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FINANCIAL STABILITY AND MONETARY POLICY

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Abstract

We argue that although UK monetary policy can be described using a Taylor rule in 1992-2007, this rule fails during the recent financial crisis. We interpret this as reflecting a change in policymakers' preferences to give priority to stabilising the financial system. Developing a model of optimal monetary policy with preference shifts, we show this provides a superior empirical model over crisis and pre-crisis periods. We find no response of interest rates to inflation during the financial crisis, possibly implying that the UK abandoned inflation targeting during the financial crisis.

1. Introduction

The global economic crisis that began in 2007 has presented a series of severe challenges to monetary policy. Deep and rapid reductions in output have opened up an output gap of over 5% in many countries. Profound shocks to the financial system have disrupted the transmission mechanism linking monetary policy to the real economy and created fears for the stability of the system. Objections have been raised to low and stable inflation being the main aim of monetary policy and dissatisfaction has been expressed with the New Keynesian and DSGE models that provided the theoretical underpinning for that aim. In this context, it would not be surprising if the behaviour of policymakers had changed during the crisis.

This paper explores the interest rate setting behaviour of monetary policymakers in the UK during the financial crisis. We have three main findings. First, although interest rates can be described using a simple Taylor rule in the period before the crisis, the Taylor rule breaks down during the crisis. Second, addition of "spread adjustments" to correct for the widening gap between policy rates and libor and other unsecured borrowing rates that were a prominent feature of the crisis does not solve the problem. Third, policymakers appear to cease targeting inflation during the crisis and focus instead on setting low interest rates in order to stabilise the financial system.

We develop a series of models of optimal monetary policy which we estimate on monthly UK data for 1992-2009; our use of monthly data gives us enough observations to estimate a policy rule in the crisis period. In section 2) we develop a simple Taylor rule representation of optimal monetary policy. We show that estimates of this model using a pre-crisis period that ends in early 2007 conform to expectations with a response to inflation in excess of unity and a strong response to

the output gap. Estimates that use the full sample that ends in 2010M1 are very different. Although the crisis period represents only 15% of the sample, the estimate on inflation becomes insignificant and the point estimate is negative. The response to output remains significant but is more than halved.

Some writers, most prominently Curdia and Woodford (2009), have suggested a "spread-adjusted" optimal monetary policy rule in the presence of credit frictions. In essence this implies policymakers should respond to a widening of the spread between policy rates and key borrowing rates such as the Libor rates by reducing policy rates in order that the effective interest rates facing the private sector are unchanged. This suggests that the rapid cuts in interest rates during the financial crisis might be in response to widening spreads between policy rates and effective borrowing rates and that including the determinants of these spreads in a policy rule would result in an augmented spread-adjusted Taylor rule that provides a coherent account of policymaking during the crisis. We investigate this hypothesis in section 3) where we estimate a series of policy rules that include measures of financial market liquidity, the spread between unsecured and secured borrowing rates on financial markets and an index of financial market stress as plausible determinants of credit spreads. We find that estimates on these variables are insignificant in the pre-crisis period but become significant and correctly signed when the crisis period is added to the sample. However estimates on inflation in the full sample remain insignificant, the response to output is again much reduced and there are marked differences between estimated coefficients in pre-crisis and full sample estimates.

This evidence suggests there may have been a change in the behaviour of policymakers during the financial crisis. To analyse this, in section 4) we develop a model in which the objectives of policymakers differ between a no-crisis regime,

where the objective is to stabilise inflation and a crisis regime in which policymakers also desire to stabilise the financial system and believe this can be done through lower interest rates. We show this implies an optimal policy rule in which interest rates respond to inflation and output gaps and to measures of financial stability, but where these responses differ according to the probability of there being a financial crisis. In section 5) we estimate the switching regression optimal monetary policy rule implied by this analysis. We find empirical support for the model. We find a strong response to inflation in the no-crisis regime but no response where there is a crisis and infer that this reflects a desire to stabilise inflation only when there is no financial crisis. We find a strong response of interest rates to measures of financial stability, but only in the crisis regime; we infer that this becomes the over-riding objective of monetary policy during financial crises.

