Monetary policy activism and interest rate smoothing

at the European Central Bank, the

Bank of England and the Federal Reserve Board

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Abstract
This paper attempts to assess the relative activism of these three central banks, with reference to the debate on interest rate smoothing. It investigates smoothing in terms of the pattern of interest rate changes, and estimates a series of Taylor-type policy rules for each bank, using quarterly and monthly data, with 'backward' and 'forward'-looking arguments, and with and without lagged dependent variables. It also examines the effect of introducing an auto-correlated error term. There is some (non-robust) evidence that the FRB is more activist, but it also seems to be more smooth; the ECB seems to adjust faster but less strongly in the long run; and the BoE's behaviour is more difficult to identify. However, these standard policy rules are out of kilter with central banks' own descriptions of what they do, while the long lags involved raise questions about the relevance of the Taylor principle as conventionally applied. It is therefore suggested that researchers should pay more attention to the institutional context of central banks' behaviour, in order to produce better estimates of their policy rules which would in turn shed more light on the issues of activism and smoothing.

Keywords: monetary policy, activism, interest rate smoothing, central banks.

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This paper investigates the interest-setting behaviour of three central banks, the Federal Reserve Board (FRB), the Bank of England (BoE) and the European Central Bank (ECB), with a view to identifying differences between them. It is well known that there are some important differences between the three central banks in independence, accountability and transparency (e.g. Favero, Freixas, Persson and Wyplosz, 2000). It is also clear that there are major differences in the size and openness of the currency areas as between the BoE, on the one hand, and the ECB and the FRB on the other. Here, however, the focus is on the way they set interest rates and, in particular, the relative 'activism' of the three banks. One reason for trying to identify differences in interest-setting behaviour is that evaluations of the relative success of the three central banks in meeting their targets need to be undertaken against the background of their interest-setting behaviour and may have implications for possible changes in that behaviour, as well as in the broader institutional arrangements. One reason for the focus on relative activism is that if the ECB could be shown to be systematically less activist than the other central banks, this might explain some of the poor macroeconomic performance of the Eurozone since 1999; if not, it would strengthen the presumption that the main factors responsible for the latter are structural ones, including the alleged lack of structural reform.

Activism can be understood as the extent to which monetary policy reacts to changes in the economic environment rather than maintaining a constant growth rate of the money supply as recommended by Friedman (1959/60) (von zur Muehlen, 2001; Trichet, 2005). In a world where the behaviour of the monetary authorities is commonly captured by estimating Taylor-type monetary policy rules, the natural way to measure activism is in terms of the magnitude of the coefficients in the estimated policy rule on inflation and, to perhaps a lesser extent, output. The core of the paper is therefore the presentation of a series of standard policy rule estimations for each of the three central banks. Since these estimations typically include a lagged dependent variable, it is necessary to take account of the ongoing debate over whether central banks really smooth interest rates and over the correct interpretation of the presence of a significant lagged dependent variable in an estimated policy rule.

The next section selectively reviews the recent literature on estimating policy rules and on interest rate smoothing. Section 2 examines the behaviour of the three central banks in terms of the earlier literature on smoothing which focused on patterns of interest rate change, notably the ratio of continuations (interest rate changes in the same direction as the previous change) to reversals (changes of direction), and notes measures of the variability of the policymakers' instrument and the economic environment facing them. Section 3 presents estimates of 'backward-looking' policy rules for the three central banks, with and without lagged dependent variables. Section 4 presents corresponding forward-looking estimates. Section 5 examines the effect of introducing in the policy rules a term to allow for serially correlated shocks. Section 6 brings these various findings together in an attempt at an overall assessment. Section 7 considers what conclusions if any can be drawn.

1 Taylor rules and interest rate smoothing

The concept of interest rate smoothing, understood as a tendency for the monetary authorities to adjust interest rates in sequences of small steps in the same direction and with few reversals, goes back at least to Goodfriend (1987, 1991). Detailed data on the US was first presented by Rudebusch (1995), and comparable data for other countries have been presented by, for example, Goodhart (1997, 1999), Lowe and Ellis (1997) and Cobham (2003). In this literature smoothing is identified primarily in terms of a 'high' ratio of continuations to reversals, but attention has also been paid to whether the duration (length of time *since* the previous change) is higher for reversals than for continuations, and whether the average size of changes is the same for reversals and continuations and for increases and decreases.

This literature typically argued that major central banks such as the FRB smoothed interest rates 'excessively', that is, optimal monetary policy would have involved more reversals with a lower ratio of continuations to reversals (e.g. Sack, 2000; Martin and Salmon, 1999). A number of possible explanations for such smoothing were put forward, the most prominent in academic circles being the argument that smoothing is an optimal response to (especially multiplicative) uncertainty (Sack, 2000; Goodhart, 1999; Martin and Salmon, 1999), and the argument that the monetary authorities may choose to minimise reversals and adjust in predictable ways in order to maximise the pass-through from the policy rate to the long term interest rates which most affect aggregate demand (Woodford, 1999).[1]

The formulation of a monetary policy rule which sees the interest rate as responding to deviations of inflation from some target and deviations of output from the natural rate goes back to Taylor (1993). From the late 1990s there is a substantial literature of papers which estimate such policy rules for different countries and different periods, in order to characterise (and compare) the behaviour of the monetary authorities (notably Clarida, Galí and Gertler, 1998, 2000; Angeloni and Dedola, 1999; Nelson, 2000; Adam, Cobham and Girardin, 2005, Hayo and Hofmann, 2005). A major emphasis in these papers has been placed on whether the inflation coefficient is greater than unity, which implies that real interest rates rise in response to positive inflation shocks (Taylor, 1999; Clarida, Galí and Gertler, 1999). One common feature of much of this work is that a lagged dependent variable is included in the estimated policy rule, and this is rationalised by assuming that the interest rate adjusts gradually towards the desired or target level. Thus the presence of a significant lagged dependent variable in an estimated policy rule has come to be identified as evidence of interest rate smoothing.

However, that identification has been disputed by Rudebusch (2002, 2005), who argues that while there may be some short term, intra-quarter, smoothing in the sense of deliberate partial adjustment, there is no partial adjustment at the quarterly frequency. He focuses on estimates of Taylor rules which use quarterly data, such as Clarida, Galí and Gertler (2000). However, many of the estimates in the literature, including Clarida, Galí and Gertler (1998), Adam, Cobham and Girardin (2005) and Hayo and Hofmann (2005), use monthly data. Rudebusch cites Mankiw and Miron (1986) and his own earlier work (Rudebusch, 1995) and provides a range of new evidence, to the effect that the term structure does not contain information about future interest rate changes beyond a couple of months, which it would do if the monetary authorities were operating systematic partial adjustment. Instead he proposes that interest rates appear to be smooth on an inter-quarter basis because the authorities are responding to serially correlated shocks, and offers (in his 2005 paper) a brief narrative account of those shocks for the US since 1988. For the UK Cobham (2003) has used the minutes of the Monetary Policy Committee (MPC) to argue against the existence of deliberate partial adjustment, and to provide a narrative of interest rate changes which also emphasises serially correlated shocks. English, Nelson and Sack (2003) and Gerlach-Kristen (2004) have examined econometrically the Rudebusch emphasis on serially correlated shocks versus partial adjustment of interest rates, for the US, and have found that both exist but the latter seems to be more important, though Rudebusch (2005) is able to claim that these estimates are not very precise and they test only a simple AR(1) version of the serial correlation hypothesis.

