor rule model would imply frequent small interest rate adjustments in this period. Figure 4) depicts the respond of interest rates to inflation implied by the estimates of column (i) of table 2), calculated as:

(17) $$\rho_{\pi t} = (1-\theta_t^{\pi})\{\theta_t^{eO}\rho_{\pi 4} + \theta_t^{eU}\rho_{\pi 5} + (1-\theta_t^{eO} - \theta_t^{eU})\rho_{\pi 6}\}$$

To illustrate, although inflation was excessively high in 1995-1996 and in 1997-1998, the response to inflation was stronger in the first period when the exchange was under-valued and weaker in the latter when the exchange rate was over-valued.

4) Conclusions

This paper has estimated a flexible non-linear monetary policy rule for the UK to examine the response of policymakers to the real exchange rate. Three main findings emerge. First, policymakers respond to real exchange rate misalignments rather than to the exchange rate itself. Second, policymakers ignore small deviations of the exchange rate; they only respond to real exchange under-valuations of more than 4% and over-valuations of more than 5%. Third, the response of policymakers to inflation depends on the exchange rate. The response to inflation is smaller when the exchange rate is over-valued and larger when it is under-valued.

Our work can be extended in several ways. We might estimate our model using data for different countries in order to investigate the impact of the exchange rate on monetary policy and assess whether the response of monetary policy to inflation depends on the exchange rate. We might also develop a more structural model of the exchange rate and examine its effect on the monetary policy rule. We intend to address these issues in future work.

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Table 1: Estimates of Augmented Taylor rules (1992Q4 2005Q4)

	(i)	(ii)	(iii)	(iv)
	Model with US interest rate and exchange rate misalignment regressors	Model with German (Euro) interest rate and exchange rate misalignment regressors	Model with US interest rate and exchange rate regressors	Model with German (Euro) interest rate and exchange rate regressors
$\tilde{i}$	0.691 (0.041)	0.487 (0.103)	1.044 (0.473)	0.545 (0.273)
ρ_i	0.820 (0.010)	0.844 (0.027)	0.776 (0.315)	0.872 (0.041)
ρ_π	1.762 (0.126)	1.839 (0.538)	1.820 (0.320)	1.713 (0.539)
ρ_y	0.911 (0.140)	1.090 (0.488)	1.311 (0.336)	1.662 (0.872)
ρ_f	0.380 (0.021)	0.311 (0.076)	0.417 (0.047)	0.193 (0.007)
ρ_e	0.096 (0.007)	0.056 (0.020)	0.168 (0.112)	0.103 (0.074)
$\overline{R}^2$	0.90	0.88	0.89	0.87
Standard error	0.320	0.351	0.340	0.371
Inst. validity	[0.98]	[0.93]	[0.98]	[0.99]
Normality	[0.61]	[0.67]	[0.73]	[0.91]
Break-mpc	[0.12]	[0.07]	[0.01]	[0.06]

Notes:

(a) Numbers in parentheses are the standard errors of the estimates. Numbers in square brackets are the probability values of the test statistics. Inst.validity is the p-value of J test of the exogeneity of the instruments, normality is the is the p-value of the Jarque-Bera test for normality of the estimate residuals, while break-mpc is the p-value of a Chow test for a structural break in 1997Q2 following the formation of the Monetary Policy committee.

(b) A constant and up to 6 lags of all variables are used as instruments for the estimates.

Table 2: A more complex model (1992Q4 2005Q4)

a) estimates

	Variable	**(i) Model with US interest rate regressor**	**(ii) Model with German (Euro) interest rate regressor**
$\tilde{i}$	Constant	1.285 (0.054)	0.796 (0.024)
ρ_i	Lagged interest rate	0.633 (0.016)	0.717 (0.010)
ρ_f	Foreign interest rate	0.411 (0.010)	0.271 (0.020)
Exchange rate Over-valued , inflation close to target			
ρ_{e1}	Exchange rate	0.075 (0.011)	0.147 (0.017)
Exchange rate Under-valued, inflation close to target			
ρ_{e2}	Exchange rate	0.075 (0.011)	0.147 (0.017)
Exchange rate close to fundamentals, inflation close to target			
ρ_{y3}	Output gap	0.896 (0.205)	1.141 (0.433)
Exchange rate Over-valued, inflation not close to target			
$\rho_{\pi 4}$	Inflation	1.269 (0.087)	1.569 (0.037)
ρ_{e4}	Exchange rate	0.027 (0.009)	0.067 (0.007)
Exchange rate Under-valued, inflation not close to target			
$\rho_{\pi 5}$	Inflation	3.047 (0.390)	2.167 (0.868)
ρ_{e5}	Exchange rate	0.027 (0.009)	0.067 (0.007)
Exchange rate close to fundamentals, inflation not close to target			
$\rho_{\pi 6}$	Inflation	1.468 (0.062)	1.233 (0.045)
τ^L		-0.522 (0.038)	-0.660 (0.048)
τ^U		0.261 (0.071)	0.194 (0.010)
ϕ^O		-5.112 (0.107)	-5.863 (1.874)
ϕ^U		4.368 (0.248)	4.962 (1.001)
γ^π		5.525 (19.086)	22.981 (48.105)
γ^{eO}		20.005 (79.543)	89.598 (579.543)
γ^{eU}		10.876 (132.043)	332.755 (330.040)
$\bar{R}^2$		0.934	0.900
Standard error		0.262	0.319
Inst. Validity		[0.98]	[0.98]
Normality		[0.14]	[0.63]

