The Complex Response of Monetary Policy to Asset Prices.

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There is a large literature on monetary policy and asset prices.

There are 2 aspects to this literature:

- do monetary policymakers respond to asset prices?
- should monetary policymakers respond to asset prices?

This paper addresses the first of these.

We consider 3 issues:

•does monetary policy respond to asset prices or to asset price misalignment?

i.e. do policymakers always respond to changes in asset prices irrespective of whether these changes represent changes in the equilibrium real exchange rate or changes relative to the underlying equilibrium? The existing literature assumes that they do, but this seems at least debatable

•does the response of monetary policy to asset prices vary according to asset price misalignment?

i.e. do policymakers respond more vigorously to asset prices when misalignment is greater? Indeed, do they *only* respond to asset prices when misalignment is sufficiently strong?

- does the response of policymakers to inflation or output depend on asset price misalignment?

    e.g. do policymakers respond less vigorously to inflation when exchange rate over-valuation creates additional downward pressure inflation?

We find clear evidence of all 3 effects. In particular:

- Models in which policymakers only respond to asset price misalignment outperform models in which they respond to all asset price movements
- Policymakers only respond to asset prices (in this paper, exchange rates) when there is significant misalignment
- The response to inflation is more muted when there is significant exchange rate misalignment (although this effect is relatively small). This implies, for example, that the increase in interest rates in response to excessive inflation is moderated when the real exchange rate is significantly overvalued; this is plausible since the overvaluation also creates downward pressure on inflation.

Addressing these issues requires a more sophisticated model than the usual Taylor rule. We use a 4-regime smooth transition model in which the behaviour of policymakers' is allowed to differ between 4 distinct regimes, depending on whether inflation is close to the target and whether real exchange rate misalignment is large or small.

We estimate our model using data from the inflation targeting regime that began after 1992.

For the regimes, we find

- The economy is in the inner inflation regime if expected inflation is between 2% and 2.75%

- The economy is in the inner exchange rate regime if the real exchange rate is no more than 4.4% above equilibrium or no less than 5.1% below equilibrium.

In each regime, the behaviour of policymakers is described by a regime-specific augmented Taylor rule in which interest rates can respond to inflation relative to the target, the output gap, real exchange rate misalignment and a foreign (in our case, US) interest rate.

The complexity of the model prevents us considering responses to a wider set of asset prices, such as stock prices or house prices.

We find:

•Policymakers only respond to output if both inflation and the exchange rate are in their inner regimes.

•Policymakers only respond to inflation or the the real exchange when these variables are in their outer regimes.

•Policymakers also respond to the foreign interest rate; we find that a 1% increase in the US rate increases UK rates by 0.43%; this response does not depend on regimes or other variables.

•(as explained above) The response to inflation in the outer inflation regime is smaller if there is also significant misalignment of the real exchange rate

These findings may help explain the confused state of the existing literature.

Some papers find that monetary policy responds to the exchange rate but not the foreign interest rate; other papers find the opposite. These studies use Taylor rules, which assume a constant response to policy variables. Since our findings suggest that these strengths of these responses actually vary over time, the diversity of findings in the literature is not surprising.

Empirical studies of the impact of asset prices on monetary policy typically use an extension of the Taylor rule, eg

$$i^*_t = \bar{i} + \rho_\pi E_{t-1}(\pi - \pi^T)_{t+j\pi} + \rho_y E_{t-1} y_{t+jy} + \rho_{if} E_{t-1} i^f_{t+jif} + \rho_e E_{t-1} e_{t+je}$$

In this model, the desired nominal interest rate (i*) depends on the equilibrium nominal interest rate, the rate of inflation (π) relative to the inflation target (π^T) expected for time (t+jπ), the output gap expected for time (t+jy), the foreign interest rate (i^f)expected for time (t+jif) and the real exchange rate (e) (defined as the real price of domestic currency in terms of foreign currency) expected at at time (t+je)

The model is typically closed by assuming that the observed nominal interest adjusts towards the desired nominal rate with a lag (Woodford, 2003), so

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

Estimates of this model using UK quarterly data for the inflation targeting regime, 1992Q4-2005Q2, are presented in column (I) of Table 1)

After initial experimentation we chose (t+jπ)=(t+jy)=1 and (t+jif)=(t+je)=0, so policymakers respond to inflation and the output gap expected in the next period (our model thus exhibits expected inflation targeting as proposed by Svensson, 1997).