Our estimated model is able to explain movements in the policy rate over the crisis period and, in particular, predicts the series of deep cuts in policy rates in the second half of 2008, the most dramatic movements in interest rates in over 30 years. The simply Taylor rule is unable to do this, only predicting cuts in interest rates several months after the event. Our estimates suggest that UK monetary policy shifted back to the no-crisis monetary policy regime in July 2009. The implied interest rates from crisis and no-crisis regimes were very close at that time, suggesting the transition between regimes has had no discernable impact on interest rates.

Section 6 of the paper concludes by addressing the issue of whether the UK abandoned inflation targeting during the financial crisis. We argue that if inflation targeting implies setting interest rates according to a policy rule that gives considerable weight to deviations of inflation from the target, then the UK did

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abandon inflation targeting during the financial crisis. However if inflation targeting is interpreted in the looser sense of setting interest rates to ensure that deviations of inflation from the target are neither too large not too prolonged, then policymakers perhaps did not abandon the target. The negative demand shock caused by the financial crisis put downward pressure on inflation. The policy response to this, lower interest rates, is the same as the policy response to instability on the financial system we detect in our estimates. In that sense, giving priority to financial stability in monetary policy did not put the inflation target at risk. However there have also been short-lived adverse commodity price shocks that offset the downward pressure on inflation; policymakers clearly did not responded to these. On balance, if policymakers did not abandon inflation targeting during the financial crisis, they did step back from a "strict inflation targeting" approach of prioritising inflation above all other objectives.

2. Taylor Rules and the Financial Crisis

In this section we present evidence on a Taylor (1993)-type rule model of monetary policy using monthly data for the period 1992M10-2010M1. We first derive an optimal monetary policy rule. The model is

(1) $\pi_t = \alpha_\pi E_{t-1} \pi_{t+1} + \alpha_y y_t + \varepsilon_t$

(2) $y_t = \alpha_\phi E_{t-1} y_{t+1} - \alpha_r (i_{t-1} - E_{t-1} \pi_t - \overline{r}) + \eta_t$

(3) $$L_t = E_{t-1}\sum_{k=0}^{\infty}\delta^i\{\frac{1}{2}(\pi_{t+k} - \pi^T)^2 + \frac{\lambda_y}{2}y_{t+k}^2 + \frac{\lambda_i}{2}(i_{t+k} - \bar{i}_{t+k})^2\}$$

Equation (1) is a standard New-Keynesian Phillips curve in which the inflation rate (π) depends on the output gap (y), expected future inflation and a supply shock (ε). Equation (2) is an aggregate demand relationship in which the output gap depends on expected future output gap, the real policy rate (defined as $i - \pi$ where i is the nominal interest rate) lagged one period relative to its equilibrium value ($\bar{i} = \bar{r} + \pi^T$ where $\bar{r}$ is the equilibrium real interest rate and π^T is the inflation target) and on a demand shock (η). Equation (3) specifies the policymakers' loss function in terms of expected discounted sums of quadratic deviations of inflation from the inflation target, output gaps and deviations of the nominal interest rate from its equilibrium value, where δ is the discount factor. In common with many other models of this type, we interpret a time period as corresponding to three calendar months.

Assuming policymakers select the nominal interest rate at time t under discretion, the first-order condition is

(4) $$E_{t-1}\{\delta(\pi_{t+1} - \pi^T)\frac{\partial \pi_{t+1}}{\partial i_t} + \delta\lambda_y y_{t+1}\frac{\partial y_{t+1}}{\partial i_t} + \lambda_i(i_t - \bar{i})\} = 0$$

Using (1)-(3), we can express the optimal policy rule as[1]

(5) $\hat{i}_t = \bar{i} + \dfrac{\delta \alpha_r \alpha_y}{\lambda_i} E_{t-1}(\pi_{t+1} - \pi^T) + \dfrac{\delta \lambda_y \alpha_r}{\lambda_i} E_{t-1} y_{t+1}$

where $\hat{i}$ is the optimal interest rate. This is a standard Taylor rule in which interest rates are set with reference to expected inflation and output gaps one period ahead.