b) Hypothesis tests

$H_0 : \rho_{e1} = \rho_{e2}$	Test of common exchange rate effects when inflation close to target	[0.17]	[0.32]
$H_0 : \rho_{e4} = \rho_{e5}$	Test of common exchange rate effects when inflation not close to target	[0.10]	[0.07]
$H_0 : \rho_{\pi 4} = \rho_{\pi 5} = \rho_{\pi 6}$	Test of common inflation effects	[0.00]	[0.00]
$H_0 : \tau^L = -\tau^U$	Test of symmetric inflation bounds.	[0.00]	[0.00]
$H_0 : \phi^O = -\phi^U$	Test of symmetric exchange rate bounds.	[0.00]	[0.00]

Notes: See the notes of Table 1.

Figure 1: Plots of TBR, inflation, output gap, US interest rate and EU interest rate

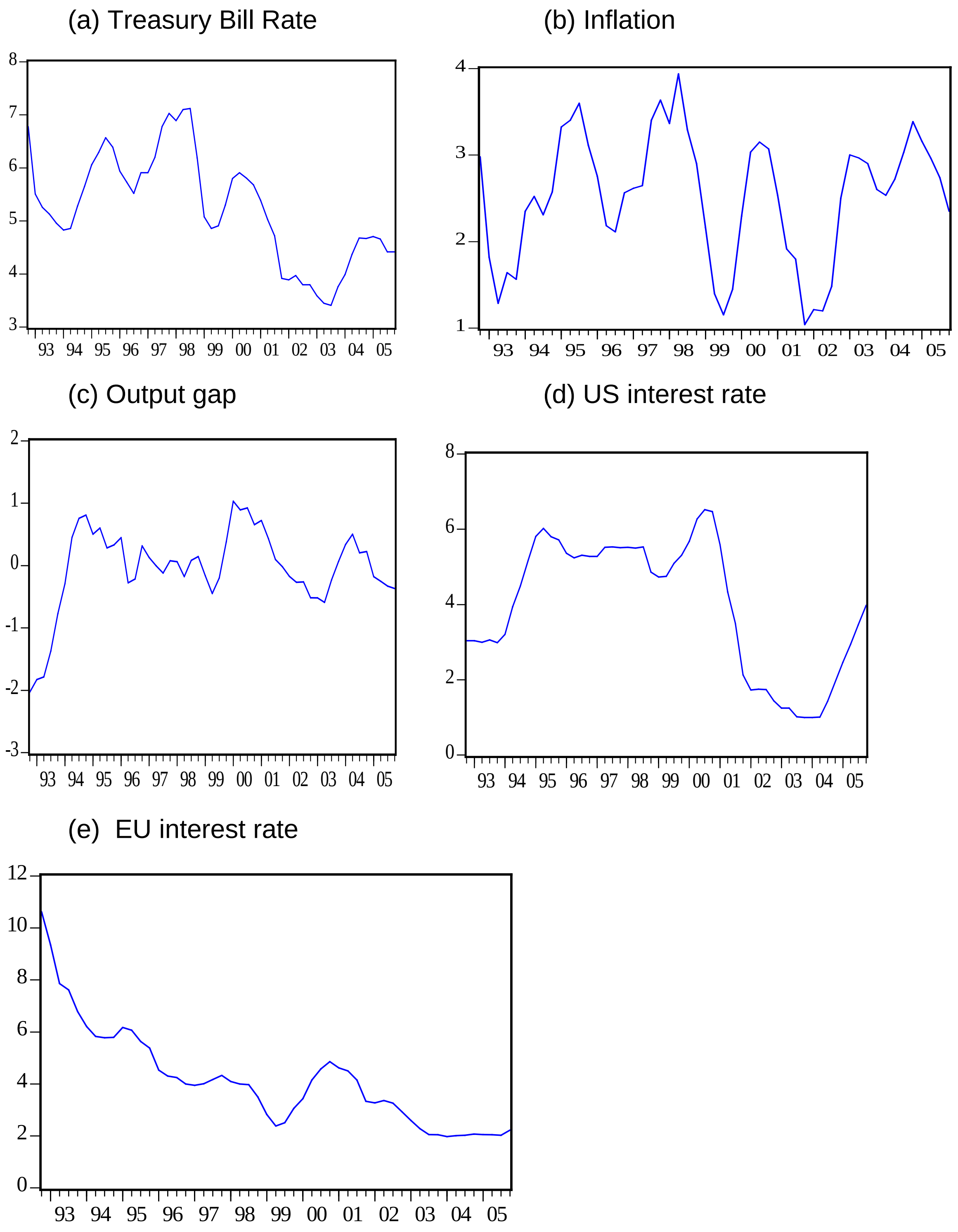
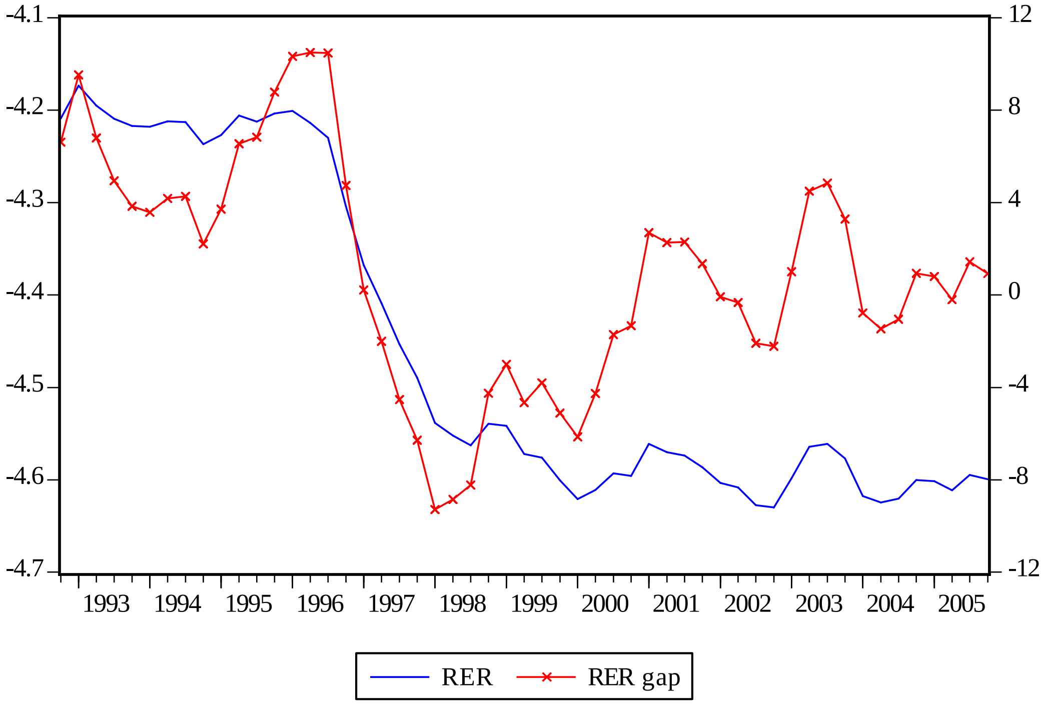
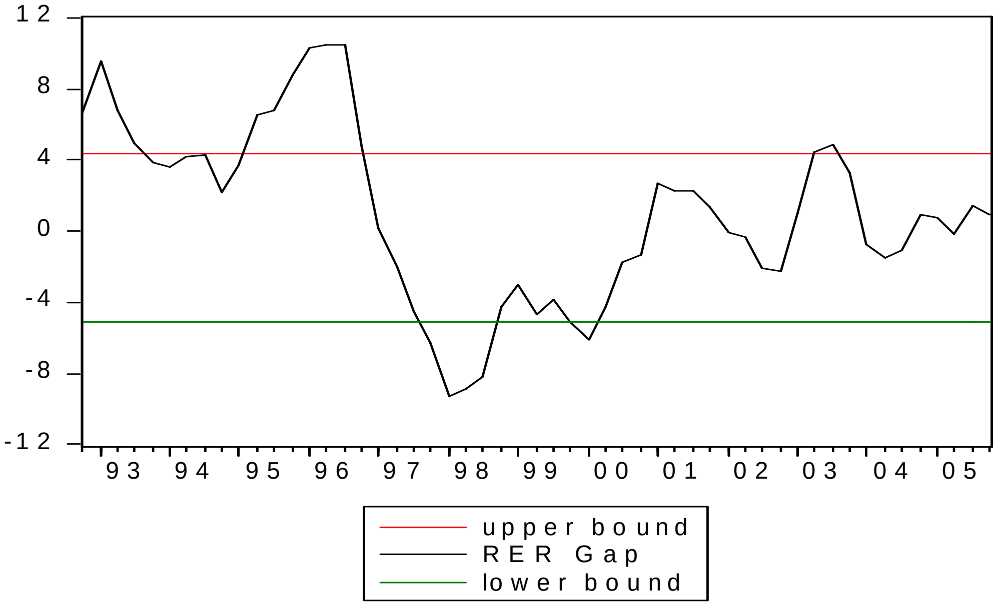