The model we estimate is therefore

$$i_t = \rho_i i_{t-1} + (1-\rho_i)\{\bar{i} + \rho_\pi E_{t-1}(\pi - \pi^T)_{t+1} + \rho_y E_{t-1} y_{t+1} + \rho_{if} E_{t-1} i_t^f + \rho_e E_{t-1} e_t\}$$

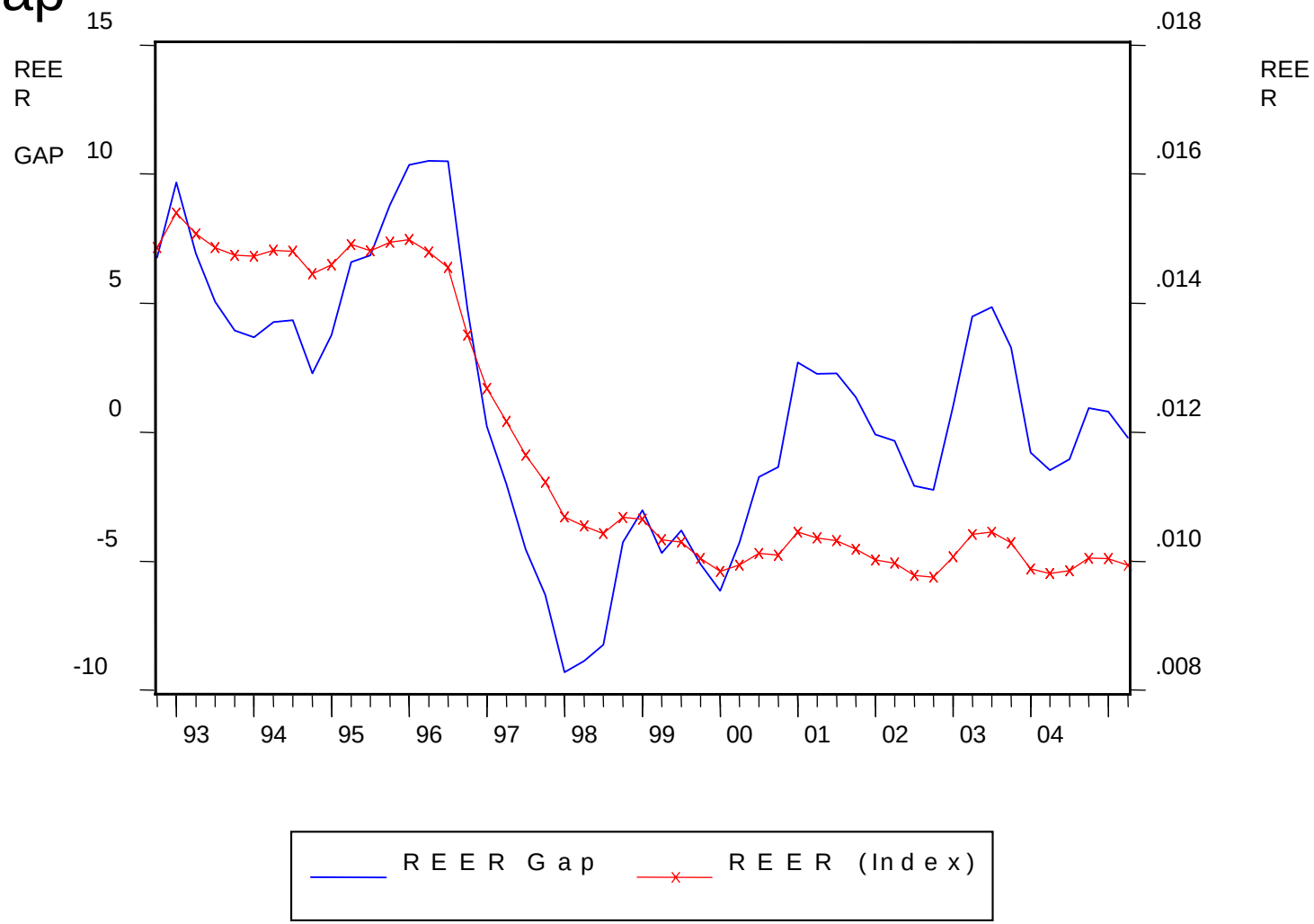
We measure i using the 3-month Treasury Bill Rate, π as the year-on-year proportional change in the retail price index, y as the the proportional deviation of output from its underlying (HP) trend, i^f is the US 3-month effective funds rate and e is the real effective exchange rate (see the data appendix for details of data sources and definitions).