Interest rate smoothing, particularly on an inter-quarter basis, is at first sight the opposite of monetary policy activism: the smoother the adjustment of interest rates the less the monetary authority must be reacting to shocks. However, for countries like the UK, where the patterns of interest rate changes were very different in the 1990s from what they had been in the 1970s and 1980s (Cobham, 2003), the increased 'smoothness' is clearly associated with a major improvement in the conduct of monetary policy and in its success in meeting targets for price stability, which would suggest greater, or at least better, activism. Moreover, the presence of a lagged dependent variable in a policy rule makes it possible to distinguish between short run and long run responses, so that activism needs to be understood in terms of two dimensions: first, the speed of response and second, the magnitude of the full long-run response. In principle one central bank could have a larger short run (say, two quarters or six months) response than another but a smaller long run response. At the same time, following Rudebusch, it is important to distinguish between short run and longer run partial adjustment.

Sections 3-5 of the paper therefore present a range of policy rule estimates, on both quarterly and monthly data; with and without lagged dependent variables; both 'backward-looking' and 'forward-looking'; with and without a serially correlated error term. The rules are estimated on a common basis for each of the three central banks (though using mainly 'national' rather than 'international' data). The aim is to identify differences from common regressions, rather than to search for the 'true' policy rule for each central bank. In section 6, however, the differing policy rules discovered for each bank by Clarida, Galí and Gertler (1998, 2000), Adam, Cobham and Girardin (2005) and Hayo and Hofmann (2005) are also considered. First, however, the patterns of interest rate changes are examined.

2 Patterns of interest rate changes

Figure 1 shows the policy interest rates for the three central banks from the inception of the ECB in January 1999 to the end of June 2006. Table 1 reports the patterns of interest rate changes in line with the earlier literature on smoothing. While for each of the three central banks there are far more continuations than reversals, and the duration of reversals is much longer than that of continuations, the patterns of the size of changes are less clear (the BoE has on average relatively similar changes of each type but the other two have larger differences), the most striking point is the sharp contrast in the ratio of continuations to reversals, where the FRB's ratio is more than twice that of the other two. Table 1 is constructed in terms of individual interest rate changes, but an alternative view is offered in Table 2, which considers the (total) change in each quarter. It separates quarterly interest rate changes first by size and then in terms of continuations, reversals and no change. When the ratio of continuations to reversals is taken on this basis, all three have lower ratios and the

FRB becomes much closer to the ECB, whose ratio is in turn a little higher than that of the BoE. Thus the tables show that a lot of the FRB's smoothing is intra-quarter rather than inter-quarter, which is at least partly in line with Rudebusch's claim, and on the quarter basis the BoE and the ECB smooth interest rates only a little less than the FRB.

A rather different perspective is provided by considering the extent to which differing environments faced by the three central banks might have led to differences in the patterns of interest rate changes in abstraction from any differences in underlying behaviour. Table 3 presents data first on the variability of nominal policy rates, inflation and the output gap. It shows that the nominal policy rates were much more variable in the US than in the eurozone, but this was also true of inflation and (only just) the output gap. As between the eurozone and the UK, the nominal policy rates were more variable in the eurozone, and inflation and the output gap were also more variable in the eurozone than in the UK. Overall, while it could be said that the FRB was the most activist of the three central banks, it was also the one facing the most unstable environment; the BoE was least activist but had the most stable environment;[2] and the ECB was in the middle. Table 3 also shows that the real policy rate (ex post) was more variable for the FRB than for the other two, while if policy and the environment are combined by taking crude ratios of the standard deviations, as in the lower part of Table 3, the BoE appears to be the most active with regard to inflation, and the FRB with regard to output, while the ECB is the least active on both counts. However, it would be unwise to make much of these differences.[3]

3 'Current argument' policy rules

Table 4 presents the results of OLS estimations of the following policy rule, often referred to as 'backward-looking', without a lagged dependent variable, for each of the three central banks on quarterly data:

$$i_t = \alpha + \beta y_t + \gamma \pi_t + \varepsilon_t$$

where the (end-of-quarter) interest rate i_t responds to the current quarter value of inflation π_t and the current quarter value of the output gap y_t; and the following corresponding rule for monthly data:

$$i_t = \alpha + \beta y_{t-1} + \gamma \pi_{t-1} + \varepsilon_t$$

where the (end of month) interest rate responds to last month's inflation rate and last month's output gap. The interest rates used are end-of-period policy rates;[4] the inflation measures are 'local', i.e. CPI for the US, RPIX for the UK[5] and HICP for the ECB; and the output gaps are derived from a linear and quadratic trend regression on GDP, with the monthly output gaps interpolated from the quarterly (following Adam, Cobham and Girardin, 2005).[6]

The first set of results covers the January 1999 to December 2005 period, which is the maximum period available for the ECB, for each central bank. The second set of results is for longer periods – from 1990 for the FRB and from the granting of 'independence' in 1997 for the BoE.[7]

It should be noted first of all that in each case the monthly and quarterly results are reassuringly close, except that the Durbin-Watson (D-W) statistics are typically lower for the monthly estimates. However, in all cases the D-Ws are low enough to indicate serial correlation, which implies misspecification of some kind. The best defined reaction function in the basic period (1999-2005) is that for the FRB, where the coefficients on the output gap are highly significant and just above unity while those on inflation are significant at around 0.5. The BoE, on the other hand, has the poorest reaction function for the basic period: the output gap coefficients are significant and positive but small, the inflation coefficients are negative, and these regressions have the lowest adjusted $\overline{R}^2$s and D-Ws and the highest standard errors (SEs) of the regression relative to the standard deviation of the policy rate over the period. The ECB is somewhere in the middle: the output gap coefficients are positive and highly significant at around 0.6 but the inflation coefficients are lower and not significant, while the $\overline{R}^2$s are close to those for the FRB.

Over the longer periods in the second half of the table, the FRB's reaction function has lower output gap and higher inflation coefficients but is otherwise not much different, but the BoE's function makes more sense, with inflation coefficients greater than or close to +1 though not significant, though the $\overline{R}^2$s for the BoE (and to a lesser extent for the FRB) are very low. The difference in the BoE results between the basic and the longer periods suggests that if a longer period were available for the ECB the results might also be rather different. On the other hand, it is notable that the $\overline{R}^2$s are much lower and the SEs much higher, for both the FRB and the BoE, in the longer period.

Table 5 presents the results of estimates which incorporate a lagged dependent variable, as in the following equations:

quarterly: $i_t = (1-\lambda)\alpha + (1-\lambda)\beta y_t + (1-\lambda)\gamma\pi_t + \lambda i_{t-1} + \varepsilon_t$

monthly: $i_t = (1-\lambda)\alpha + (1-\lambda)\beta y_t + (1-\lambda)\gamma\pi_t + \lambda i_{t-1} + \varepsilon_t$

which can be thought of as derived from the following in, for example, the quarterly case:

$$\hat{i}_t = \alpha + \beta y_t + \gamma \pi_t$$
$$i_t = (1-\lambda)\hat{i}_t + \lambda i_{t-1} + \varepsilon_t$$

where $\hat{i}_t$ is the desired or target rate and the actual policy rate i_t adjusts gradually towards the target rate.