We make some modifications to (5) prior to estimation. Interpreting a period in our theoretical model as representing three calendar months, we assume that policymakers respond to forecasts of inflation and the output gap over the coming quarter, so

(6) $\hat{i}_t = \bar{i} + \rho_\pi \displaystyle\sum_{k=1}^{3}(E_{t-1}\pi_{t+k} - \pi^T) + \rho_y \sum_{k=1}^{3}(E_{t-1} y_{t+k})$

where $\rho_\pi = \dfrac{\delta \alpha_r \alpha_y}{\lambda_i}$ and $\rho_y = \dfrac{\delta \lambda_y \alpha_r}{\lambda_i}$. The assumption of a 3-month horizon in (6) makes our specification similar to models estimated on quarterly data in which

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[1] If the final term in the loss function is omitted, the first-order condition becomes $E_{t-1}\{(\pi_{t+1} - \pi^T) = -\dfrac{\lambda_y}{\alpha_y} y_{t+1}\}$. This expression is familiar from, e.g. Clarida et al (1999), Gali (2008) and Walsh (2010). However there is no simple way of converting this into an optimal interest rate rule. The final term in the loss function provides is a convenient way of doing this.

policymakers react to expected inflation and output in the next period. We also allow for interest rate smoothing, so the actual interest rate is given by $i_t = \rho_i i_{t-1} + (1 - \rho_i)\hat{i}$. Replacing expected inflation and output gaps with their actual values, we obtain our empirical model, given by

$$(7) \qquad i_t = \rho_i i_{t-1} + (1 - \rho_i)\{\bar{i} + \rho_\pi \sum_{k=1}^{3}(E_{t-1}\pi_{t+k} - \pi^T) + \rho_y \sum_{k=1}^{3}(E_{t-1}y_{t+k})\} + \xi_t$$

where ξ is the error that results from substituting expected with actual values of explanatory variables. We measure i using the policy rate set by the Bank of England. For π, we use the RPIX measure of the inflation rate from 1992-2003 and the CPI inflation rate for 2004-2010; this matches the inflation rate targeted by monetary policy at different dates. Correspondingly, the inflation target is 2.5% for the 1992-2003 period and 2% for 2004-2010. The output gap, y, is constructed as the proportional difference between an ex-post measure of monthly GDP (available from the National Institute of Economic and Social Research) and its Hodrick and Prescott (1997) trend [2]. Figure 1 plots the policy rate, inflation and the output gap. We note that the spike in inflation in early 2007 was not matched by an increase in the policy rate and that the most dramatic movements in interest rates in more than a generation, the rapid and deep cuts in late 2008 did not coincide with a fall in inflation below the target.

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[2] To tackle the end-point problem in calculating the Hodrick-Prescott trend (see Mise et al, 2005a,b), we applied an autoregressive AR(n) model (with n set at 4 to eliminate serial correlation) to the output measure. The AR model was used to forecast twenty-four additional months that were then added to the output series before applying the Hodrick-Prescott filter. In calculating the filter, we use the Ravn and Uhlig (2002) adjustment.