This simple model assumes that policymakers respond to all movements in the real exchange rate.

However, they may not. They may respond differently to movements in the underlying equilibrium real exchange rate than to temporary deviations of the exchange rate from that equilibrium; they may also respond differently to larger misalignments.

Figure 1 plots the real exchange rate and deviations of the real exchange rate from its' underlying trend (denoted as the *real exchange rate gap*, constructed using a HP trend).

Figure 1: Real exchange rate and Real exchange rate gap



The real exchange rate appreciates sharply and permanently in 1997.

By contrast, the appreciation of the real exchange rate gap in 1997 is only temporary since the data suggests that the appreciation of the real exchange rate is permanent.

Members of the MPC appear to have differed as to how to respond to the 1997 appreciation. Part of this debate concerns whether the 1997 appreciation was permanent. A recent speech by Steve Nickell argues that the appreciation was indeed permanent and that policymakers realised this within 18 months; this is consistent with our graph of the exchange rate gap

Column (ii) of table 1) present estimates of the modified model

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

where e* is the equilibrium real exchange rate.

This model assumes that policymakers respond to the real exchange rate gap and so do not respond to shifts in the equilibrium real exchange rate. (However the model does not as yet allow policymakers only to respond to large rather than small misalignments)

Table 1
Estimates of linear policy rules
GMM estimates, 1992Q4-2005Q2

	(I)	(ii)
respond to	real exchange rate	real exchange rate gap
ρ_I	0.825 (0.014)*	0.815 (0.047)*
ρ_π	1.837 (0.166)*	1.272 (0.317)*
ρ_y	1.508 (0.304)*	0.925 (0.500)**
ρ_{if}	0.529 (0.036)*	0.447 (0.062)*
ρ_e	0.160 (0.310)	0.084(0.037)*
se.	0.305	0.295

The estimates in column (i) of table 1) reveal that the real exchange rate is insignificant, but that there is a strong response to the foreign interest rate. These findings are similar to those in a recent paper by Adams, Cobham and Girardin (OBES, 2005)

The estimates in column (ii) of table 1) reveal a significant effect from the real exchange rate gap in a model that fits the data better than that in column (i).

This provides some evidence that policymakers respond to the real exchange rate gap. This answers the first question posed at the start.

The Taylor rule models considered so far make two key assumptions:

- there is a constant response to movements in the explanatory variables

- the response to one variable does not depend on the value of other variables.

We therefore consider a model that relaxes these assumptions.

We consider the 4-regime Multiple Regime Smooth Transition model:

$$i_t = i^* + \rho i_{t-1} + (1-\rho)[M_{1t}\theta_{1t}\theta_{2t} + M_{2t}(1-\theta_{1t})\theta_{2t} + M_{3t}\theta_{1t}(1-\theta_{2t}) + M_{4t}(1-\theta_{1t})(1-\theta_{2t})] + \varepsilon_t$$

$$\theta_{1t} = \Pr\{\phi^L \le (e_t - e_t^*) \le \phi^U\} \qquad \theta_{2t} = \Pr\{\tau^L \le (\pi_{t+2} - \pi^*) \le \tau^U\}$$

$$M_{1t} = k_{11}E_{t-1}(\pi_{t+1} - \pi^*) + k_{12}E_{t-1}(y_{t+1} - y_{t+1}^*) + k_{13}E_{t-1}(e_t - e_t^*) + k_{14}E_{t-1}i_t^f$$