As measured by the $\overline{R}^2$s and the SEs these results are substantially better than those in Table 4, which is in line with conventional findings that the presence of a lagged dependent variable is justified (and the latter are all significant), but the DWs still indicate the presence of serial correlation. The monthly results are generally less close to the quarterly results than in the preceding table, while the $\hat{\lambda}$ s, the estimated coefficients on the lagged dependent variable, in the monthly estimates are rather lower than those in the quarterly estimates. This is at least partly consistent with Rudebusch's claim that smoothing operates at the intra-quarter rather than the inter-quarter level. However, the $\hat{\lambda}$s are not entirely consistent with each other, with the implied adjustment from the monthly estimates systematically slower than that from the quarterly estimates, as shown in Table 6. In addition the $\hat{\lambda}$s are lowest for the ECB, and highest for the BoE.

For the FRB on the basic period the $\hat{\gamma}$s (estimated long run inflation coefficients) are both significant, at 0.66 for the quarterly and 0.51 for the monthly estimates. For the BoE the $\hat{\gamma}$s are significantly negative at around -1.5, which is implausible. For the ECB the quarterly $\hat{\gamma}$ is significant at 0.44, but the monthly one is insignificant at

0.21. Over the longer periods all four estimates given are unsatisfactory: the output gap coefficients are insignificant, the inflation coefficients are negative for the FRB and positive for the BoE but all insignificant, and the $\hat{\lambda}$s are close to, and in three cases insignificantly different from, 1.

4 'Forward argument' policy rules

There are strong, obvious reasons – notably the lags in the transmission mechanism, on the one hand, and official descriptions of policy by the central banks themselves, on the other – for supposing that the monetary authorities react to forecasts rather than current or past values of inflation and the output gap. In addition, the empirical literature has found evidence in favour of forward-looking responses and, following Clarida, Galí and Gertler (1998), this has become the norm. The standard form for these forward-looking regressions, as identified by Favero (2001), is as follows:

monthly: $i_t = (1-\lambda)\alpha + (1-\lambda)\beta E y_t + (1-\lambda)\gamma E\pi_{t+12} + \lambda i_{t-1} + \varepsilon_t$

Table 8 presents the results of forward-looking regressions of this kind, except with a shorter time horizon – nine months/three quarters – which gives a better fit for each of the three central banks discussed here:

quarterly: $i_t = (1-\lambda)\alpha + (1-\lambda)\beta E y_t + (1-\lambda)\gamma E\pi_{t+3} + \lambda i_{t-1} + \varepsilon_t$

monthly: $i_t = (1-\lambda)\alpha + (1-\lambda)\beta E y_t + (1-\lambda)\gamma E\pi_{t+9} + \lambda i_{t-1} + \varepsilon_t$

But first, for completeness, Table 7 presents the results of comparable forward-looking regressions without a lagged dependent variable:

quarterly: $i_t = \alpha + \beta E y_t + \gamma E\pi_{t+3} + \varepsilon_t$

monthly: $i_t = \alpha + \beta E y_t + \gamma E\pi_{t+9} + \varepsilon_t$

The estimates are GMM estimates generated through TSP in GiveWin. The instruments for the quarterly regressions are one to two lags of each of the US output gap, eurozone output gap, US inflation, eurozone inflation, US policy rate and eurozone 3-month interbank rate; plus for each currency area the four quarter change in non-oil commodity prices, in the oil price and in the real effective exchange rate; plus, for the UK, one to two lags of the UK policy rate, UK inflation and the UK output gap. The instruments for the monthly regressions are one to four lags of each of the US output gap, eurozone output gap, US inflation, eurozone inflation, US policy rate and eurozone 3-month interbank rate; plus for each currency area the 12-month change in non-oil commodity prices, in the oil price and in the real effective exchange rate; plus, for the UK, one to four lags of the UK policy rate, UK inflation and the UK output gap. The eurozone interbank rate is used instead of the policy rate to allow the inclusion of earlier data. Because eurozone data is included in the instruments, and some of this is not available for many years before 1999, however, the longer periods in these tables for the US are much shorter than in Tables 4 and 5.

In Table 7, while all the equations have positive, and most significant, $\hat{\beta}$s (estimated output gap coefficients), seven out of the ten have negative $\hat{\gamma}$s (estimated inflation coefficients), and all have high SEs and low D-Ws. The only conclusion to be drawn is that these equations are strongly misspecified.

The results in Table 8 are of more interest. The SEs are lower, the $\hat{\beta}$s (estimated long run output gap coefficients) are mostly significantly positive and most of the $\hat{\gamma}$s (estimated long run inflation coefficients) are positive. For the basic period, the FRB reaction functions have large (>> 1) but not significant $\hat{\gamma}$s. For the BoE the $\hat{\gamma}$ in the quarterly case is near zero, but that in the monthly case is 0.88 (but not significant). The ECB also has $\hat{\gamma}$ s which are < 1 but they are significant (at the 5% level). The $\hat{\lambda}$ s, which are again larger for the monthly than for the quarterly regressions, are all higher than those in Table 5 (the comparable backward-looking regressions), with the highest here being those for the FRB but the lowest again those for the ECB.

For the longer period for the FRB, which as already noted is not that much longer here, the $\hat{\lambda}$ s are 1.00 and 1.04 and the $\hat{\gamma}$ s are either implausibly large and utterly insignificant (quarterly regression) or significantly negative (monthly). The BoE long period regressions have large positive, but not significant, $\hat{\gamma}$ s, and very high $\hat{\lambda}$ s.

Table 9 shows the extent of implied adjustment on each of the regressions. The basic period FRB results imply that less than half of the adjustment is made within four quarters or 12 months, and the longer period BoE results have an even slower adjustment. Such lags in adjustment are clearly either implausible or indicative of much greater inefficiency on the part of the central banks than their success vis-à-vis price stability would suggest. The basic period results for the BoE and the ECB, on the other hand, suggest that 80-90% of the adjustment is made within the year, which is at least less implausible.

5 Serially correlated shocks

The final set of results to be presented involve the introduction of a serially correlated error AR(1) term, as in English, Nelson and Sack (2003) and Gerlach-Kristen (2004). This cannot be done through GMM, because the ‘black box’ of GMM allows for serial correlation of the forecasts and it is therefore not possible to separate out a serially correlated shock term. Instead, TSLS estimates are presented, with and without the serial correlation term, for the following equations:

quarterly: $i_t = \delta + \eta E y_t + \theta E \pi_{t+3} + \varphi i_{t-1} + \varepsilon_t$

quarterly: $i_t = \delta + \eta E y_t + \theta E \pi_{t+3} + \varphi i_{t-1} + v_t$

monthly: $i_t = \delta + \eta E y_t + \vartheta E \pi_{t+9} + \phi i_{t-1} + \varepsilon_t$

monthly: $i_t = \delta + \eta E y_t + \vartheta E \pi_{t+9} + \phi i_{t-1} + v_t$

where ε_t is i.i.d., $v_t = \rho v_{t-1} + \varepsilon_t$ and the coefficients on the output gap and inflation are estimated in the direct, short run form.[8]

The top half of the table covers the quarterly, and the bottom half the monthly, regressions, for the basic period only. In each case the equation is estimated first without, and then with, the serial correlation parameter. For the FRB the 'without' equations are reasonably well defined, with long run inflation coefficients (obtained by dividing the $\hat{\theta}$ s by (1- $\hat{\varphi}$)) greater than 1 and significant. When the serial correlation term is included, the estimated output gap and inflation coefficients are not much changed. In the quarterly regression the $\hat{\varphi}$ (estimated coefficient on the lagged policy rate) increases from 0.87 to 0.96, while the $\hat{\rho}$ (estimated coefficient on the serial correlation term) is -0.30 but not significant; in the monthly case the $\hat{\varphi}$ increases slightly, and the $\hat{\rho}$ is small and insignificant.