We begin by estimating our model over the pre-crisis period. Some commentators have suggested the crisis began in August 2007, reflecting the failure of the American Home Mortgage Investment Corporation, a prominent announcement from BNP Paribas and a statement by the US Federal Reserve stressing its willingness to provide funds to support the Federal Funds Rate market. However the crisis arguably began earlier that year, as the Federal Home Loan Mortgage Corporation ceased buying the most risky subprime mortgages and MBRSs in February, the New Century Financial Corporation filed for Chapter 11 protection in April and June saw downgrades on more than 100 bonds backed by subprime mortgages by ratings agencies, and the suspension of redemptions on some subprime-related securities by Bear Sterns. Events in July included the announcement of "difficult trading conditions" by a prominent, the Countrywide Financial Corporation and the liquidation by Bear Stearns of hedge funds specialising in mortgage-backed securities. Given this cascade of events, we end our pre-crisis sample in April 2007.

Column (i) of Table 1) presents GMM estimates of (7) using monthly data from before the onset of the financial crisis. We treat all variables as endogenous, using the first four lags of each as instruments. The estimates are in line with a number of other estimates (e.g. Martin and Milas, 2004, and Mihailov, 2005), with significant responses to inflation and output gaps, the former exceeding unity as required by the Taylor Principle. Column (ii) presents estimates of the same model using data from 1992M10 to 2010M1, extending the sample by 32 months to include the financial crisis. Although the data are dominated by observations from before the onset of the crisis, which constitute 85% of the sample, the estimates are now are markedly different. The response to inflation is insignificant and the point estimate is

negative. The response to the output gap is more than halved, although this remains significant. The equilibrium nominal interest rate falls by around 50 basis points, reflecting a reduction in the equilibrium real rate, but there is no change in the degree of interest rate inertia. These estimates are consistent with results in Belke and Klose (2010), who report a negative and significant estimated response to inflation using both pre-crisis and crisis period data for the US (although not for the Eurozone).

These results clearly suggest a marked change in monetary policy, dating from the onset of the financial crisis. To test for the date of the break, we apply the Quandt-Andrews breakpoint test. Since this test is unreliable at the extremes of the sample, it is usual to trim 15% of observations from the start and end of the sample. No structural break is detected in the model estimated on the pre-crisis sample. With the full sample a single structural break is detected, in April 2007. This is consistent with the marked change in the estimated response to inflation between the pre-crisis and full samples[3].

3. Spread-Adjusted Taylor Rules

Recent analyses of optimal monetary policy in the presence of credit frictions (e.g. Curdia and Woodford, 2009, Teranishi, 2009) consider models in which the private sector can only borrow at an interest rate that exceeds the policy rate. Since aggregate demand depends on the borrowing rate, policymakers take account of the

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[3] The finding of a single structural break may be questionable. The financial crisis entered its most intense in September 2008 with the collapse of Lehman Brothers and associated events; steep reductions in UK policy rates began in the following month. Since these events are excluded from a 15% trimmed sample, we also ran the Quandt-Andrews test with trimming rate of 5%; in this case two structural breaks were detected, in October 2008, and again in April 2007. There are too few observations on the post-Lehman period in our sample (13) to permit estimation of a separate policy rule in this period.

spread between this and their policy rate. If this spread widens, the policy rate is reduced to maintain the borrowing rate at the level that best delivers desired output and inflation rates. This implies a "spread-adjusted" policy rule of the form

$$(8) \quad i_t = \rho_i i_{t-1} + (1 - \rho_i)\{\bar{i} + \rho_\mu \mu_t + \rho_\pi \sum_{k=1}^{3} (E_{t-1}\pi_{t+k} - \pi^T) + \rho_y \sum_{k=1}^{3} (E_{t-1} y_{t+k})\} + \varepsilon_t$$

where μ are factors that determine the spread between the policy rate and the borrowing rate (see Martin and Milas, 2010 for an empirical application). Since the financial crisis has seen a dramatic widening in credit spreads, exclusion of credit spread effects from (7) may explain the poor performance of the estimated Taylor rules in Table 1).