$$M_{2t} = k_{21}E_{t-1}(\pi_{t+1} - \pi^*) + k_{22}E_{t-1}(y_{t+1} - y_{t+1}^*) + k_{23}E_{t-1}(e_t - e_t^*) + k_{24}E_{t-1}i_t^f$$

$$M_{3t} = k_{31}E_{t-1}(\pi_{t+1} - \pi^*) + k_{32}E_{t-1}(y_{t+n} - y_{t+n}^*) + k_{33}E_{t-1}(e_t - e_t^*) + k_{34}E_{t-1}i_t^f$$

$$M_{4t} = k_{41}E_{t-1}(\pi_{t+n} - \pi^*) + k_{42}E_{t-1}(y_{t+n} - y_{t+n}^*) + k_{43}E_{t-1}(e_t - e_t^*) + k_{44}E_{t-1}i_t^f$$

This model allows the behaviour of policymakers to vary depending on whether inflation is close to the target or not and on whether the real exchange rate is close to equilibrium or not.

The model has 4 regimes:

- regime 1: inflation close to target and exchange rate misalignment low

  the behaviour of policymakers in this regime is described by the (augmented) Taylor rule M1.

- regime 2: inflation close to target but exchange rate misalignment high

  the behaviour of policymakers in this regime is described by the Taylor rule M2.

•regime 3: inflation not close to target but exchange rate misalignment low

the behaviour of policymakers in this regime is described by the Taylor rule M3.

•regime 4: inflation not close to target and exchange rate misalignment high

the behaviour of policymakers in this regime is described by the Taylor rule M4.

The (possibly asymmetric) boundaries to these regimes are described by the tau parameters, which we are able to estimate.

•the model simplifies to the Taylor rule above if behaviour does not differ between regimes (ie $k_{jn}=k_{jm}$, $m \neq n$, for all j)

•there can be different responses to inflation in the inner and outer inflation regimes; we might expect a larger response in the outer regime (ie $k_{31}>k_{11}$, $k_{41}>k_{21}$)

•similarly, there can be different responses to exchange rate misalignment in the inner and outer exchange rate regimes; we might expect a larger response in the outer regime (ie $k_{23}>k_{13}$, $k_{43}>k_{33}$)

•the response to inflation differs according to the exchange rate if $k_{11} \neq k_{21}$ and $k_{31} \neq k_{41}$

•we might also consider regimes for the output gap; however this would imply an 8-regime model, which is computationally infeasible on a sample of this size.

•Tentative estimates suggested that replacing one of the existing regimes with an output regime did not improve the model

Clearly, estimating such a complex model on a relatively short span of data is difficult.

Fortunately, initial estimates suggested a set of restrictions that were acceptable to the data and greatly simplified the model.

These restrictions were

•policymakers only respond to the output gap in regime 1, when inflation is close to target and exchange rate misalignment is low (ie k22=k32=k42=0)

•the response to the foreign interest rate is the same in all regimes (ie k14=k24=k34=k44)

•there is no response to inflation when inflation is in the inner inflation regime (ie k11=k21=0)

•there is no response to the exchange rate in the inner exchange rate regime (ie k13=k33=0)

Table 2
Estimates of 4-regime model of monetary policy
GMM estimates, 1992Q4-2005Q2

- Regime 1 (inflation close to target; exchange rate misalignment low)
output gap (k12) 5.829 (0.204)*

- Regime 2 (inflation close to target; exchange rate misalignment high)
exchange rate gap (k23) 0.062 (0.01)*

- Regime 3 (inflation not close to target; exchange rate misalignment low)
inflation (k31) 2.845 (0.100)*

- Regime 4 (inflation not close to target; exchange rate misalignment high)
inflation (k41) 2.611 (0.080)*
exchange rate gap (k43) 0.062 (0.01)*

continues…….