For the BoE, on the other hand, the 'without' equations are much less plausible, with inflation coefficients which are small and insignificant. In the 'with' equations the inflation coefficient is unchanged in the monthly case, while the $\hat{\varphi}$ is slightly reduced and the $\hat{\rho}$ is large, half as large as the $\hat{\varphi}$, and significant. In the quarterly case the inflation coefficient becomes positive and significant (though the long run coefficient is still < 1), while the $\hat{\varphi}$ falls from 0.69 to 0.51 and the $\hat{\rho}$ is larger at 0.86 and significant. Thus in both cases the serial correlation parameter seems important, and in the quarterly case it seems to have a big effect in making the overall equation more plausible.

For the ECB the 'without' equations are broadly plausible, with long run inflation coefficients which are positive and significant but < 1. The effect of including the AR(1) term in the monthly case is small: the other coefficients are more or less unchanged and the $\hat{\rho}$ is small and insignificant. In the quarterly case, however, the $\hat{\theta}$ is reduced from 0.49 to 0.14 (and becomes insignificant), the $\hat{\varphi}$ falls from 0.41 to 0.30 (and becomes insignificant) but the $\hat{\rho}$ is 0.52 (though not significant).

6 Assessment

This section proceeds from a summary of the results of sections 2-5 to an overall evaluation of activism and smoothing at the three central banks.

Section 2 showed that in terms of the pattern of interest rate changes the FRB smoothes heavily on an intra-quarter basis, and less on an inter-quarter basis, while the BoE and the ECB smooth much less than the FRB in the former case but only a little less in the latter. At the same time the environment facing the FRB was more variable, particularly in terms of inflation, than that facing the other two. Crude measures of the activism of policy relative to the variability of the environment suggest the ECB was the least active of the three. However, too much emphasis should not be placed on such measures.

Section 3 presented backward-looking policy rule regressions, on quarterly and monthly data, with and without a lagged dependent variable. The without equations were generally poor and clearly misspecified, particularly for the BoE on the basic period and the ECB. Those including a lagged dependent variable were better, but there was still evidence of misspecification in the D-Ws, while most of the inflation coefficients were insignificant and/or < 1. The $\hat{\lambda}$ s suggested consistently slower adjustment for the monthly than for the quarterly regressions, and were lowest for the ECB and highest for the BoE.

Section 4 presented corresponding forward-looking policy rule regressions of a standard GMM kind. Again the equations without a lagged dependent variable were poor and clearly misspecified. Those with a lagged dependent variable were generally better, but there were no examples of long run inflation coefficients which were both significant and > 1. The implied speeds of adjustment were slower than those in the backward-looking regressions, slowest for the FRB and fastest for the ECB, and implausibly slow for the FRB (where the implied speed was zero) and the BoE in the longer periods.

Section 5 showed the effect of including an AR(1) term as well as a lagged dependent variable in TSLS estimates of the policy rules. This made little difference for the FRB, but seemed to make a major difference for the BoE, where it made the quarterly regression much more plausible, and some difference for the ECB quarterly regression.

In general, however, the estimates reported are not impressive: there are too many negative and/or insignificant coefficients, there is frequent evidence of autocorrelation, and the speeds of adjustment are often implausibly slow. The estimates for the FRB look more like conventional Taylor rules than those for the BoE and the ECB. The greater variability of both policy rates and inflation/output for the FRB may explain why it is much easier to obtain reasonable-looking policy rule estimates for the FRB than for the others, particularly the BoE.

Overall, the FRB seems, from interest rate patterns and from the high lagged dependent variables (and unimportance of auto-correlation) in forward-looking regressions, to adjust interest rates more smoothly than the other two; but, on the basis of the size and significance of the long run inflation coefficient point estimates, it may also be more activist. The ECB consistently has the lowest coefficients on the lagged dependent variable, which implies the highest speed of adjustment, but its long run inflation coefficients (from Table 8 and the Table 10 'without' regression) are consistently positive and significant but less than unity; the importance of auto-correlation is unclear. For the BoE, on the other hand, the results from the regressions reported here are very mixed, but the inclusion of a serial correlation term seems to produce more plausible results.

One possible way to put some of these results together is to consider the time profile of the response to inflation and the output gap, that is the estimated extent of adjustment in each period multiplied by the long run estimated coefficient on inflation or the output gap (these are point estimates, and not always significant). Figures 2-3 give the response profiles from the quarterly without serial correlation estimates in

Table 10 for the FRB and the ECB, and for the 'with' estimates for the BoE (the 'without' estimates, which involve a negative inflation coefficient, are implausible).[9] With regard to inflation the FRB has the strongest response at all time horizons, followed at some distance by the ECB, and with regard to the output gap the BoE has the strongest response, followed by the ECB, with the FRB's response rising towards the ECB's by the 12th quarter. The corresponding profiles from the monthly estimates (not shown) are broadly comparable.

These profiles derive from estimates designed to be comparable and generated from the same number of observations and with the same methods and instruments. However, it may well be that the three central banks make their forecasts in different ways so that their instruments should be allowed to differ. Table 11 brings together a selection of results from the wider literature of monthly regressions (in which authors have searched for the model which best fits each individual central bank): Clarida, Galí and Gertler (1998) for the FRB, 1982-93; Hayo and Hofmann (2005) for the ECB, 1999-2003; and Adam, Cobham and Girardin (2005) for the BoE, 1997-2003. Here, in contrast with the previous results, the BoE and the ECB as well as the FRB have long run inflation coefficients well above unity while, in line with the previous results, these two banks have rather faster adjustment than the FRB. The corresponding response profiles are presented in Figures 4-5. On this basis the BoE has much the strongest response to inflation, particularly after 2-3 months, while the ECB has a stronger response than the FRB, over at least the first 36 months. The BoE also has the strongest response to the output gap, and the ECB's response is much stronger than those of the FRB.

In general the results reported here are not sufficiently clear-cut or convincing. Better – more robust, more satisfactorily specified and more precisely identified – estimates of the policy rules are needed, particularly for the BoE and the ECB, before firm conclusions can be drawn about relative activism or smoothing. 'Better' estimates might come over time with longer sample periods, but the evidence indicates that the length of the samples may not be the only problem.

7 Conclusions

This paper has examined direct evidence on interest rate smoothing from the patterns of interest rate changes in the three central banks, and then presented a range of estimates of policy rules in an attempt to identify differences in activism and smoothing. These investigations have thrown up some apparent differences between them – notably that the FRB has stronger long run responses to inflation, but adjusts its policy rate slowly, which at least in part works in the opposite direction; the ECB has smaller long run responses but faster adjustment; the BoE's behaviour is more difficult to pin down, but when decent estimates are obtained they indicate both strong long run responses and adjustment which is faster than the FRB. However, at this stage it is not possible to offer a confident or convincing judgment about the relative activism of the three central banks.