We use three alternative measures of μ. The first is the index of liquidity calculated by the Bank of England, shown to be useful in explaining the spread between policy and Libor rates by Martin and Milas (2010). This index reflects bid-ask spreads for Gilt Repos, the FTSE100 and major currencies, the return-to-volume ratio of Gilts, the FTSE100 and equity options and the spreads between corporate bonds and a credit spread and between bond and Libor rates in the US, Eurozone and the UK (for further details, see Bank of England, 2007). Our second measure is the spread between 3-month Libor and Gilt-repo rates. This measure of the difference between rates on unsecured and secured lending is widely used to illustrate the financial crisis and has been used to capture perceived risk in the inter-bank market (e.g. Michaud and Upper, 2008, Taylor and Williams, 2009, Martin and Milas, 2010). We also use the index of financial stress in the UK calculated by the IMF. As described in Balakrishnan et al (2009), this measure is a composite of the

TED, term and corporate debt spreads, returns and volatility in the stock market and exchange rate volatility. The liquidity index is negatively related to the credit spread whereas the Llibor-Gilt Repo spread and the financial stress index are positively related; we therefore expect ρ_μ to be positive for the first measure of μ but negative for the others.

These measures are shown in Figure 2, where their close similarities are apparent. The liquidity index increased steadily over the five years before the crisis before falling sharply in 2007 and again in late 2008. The Libor-Gilt Repo spread rarely rose above 25 basis points in the five years before the crisis but jumped to 100 points in July 2007 and to 250 points in late 2008, before gradually declining throughout 2009. The IMF measure of financial stress follows a similar pattern, rising sharply in July 2007 and late 2008[4].

Estimates of (8) on both pre-crisis and full samples using these measures of the determinants of credits spreads are reported in Table 2[5]. Although the models fit the data better than estimates of (7) and there is no evidence of structural breaks, the estimates are not satisfactory. We again obtain significant and sensible responses to inflation and output gaps using the pre-crisis sample but an insignificant response to inflation and a much reduced response to output gap using the full sample. All three credit spread measures are insignificant in the pre-crisis

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[4] The correlations between the liquidity index and the Libor-Gilt Repo spread and IMF measure of financial stress are -0.79 and -0.76 respectively. The correlation between these latter measures is 0.81. Credit default swap premia are an alternative measure of financial stress; we were unable to use these are they are only available after 2004; lack of data also prevented us from using the Libor-OIS spread.

[5] Variations in sample size reflect differences in data availability; the liquidity index is available from 1992 until June 2009; the Libor-Gilt Repo spread from 1996 and the IMF stress index from 1992 to February 2009.

period but become significant and correctly signed in the full sample. The reduction in the equilibrium nominal interest rate is less clear and there is again no change in the degree of interest rate inertia.

4. Modelling Switching Policy Objectives

The estimates in Table 1) suggest that monetary policy can be described using a simple Taylor rule before the Financial crisis but not thereafter while the estimates in Table 2) suggest a spread-adjusted policy rule can describe monetary policy during the financial crisis, but not before. When considered alongside the sharp differences in estimated parameters between pre-crisis and crisis periods in Tables 1) and 2), this implies a marked change in the behaviour following the onset of the financial crisis.

In order to explain this and derive a model that can explain monetary policy in both periods, we adapt our theoretical model to allow for changed in the preferences of policymakers when there is a financial crisis. We now suppose now that the objective function of policymakers is

(9) $$L_t = \phi_t L_{1t} + (1 - \phi_t)L_{2t}$$

where ϕ_t is the probability of there being a financial crisis at time t. We assume that the contingent loss functions are

(10) $$L_{1t} = E_{t-1} \sum_{k=0}^{\infty} \delta^i \{ \frac{\lambda_{1\pi}}{2} (\pi_{t+k} - \pi^T)^2 + \frac{\lambda_{1y}}{2} y_{t+k}^2 + \frac{\lambda_{1\sigma}}{2} \sigma_{t+k}^2 + \frac{\lambda_i}{2} (i_{t+k} - \bar{i}_{t+k})^2 \}$$

and

(11) $$L_{2t} = E_{t-1} \sum_{k=0}^{\infty} \delta^i \{ \frac{\lambda_{2\pi}}{2} (\pi_{t+k} - \pi^T)^2 + \frac{\lambda_{2y}}{2} y_{t+k}^2 + \frac{\lambda_i}{2} (i_{t+k} - \bar{i}_{t+k})^2 \}$$