Table 2
Estimates of 4-regime model of monetary policy
GMM estimates, 1992Q4-2005Q2 (cont)

- Common to all regimes:	
lagged interest rate (ρ)	0.854 (0.004)*
foreign interest rate	0.361 (0.009)*
-inflation regime boundaries	
	1.978 (0.038)*
	2.764 (0.071)*
- real exchange rate regime boundaries	
	-5.112 (0.107)*
	4.368 (0.248)*
s.e.	0.233

In terms of the two remaining questions posed at the start, these estimates imply

•policymakers only respond to large real exchange rate misalignments.

interest rates are unresponsive to misalignments greater than -5.11% and less than 4.37%; these boundaries are asymmetric, as there is greater tolerance of an over-valued exchange rate (possibly because over-valued exchange rates put downward pressure on inflation)

- the response of inflation does depend on the exchange rate.

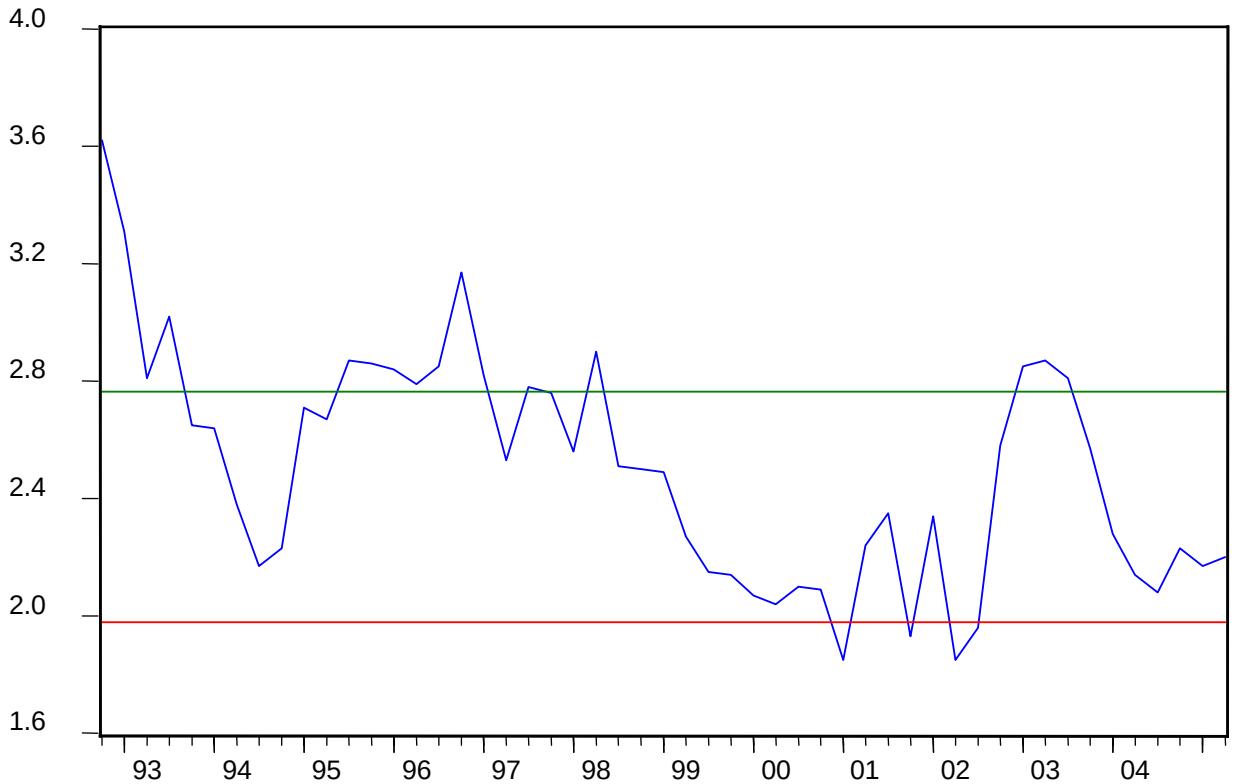
  The response to inflation when *both* inflation and exchange rates are in the outer regime is 2.61; the response when *only* inflation is in the outer regime is 2.85 (a significant difference). This is probably explained by the additional downward pressure on inflation caused by exchange rate over-valuation and the policy response.