Two further issues should be noted. On the one hand, it is remarkable that the leads involved in these and more or less all other forward-looking estimates of policy rules are much shorter than the lags which central banks themselves appear to believe exist – up to 12 months from an interest rate change to the effect on output, up to another 12 months for the effect on inflation.[10] On the other hand, the implied speeds of adjustment in these rules are in many cases so slow as to cast doubt, not just on whether central banks really smooth to that extent (and why this is not observable in the term structure) but also on the relevance of the principle that the inflation response needs to be > 1 for stability. The Taylor (1999) and Clarida, Galí and Gertler (1999) arguments for this principle were derived within an essentially static framework, but if the interest rate response to inflation does not reach 1 until 26 months after the shock (Figure 4, FRB) this leaves a lot of scope for adverse dynamics in the meantime. Indeed, it is difficult to make sense of the conventional static stability criterion when it seems that – even in what are widely agreed to be competent, anti-inflationary central banks – the short run response is so small and it takes so long for the response to reach the level of unity. More importantly, it is clearly inconsistent with conventional perceptions of the way the FRB operates.

Some contrasting insights can be drawn from two recent papers which put more emphasis on the institutional context of central banks' interest-rate setting behaviour. First, Goodhart (2005), instead of using mechanically generated 'forecasts' produced within a TSLS or GMM model, reconstructs the ex ante forecasts which the BoE's MPC had in front of it in each quarter (by using information from the BoE model to 'subtract' the effect of the interest rate changes decided by the MPC). It is notable that when he estimates policy rules using these forecasts Goodhart finds much stronger relationships for the seven- and eight-quarter ahead forecasts than for shorter horizons, which is consistent with how the BoE claims to be operating. In addition, he finds evidence that the MPC responded almost one-for-one, and without partial adjustment, to those forecasts.

Secondly, in his study of interest rate setting by the ECB, Gerlach (2004) has found that (in ordered probit estimates of policy rules) interest rates respond more clearly to the ‘economic sentiment’ indicator developed by the European Commission – which seems to forecast the output gap three or four quarters ahead – than to direct measures of the output gap. On the other hand, the ECB does not appear from his analysis to respond strongly to measures of actual or expected inflation. Gerlach has also used the Editorials from the ECB’s *Monthly Bulletin* to construct indicators of “the Governing Council’s views of the ‘risks to price stability’ arising from recent developments in economic activity, realised inflation, and M3 growth” (p. 6), and he shows that interest rate decisions are better explained by these indicator variables than by objective macro variables.

Taylor rules as conventionally estimated have undoubtedly been useful in identifying broad differences across countries and particularly across time in the behaviour of central banks, but for the questions posed in this paper they are insufficient. But the empirical results presented here, and the contrasting findings of Goodhart and Gerlach, suggest that efforts should be devoted to drawing more closely on institutional/narrative analyses of how these central banks are behaving in order to improve the econometric estimation of policy rules.

NOTES

[1] For more detailed reviews of the various explanations see Cobham (2003) and Rudebusch (2005).

[2] The BoE's policy rates, nominal and real, was also on average much higher than those of the other two.

[3] See, for example, Trichet (2006).

[4] Much of the literature uses interbank interest rates, but these may be affected by other factors, notably foreign interest rates and capital flows. Adam, Cobham and Girardin (2005) showed that for the UK the results for the actual policy rate were very close to those for interbank rates. Experimentation with interbank rates for the US and the eurozone showed that was true there also.

[5] The BoE's inflation target was formulated in terms of the RPIX measure from 1993 to the end of 2003, when it switched to the new CPI (HICP) measure. Experiments with the data here suggested that it was not necessary to take explicit account of the change for present purposes.

[6] Adam, Cobham and Girardin (2005) found that industrial production, which is available monthly, is a poor proxy for GDP in the UK. See the Data Appendix for definitions and sources of data.

[7] Adam, Cobham and Girardin (2005) show that there is a structural break in June 1997 for the BoE's policy rule.

[8] The instruments are the same as in the GMM estimation for Table 8.

[9] These are point estimates, and not all of them are significant.

[10] Estimates of policy rules comparable to those in Tables 8 and 10 but with leads of 7-8 quarters or 21-24 months on inflation typically produce significantly negative coefficients on inflation for the FRB, and insignificant and often negative inflation

coefficients (and large and highly significant coefficients on the lagged dependent variable) for the ECB and the BOE.

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Appendix: Data Definitions and Sources

Policy rates:

FRB: federal funds target rate; FRB website.

BoE: repo rate; BoE website

ECB: main refinancing operations rate; ECB website. [Note: Eurozone 3-month interbank rate, source *International Financial Statistics* (IMF), is used as instrument in place of Eurozone policy rate, to allow longer period of estimation.]

Inflation:

US: consumer price index, percentage change since four quarters/12 months before; *International Financial Statistics*.

UK: RPIX, percentage change since four quarters/12 months before; *Office of National Statistics*.

Eurozone: HICP, percentage change since four quarters/12 months before; *Eurostat*.

Output gaps:

US: real GDP, chained dollars, seasonally adjusted; US department of Commerce website.

Eurozone: real GDP, chain linked, seasonally adjusted, from ECB website, plus early 1990s data from Beyer, Doornik and Hendry (2001).

UK: real GDP, chained volume measure, seasonally adjusted; ONS website.

Gaps estimated by linear and quadratic trend, monthly interpolated from quarterly.

Non-oil commodity prices: percentage change since four quarters/12 months before, converted into local currency; *International Financial Statistics*.

Oil prices: percentage change since four quarters/12 months before, converted into local currency; *International Financial Statistics*.

Real effective exchange rate: percentage change since four quarters/12 months before, converted into local currency; *International Financial Statistics*.

Table 1: Policy rate changes, January 1999-June 2006

		number of changes					average duration (days)					average change					C/R
	months	total	C ++	R +-	R -+	C --	total	C ++	R +-	R -+	C --	total	C ++	R +-	R -+	C --	
FRB	90	36	21	1	2	12	54.4	35.2	162.0	211.0	53.3	0.32	0.26	0.5	0.25	0.42	11
BoE	90	23	7	2	2	12	74.6	43.6	256.5	74.5	62.4	0.27	0.25	0.25	0.25	0.29	4.75
ECB	90	18	8	1	2	7	107.9	41.7	229.0	154.0	89.0	0.35	0.28	0.25	0.5	0.43	5.0

Table 2: Policy rate changes by quarter, January 1999-June 2006

(%)	No change and 0.25	0.5	0.75	1+	Continuations	No change	Reversals	C/R
FRB	50.0	36.7	3.3	10.0	56.7	33.3	10.0	5.7
BoE	76.7	16.7	6.7	-	40.0	46.7	13.3	3.0
ECB	73.3	23.3	3.3	-	40.0	50.0	10.0	4.0

Table 3: Variability of the policy rate and of the environment, 1999-2005

	Policy rate				Inflation				Output gap	Real policy rate			
	mean	s.d.	max	min	mean	s.d.	max	min	s.d.	mean	s.d.	max	min
FRB	3.25	1.94	6.5	1.0	2.62	0.74	3.83	1.25	1.54	0.63	1.66	3.17	-1.62
BoE	4.71	0.77	6	3.5	2.30	0.27	2.90	1.90	1.00	2.42	0.94	3.90	0.70
ECB	2.92	0.93	4.75	2.0	2.04	0.44	2.87	0.83	1.53	0.88	0.96	2.72	-0.33

	Ratios of standard deviations	
	σ_i/σ_π	σ_i/σ_y
FRB	2.61	1.26
BoE	2.91	0.77
ECB	2.11	0.61

Notes: quarterly data, 1999Q1 to 2005Q4; real policy rates are *ex post*, equal to the nominal rates minus inflation.