Figure 2: Plot of the real exchange rate and the real exchange rate gap



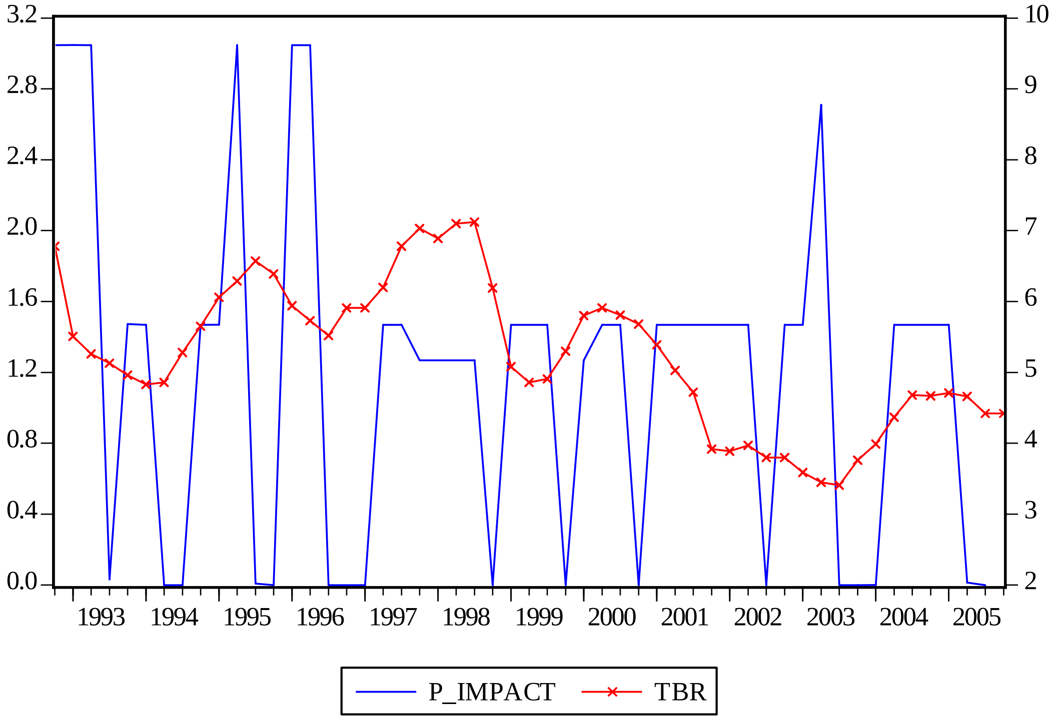
Note: LHS axis: measurement units of the real exchange rate (RER). RHS axis: measurement units of the real exchange rate gap (RER gap).

Figure 3: The real exchange rate gap and estimated boundaries



Note: The lower bound equals –5.11% and the upper bound equals 4.37%.

Figure 4: The response of interest rates to inflation



Note: LHS axis: measurement units of the inflation impact (p_impact) calculated as: $\rho_{\pi t} = (1-\theta_t^{\pi})\{\theta_t^{eO}\rho_{\pi 4} + \theta_t^{eU}\rho_{\pi 5} + (1-\theta_t^{eO} - \theta_t^{eU})\rho_{\pi 6}\}$ based on the estimates reported in column (i) of Table 2. RHS axis: measurement units of the UK Treasury Bill rate (TBR) in %.