It is also worth noting that

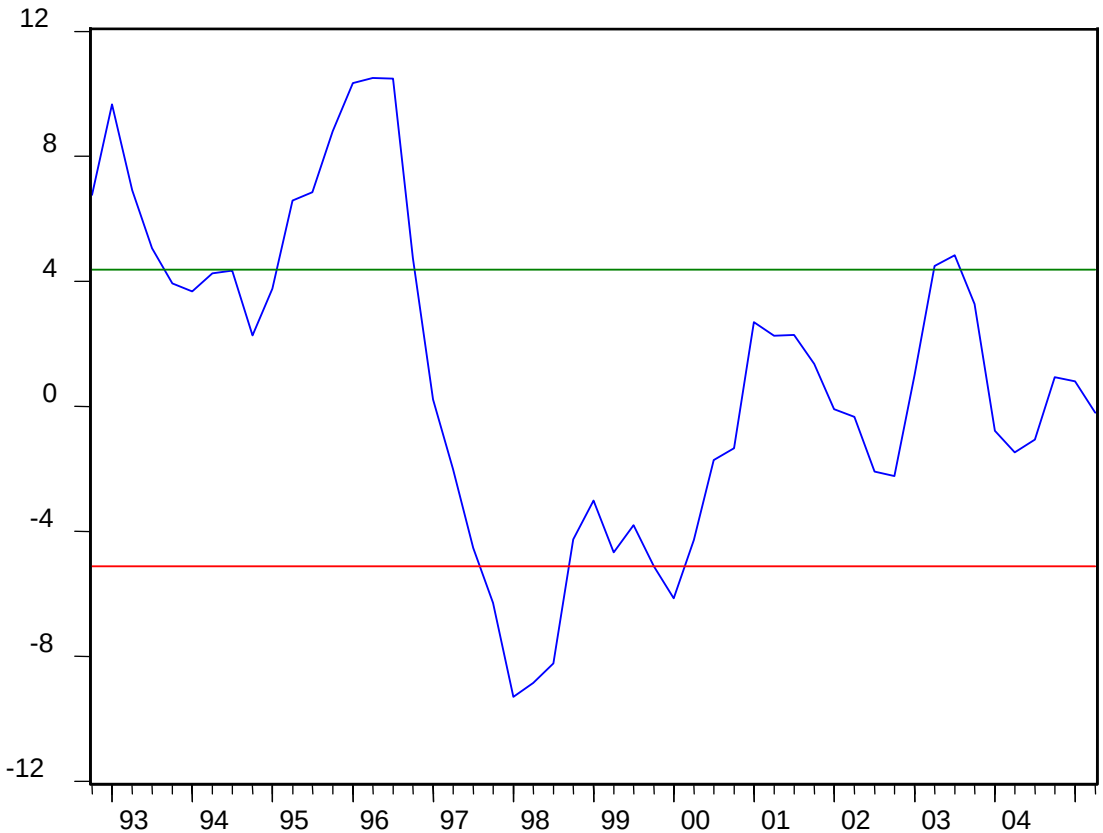
•interest rates are unresponsive to inflation when expected inflation is between 1.98% and 2.76%; these boundaries are asymmetric w.r.t the inflation target of 2.5%, as there is greater tolerance of low inflation than high inflation