Table 4: Monetary rules, quarterly and monthly, 'current' arguments, no lagged dependent variable

estimation: OLS	**FRB**	**FRB**	**BoE**	**BoE**	**ECB**	**ECB**
basic period	**99Q1-05Q4**	**99M1-05M12**	**99Q1-05Q4**	**99M1-05M12**	**99Q1-05Q4**	**99M1-05M12**
constant α	1.32 (2.96)	1.67 (5.94)	6.93 (4.60)	6.00 (6.22)	2.06 (5.56)	2.09 (5.92)
output gap β	1.07 (12.23)	1.10 (16.58)	0.39 (2.04)	0.45 (3.22)	0.56 (8.68)	0.57 (13.58)
inflation γ	0.58 (3.36)	0.42 (3.64)	-1.01 (-1.70)	-0.62 (-1.56)	0.27 (1.50)	0.26 (1.56)
$\overline{R}^2$	0.91	0.92	0.47	0.46	0.88	0.89
DW	1.00	0.27	0.39	0.11	0.63	0.29
SE of regression	0.59	0.53	0.57	0.59	0.33	0.32
S.d. of policy rate	1.97	1.91	0.79	0.80	0.95	0.93
longer periods	**90Q2-05Q4**	**90M6-05M12**	**97Q2-05Q4**	**97M6-05M12**		
constant α	2.17 (2.73)	2.26 (4.26)	1.86 (0.65)	2.37 (1.50)		
output gap β	0.60 (3.41)	0.59 (4.83)	0.67 (2.84)	0.69 (4.09)		
inflation γ	0.74 (3.53)	0.69 (4.69)	1.31 (1.00)	1.08 (1.50)		
$\overline{R}^2$	0.42	0.41	0.22	0.26		
DW	0.11	0.04	0.18	0.07		
SE of regression	1.41	1.40	1.05	1.02		
S.d. of policy rate	1.86	1.82	1.19	1.18		

Note: t-statistics in brackets, here and in tables 5 and 10, calculated from Newey-West heteroscedasticity and autocorrelation consistent standard errors

Table 5: Monetary rules, quarterly and monthly, 'current' arguments, with LDV

estimation: OLS	**FRB**	**FRB**	**BoE**	**BoE**	**ECB**	**ECB**
basic period	**99Q1-05Q4**	**99M1-05M12**	**99Q1-05Q4**	**99M1-05M12**	**99Q2-05Q4**	**99M2-05M12**
constant α	1.07 (1.51)	1.41 (2.43)	8.26 (4.56)	7.80 (5.09)	1.63 (7.17)	2.11 (6.83)
output gap β	1.10 (11.72)	1.12 (11.12)	0.33 (1.22)	0.28 (1.01)	0.59 (7.06)	0.61 (8.18)
inflation γ	0.66 (2.14)	0.51 (1.95)	-1.66 (-2.54)	-1.51 (-2.23)	0.44 (3.62)	0.21 (1.44)
lagged policy rate λ	0.51 (3.12)	0.84 (14.29)	0.74 (6.45)	0.93 (28.89)	0.37 (3.01)	0.78 (12.29)
$\overline{R}^2$	0.96	0.99	0.85	0.97	0.93	0.97
DW	1.11	1.22	0.90	1.29	0.78	1.68
SE of regression	0.42	0.21	0.30	0.14	0.26	0.16
S.d. of policy rate	1.97	1.91	0.79	0.80	0.97	0.94
longer periods	**90Q3-05Q4**	**90M7-05M12**	**97Q2-05Q4**	**97M6-05M12**		
constant α	4.62 (1.74)	7.00 (1.56)	0.60 (0.05)	0.91 (0.06)		
output gap β	0.77 (1.43)	0.59 (0.70)	0.36 (0.41)	-0.67 (-0.20)		
inflation γ	-0.35 (-0.38)	-1.39 (-0.75)	1.64 (0.35)	1.19 (0.19)		
lagged policy rate λ	0.91 (19.14)	0.98# (73.88)	0.93# (10.36)	0.99# (41.97)		
$\overline{R}^2$	0.93	0.99	0.88	0.98		
DW	0.71	1.36	0.82	1.01		
SE of regression	0.49	0.21	0.41	0.16		
S.d. of policy rate	1.80	1.80	1.19	1.18		

Table 6: Extent of implied adjustment over time from Table 5

	FRB	**FRB**	**BoE**	**BoE**	**ECB**	**ECB**
Basic period	99Q1-05Q4	99M1-05M12	99Q1-05Q4	99M1-05M12	99Q1-05Q4	99M1-05M12
2 quarters/6 months	0.74	0.65	0.45	0.35	0.86	0.77
4 quarters/12 months	0.93	0.88	0.70	0.58	0.98	0.95
Longer periods	90Q3-05Q4	90M7-05M12	97Q2-05Q4	97M6-05M12		
2 quarters/6 months	0.18	0.10	0.13	0.06		
4 quarters/12 months	0.32	0.20	0.25	0.11		

Table 7: Monetary rules, quarterly and monthly, 'forward' arguments, no lagged dependent variable

estimation: GMM	**FRB**	**FRB**	**BoE**	**BoE**	**ECB**	**ECB**
basic period	**99Q1-05Q4**	**99M1-05M12**	**99Q1-05Q4**	**99M1-05M12**	**99Q1-05Q4**	**99M1-05M12**
constant α	3.42 (6.57)	3.16 (8.60)	5.00 (4.61)	4.51 (8.49)	2.47 (3.73)	2.58 (6.65)
output gap β	1.27 (13.77)	1.20 (12.70)	0.69 (3.72)	0.70 (3.95)	0.63 (10.65)	0.59 (8.85)
inflation γ	-0.29 (-1.53)	-0.19 (-1.51)	-0.26 (-0.58)	-0.03 (-0.15)	0.02 (0.07)	-0.63 (-0.04)
$\overline{R}^2$	0.92	0.92	0.60	0.60	0.89	0.85
DW	1.23	0.20	0.34	0.08	0.74	0.24
SE of regression	0.60	0.57	0.53	0.54	0.32	0.37
S.d. of policy rate	2.08	2.02	0.83	0.84	0.95	0.93
longer periods	**97Q1-05Q4**	**96M7-05M12**	**97Q2-05Q4**	**97M6-05M12**		
constant α	5.13 (6.79)	4.42 (6.47)	4.17 (2.10)	4.39 (4.80)		
output gap β	1.26 (7.44)	1.00 (4.66)	0.72 (1.73)	0.68 (1.80)		
inflation γ	-0.79 (-2.65)	-0.39 (-1.57)	0.32 (0.40)	0.23 (0.68)		
$\overline{R}^2$	0.78	0.64	0.15	0.21		
DW	0.52	0.04	0.11	0.02		
SE of regression	0.99	1.20	1.14	1.10		
S.d. of policy rate	2.04	1.97	1.23	1.23		

Note: t-statistics in brackets, here and in Table 8, robust to autocorrelation.