Both loss functions reflect deviations of inflation from target, the output gap and deviations of the nominal interest rate from its equilibrium value. L_1 also reflects a concern with financial stability in periods of financial crisis by including a measure of domestic financial stability (σ). We assume that financial stability can be increased by reducing nominal interest rates, allowing financial institutions to re-capitalise at a lower cost:

(12) $$\sigma_t = \bar{\sigma} - \beta_\sigma (i_t - \bar{i}) + \upsilon_t$$

where υ_t is an iid shock to domestic financial stability.

The first-order condition for the interest rate that minimises (9) is

(13) $$E_{t-1} \frac{dL_t}{di_t} = E_{t-1} \{ \phi_t \frac{dL_{1t}}{di_t} + (1 - \phi_t) \frac{dL_{2t}}{di_t} + (L_{1t} - L_{2t}) \frac{d\phi_t}{di_t} \} = 0$$

Since the financial crisis is a global event we assume that the probability of a financial crisis is independent of the policy rate in the domestic economy; the first-order condition then simplifies to

(14) $\quad E_{t-1}\dfrac{dL_t}{di_t} = E_{t-1}\{\phi_t \dfrac{dL_{1t}}{di_t} + (1-\phi_t)\dfrac{dL_{2t}}{di_t}\} = 0$

This implies

(15)
$$E_{t-1}\{\phi_t[\delta\lambda_{1\pi}(\pi_{t+1}-\pi^T)\dfrac{\partial\pi_{t+1}}{\partial i_t} + \delta\lambda_{1y}y_{t+1}\dfrac{\partial y_{t+1}}{\partial i_t} + \lambda_{1\sigma}\sigma_t\dfrac{\partial\sigma_t}{\partial i_t} + \lambda_i(i_t-\bar{i})]$$
$$+(1-\phi_t)[\delta\lambda_{2\pi}(\pi_{t+1}-\pi^T)\dfrac{\partial\pi_{t+1}}{\partial i_t} + \delta\lambda_{2y}y_{t+1}\dfrac{\partial y_{t+1}}{\partial i_t} + \lambda_i(i_t-\bar{i})]\} = 0$$

Using (1)-(3), equation (15) can be written as

(16)
$$i_t = \bar{i} + \dfrac{\delta\alpha_r\alpha_y(\lambda_{1\pi}\phi_t + \lambda_{2\pi}(1-\phi_t))}{\lambda_i}(E_{t-1}\pi_{t+1}-\pi^T)$$
$$+\dfrac{\delta\alpha_r(\lambda_{1y}\phi_t + \lambda_{2y}(1-\phi_t))}{\lambda_i}E_{t-1}y_{t+1} + \dfrac{\lambda_{1\sigma}\beta_\sigma\phi_t}{\lambda_i}E_{t-1}\sigma_t$$

Equation (16) is an optimal monetary policy rule whose coefficients vary over time in response to changes in the probability of there being a financial crisis. If a crisis is

unlikely ($\phi_t \rightarrow 0$), there is no response to financial stability and the policy rule simplifies to the Taylor rule in (5) above. If a financial crisis is very likely ($\phi_t \rightarrow 1$) there is a response to financial stability and the policy rate resembles the spread-adjusted rule in (8).