•the model fits the data better than the augmented Taylor rules in Table 1

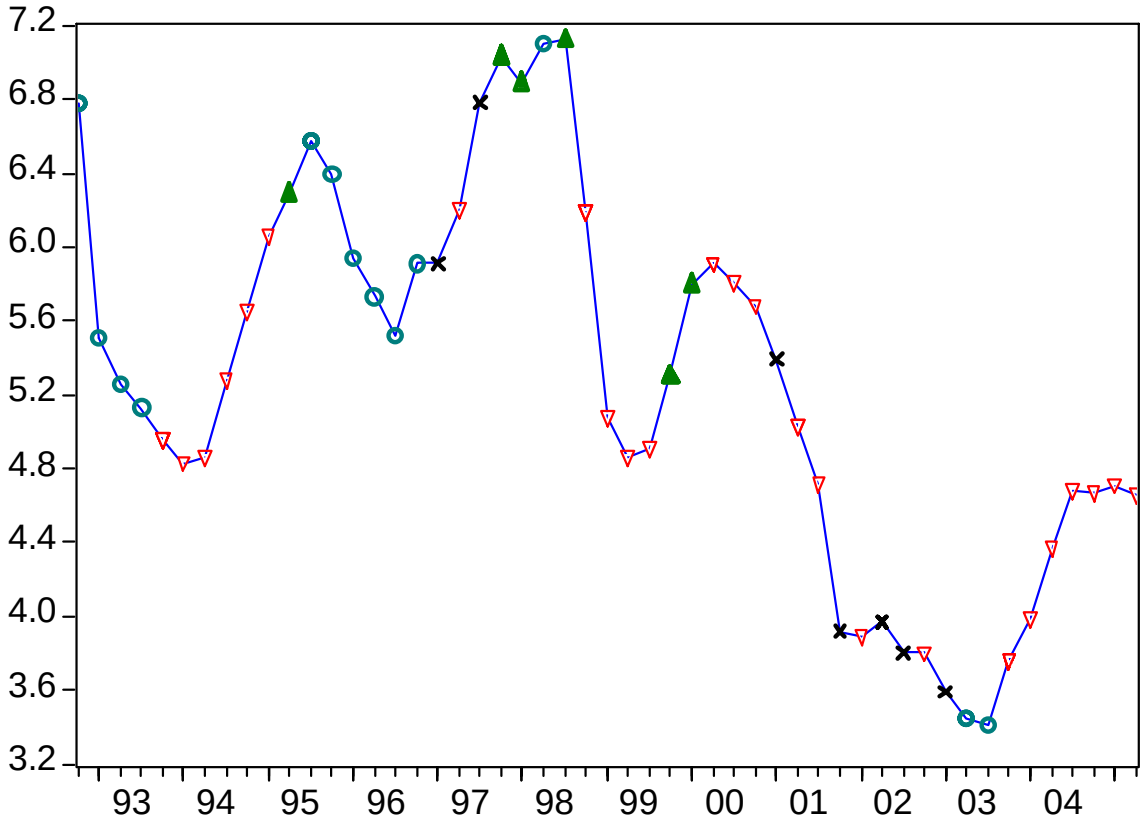
•the restrictions that simplify this model to the Taylor rule above are strongly rejected.



This shows inflation relative to the thresholds; the UK was in the outer regime in 1992-3, 1995-7, and for occasional periods thereafter



This shows the real exchange rate gap relative to the thresholds; the real exchange rate was significantly under-valued in 1992-3, 1995-7, and significantly over-valued in 1997-8



Regime 1: red triangles

Regime 2: green triangles

Regime 3: black cross

Regime 4: blue circle

This shows the pattern of regimes over time

Crudely

1992-3: regime 4: inflation too high, exchange rate under-valued

1994-5: regime 1; no problem with inflation or exchange rate

1996-7: regime 4: inflation too high, exchange rate under-valued

1998-9: mixed, but some time in regime 3; inflation OK but exchange rate over-valued

2000-1: mixed, but some time in regime 2; exchange rate OK but inflation too high

2002-: regime 1; no problem with inflation or exchange rate

Robustness checks

This is work in progress, but we have done some checks:

- Some authors eg (Gali et al, JME, 1999, Chadha, Sarno and Valente, 2004) argue that real marginal cost provides a better measure of the welfare cost of deviations from equilibrium output and that policymakers respond to this rather than the output gap (this issue is hotly debated in the literature on the New Keynesian Phillips curve). We found no evidence for this.

- Using the short-term Euro area interest rate as an alternative to the US rate did not affect our conclusions.

•An alternative model with just 2 regimes, for inflation, provides a statistical fit that is just as good as the 4-regime model above. In this model, policymakers only respond to real exchange rate misalignment when inflation is in the outer regime. It is hard to give a rationalisation for this finding, so we prefer the 4-regime model

Conclusions

We have estimated a sophisticated 4-regime smooth transition model of the UK for the post-1992 inflation targeting period. We have found:

- monetary policy responds to misalignment rather than the real exchange rate itself

- monetary policymakers only respond to large real exchange rate misalignments

- the response of policymakers to inflation depends on real exchnage rate misalignment