Table 8: Monetary rules, quarterly and monthly, 'forward' arguments, with lagged dependent variable

estimation: GMM	**FRB**	**FRB**	**BoE**	**BoE**	**ECB**	**ECB**
basic period	**99Q1-05Q4**	**99M1-05M12**	**99Q1-05Q4**	**99M1-05M12**	**99Q2-05Q4**	**99M2-05M12**
constant α	-10.28 (-0.71)	-7.22 (-0.90)	4.21 (2.41)	2.16 (1.09)	0.88 (0.98)	0.37 (0.34)
output gap β	0.72 (1.11)	0.83 (2.09)	0.76 (2.63)	0.85 (2.38)	0.65 (10.85)	0.67 (8.61)
inflation γ	4.68 (0.89)	3.56 (1.22)	0.01 (0.02)	0.88 (1.10)	0.71 (1.73)	0.94 (1.89)
lagged policy rate λ	0.88 (7.81)	0.95 (25.83)	0.61 (4.88)	0.88 (17.40)	0.41 (3.84)	0.82 (18.37)
$\overline{R}^2$	0.98	0.99	0.84	0.97	0.95	0.97
DW	2.41	2.05	0.57	1.11	1.47	2.14
SE of regression	0.30	0.17	0.33	0.15	0.21	0.16
S.d. of policy rate	2.08	2.02	0.83	0.84	0.98	0.94
longer periods	**97Q1-05Q4**	**96M7-05M12**	**97Q2-05Q4**	**97M6-05M12**		
constant α	-85.65 (-0.00)	17.20 (2.59)	-6.59 (-0.43)	-12.02 (-0.74)		
output gap β	-3.22 (-0.00)	1.69 (3.16)	0.95 (0.56)	1.48 (0.94)		
inflation γ	34.85 (-0.00)	-5.45 (-2.09)	4.69 (0.76)	6.89 (1.04)		
lagged policy rate λ	1.00 (7.02)	1.04 (49.93)	0.92 (10.84)	0.97 (34.02)		
$\overline{R}^2$	0.94	0.99	0.89	0.98		
DW	0.71	1.70	0.80	1.03		
SE of regression	0.54	0.17	0.41	0.16		
S.d. of policy rate	2.04	1.97	1.23	1.23		

Table 9: Extent of implied adjustment over time from Table 8

	FRB	**FRB**	**BoE**	**BoE**	**ECB**	**ECB**
Basic period	99Q1-05Q4	99M1-05M12	99Q1-05Q4	99M1-05M12	99Q1-05Q4	99M1-05M12
2 quarters/6 months	0.23	0.28	0.63	0.54	0.83	0.70
4 quarters/12 months	0.41	0.49	0.86	0.78	0.97	0.91
Longer periods	97Q1-05Q4	96M7-05M12	97Q2-05Q4	97M6-05M12		
2 quarters/6 months	-[1]	-[1]	0.15	0.17		
4 quarters/12 months	-[1]	-[1]	0.28	0.31		

Note [1] Zero/not calculable - $\hat{\lambda} \geq 1.00$.

Table 10: Monetary rules, quarterly and monthly, 'forward' arguments, lagged dependent variable, with and without serial correlation

estimation: TSLS	**FRB**	**FRB**	**BoE**	**BoE**	**ECB**	**ECB**
basic period	**99Q1-05Q1**	**99Q1-05Q1**	**99Q1-05Q1**	**99Q1-05Q1**	**99Q2-05Q1**	**99Q3-05Q1**
constant δ	-1.20 (-1.85)	-1.76 (-2.75)	1.45 (1.43)	1.62 (1.91)	0.35 (0.56)	1.42 (1.73)
output gap η	0.10 (0.76)	-0.03 (-0.17)	0.24 (1.28)	0.43 (2.59)	0.38 (5.07)	0.46 (2.75)
inflation θ	0.56 (3.49)	0.68 (4.17)	-0.06 (-0.24)	0.27 (1.81)	0.49 (2.29)	0.14 (0.75)
lagged policy rate φ	0.87 (9.53)	0.96 (10.54)	0.69 (4.61)	0.51 (3.81)	0.41 (3.88)	0.30 (1.07)
serial correlation ρ	-	-0.30 (-1.56)	-	0.86 (5.37)	-	0.52 (1.43)
$\overline{R}^2$	0.98	0.98	0.85	0.92	0.95	0.95
SE of regression	0.30	0.31	0.33	0.23	0.21	0.22
S.d. of policy rate	2.08	2.08	0.83	0.83	0.98	0.99
basic period	**99M1-05M3**	**99M1-05M3**	**99M1-05M3**	**99M1-05M3**	**99M2-05M3**	**99M3-05M3**
constant δ	-0.37 (-1.63)	-0.42 (-2.05)	0.25 (0.71)	0.43 (1.20)	0.25 (1.54)	0.19 (1.33)
output gap η	0.05 (0.71)	0.04 (0.62)	0.07 (1.28)	0.09 (1.60)	0.14 (4.74)	0.14 (4.98)
inflation θ	0.19 (4.91)	0.20 (5.33)	0.03 (0.43)	0.03 (0.28)	0.12 (1.96)	0.15 (2.56)
lagged policy rate φ	0.94 (17.44)	0.95 (20.51)	0.92 (18.82)	0.89 (17.02)	0.79 (18.28)	0.79 (18.11)
serial correlation ρ	-	-0.10 (-0.75)	-	0.41 (4.40)	-	-0.06 (-0.75)
$\overline{R}^2$	0.99	0.99	0.97	0.97	0.97	0.97
SE of regression	0.18	0.18	0.15	0.14	0.16	0.16
S.d. of policy rate	2.02	2.02	0.84	0.84	0.94	0.94

Note: inflation and output gap coefficient estimates are reported in direct/short run form.

Table 11: 'Best' results from other studies, monthly, 'forward' arguments, with lagged dependent variable

central bank	**FRB**	**BoE**	**ECB**
author(s)	**Clarida, Galí and Gertler, 1998**	**Adam, Cobham and Girardin, 2005**	**Hayo and Hofmann, 2005**
period	79M10-94M12	97M5-03M7	99M1-03M3
constant	-0.10 (-0.06)	0.60 (0.35)	0.32 (0.18)
output gap	0.56 (3.50)	1.30 (5.15)	0.60 (8.82)
inflation	1.83 (4.07)	1.89 (2.66)	1.48 (1.88)
lagged policy rate	0.97 (32.33)	0.85 (13.51)	0.85 (18.09)

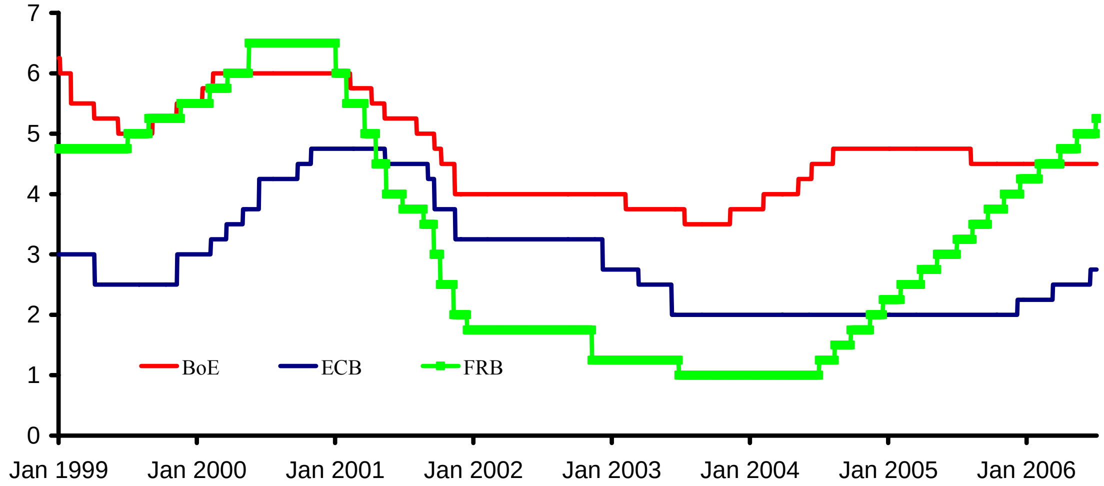

Figure 1: Policy rates, FRB, BoE and ECB, daily data

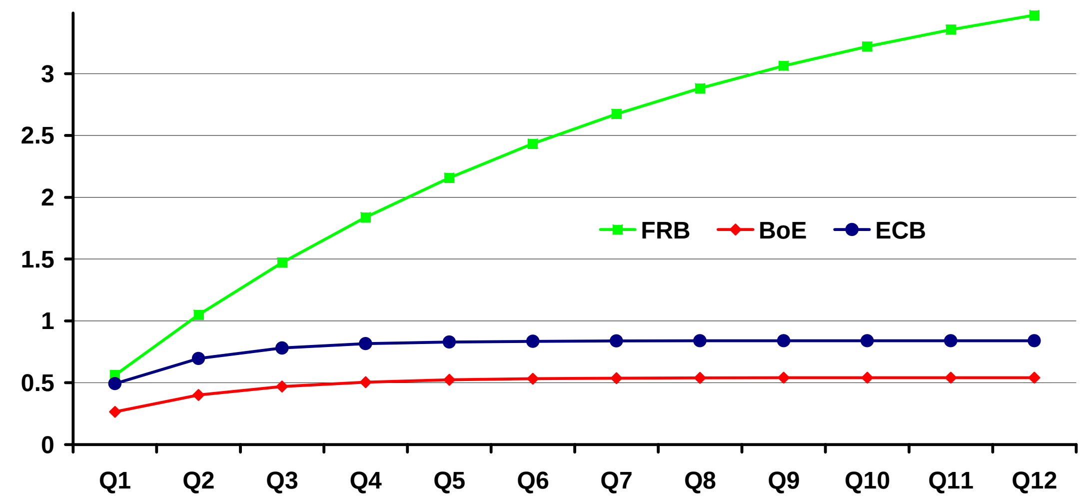

Figure 2: Response profiles, quarterly, inflation

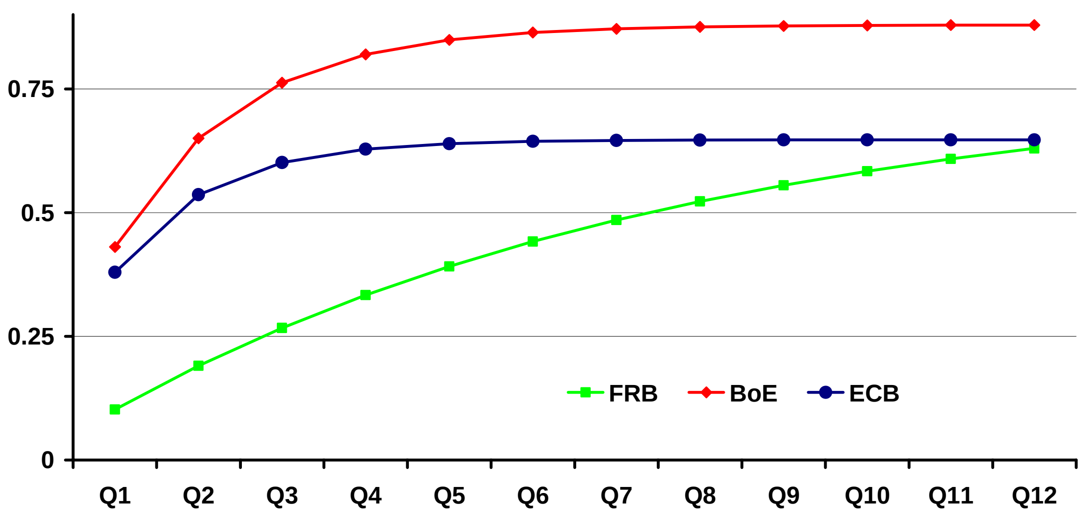

Figure 3: response profiles, quarterly, output gap

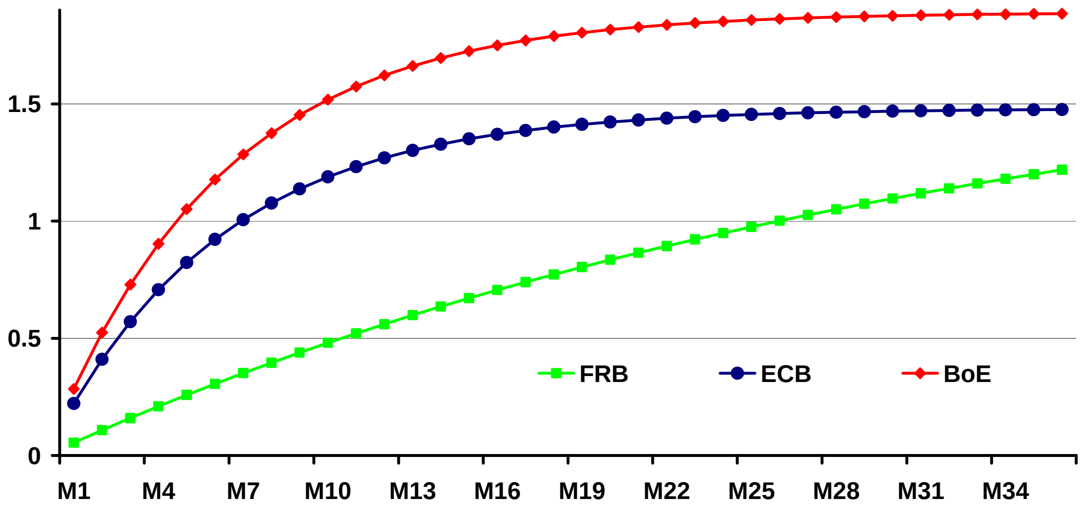

Figure 4: Response profiles, monthly, inflation, various authors

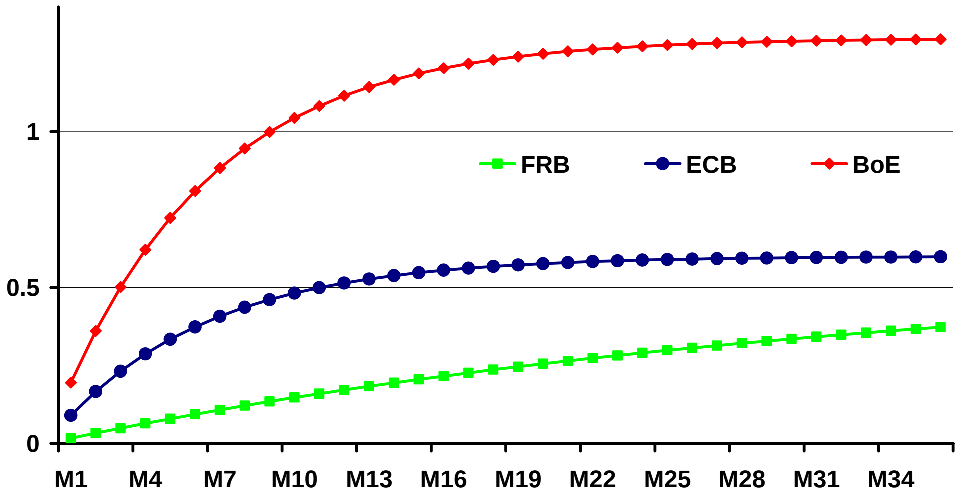

Figure 5: Response profiles, monthly, output gap, various authors