5. Estimating a Switching Optimal Monetary Policy Rule

Our empirical counterpart to the optimal monetary policy rule in (16) is

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\begin{aligned}
(17) \quad i_t &= \rho_i i_{t-1} + (1-\rho_i)\{\bar{i} + \phi_t[\rho_{1\pi}\sum_{k=1}^{3}(E_{t-1}\pi_{t+k} - \pi^T) + \rho_{1y}\sum_{k=1}^{3}(E_{t-1}y_{t+k}) + \rho_{1\sigma}\sigma_t] \\
&\quad + (1-\phi_t)[\rho_{2\pi}\sum_{k=1}^{3}(E_{t-1}\pi_{t+k} - \pi^T) + \rho_{2y}\sum_{k=1}^{3}(E_{t-1}y_{t+k})]\} + v_t
\end{aligned}
$$

where $\rho_{1\pi} = \dfrac{\delta\alpha_r\alpha_y\lambda_{1\pi}}{\lambda_i}$, $\rho_{2\pi} = \dfrac{\delta\alpha_r\alpha_y\lambda_{2\pi}}{\lambda_i}$, $\rho_{1y} = \dfrac{\delta\alpha_r\lambda_{1y}}{\lambda_i}$, $\rho_{2y} = \dfrac{\delta\alpha_r\lambda_{2y}}{\lambda_i}$ and

$\rho_{1\sigma} = \dfrac{\lambda_{1\sigma}\beta_\sigma}{\lambda_i}$. Equation (17) is a switching regression model with differing responses of interest rates to the explanatory variables depending on the probability of there being a financial crisis. We assume that the probability of there being a financial crisis is a function of a measure of global financial stability, denoted by ω. We use three alternative measures on ω in our estimates. Following Taylor and Williams (2009), we the spread between the 3-month Libor and the overnight Federal Funds rates in the United States. We also use the indices of financial stress in the US and in the G7 economies calculated by the IMF (Balakrishnan et al, 2009).

We model the probability of a crisis using the logistic function[6]

$$(18) \qquad \phi_t = \Pr\{\omega_t > \omega^O\} = \frac{1}{1 + e^{-\gamma^\omega (\omega_t - \omega^O)/\sigma_\omega}}$$

where ω^0 is the threshold value of ω above which a crisis is triggered. Figure 3 plots our measures of global financial stability, where it is apparent that the US Libor-Overnight Federal Funds rate spread is similar to the Libor-Gilt Repo spread in the UK and that IMF measures of financial stress in the UK, the US and the G7 economies are very similar. For σ, domestic financial stability, we use the same measures as for μ, above: the Bank of England index of liquidity, the spread between 3-month Libor and Gilt-repo rates and the IMF index of financial stress in the UK. We expect $\rho_{1\sigma} > 0$ for the liquidity index but $\rho_{1\sigma} < 0$ for the other measures.

Estimates of (17)-(18) are presented in Table 3), where we report estimates of simplified specifications from which insignificant variables were dropped. The model performs well: the estimates in Table 3) fit the data better than those in Tables 1) and 2) and all estimates are significant with the expected sign. In contrast to the Taylor rule and spread-adjusted rule, a coherent explanation of UK monetary policy in both crisis and no-crisis periods emerges. There is a strong response of interest

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[6] In (18), the smoothness parameter $\gamma^\omega > 0$ determines the smoothness of the transition regimes. We follow Granger and Teräsvirta (1993) and Teräsvirta (1994) in making γ^ω dimension-free by dividing it by the standard deviation of the indicator of financial stability ω_t. In addition, van Dijk et al. (2002) argue that the likelihood function is very insensitive to γ^ω, suggesting that precise estimation of this parameter is unlikely. For this reason, we run a grid search in the range [0.1, 250] and fix the γ^ω parameter to the one that delivers the best fit of the estimated models.

rates to inflation in the no-crisis regime, but this disappears during a crisis. The clear response of interest rates to the output gap in the no-crisis period is weakened when a crisis occurs (in 2 out of 9 cases the response disappears). There is a strong response to measures of financial stability in periods of crisis[7]. In terms of our theoretical model, these estimates suggest that inflation only enters the policymakers' loss function when a financial crisis is unlikely ($\lambda_{2\pi} > 0$ but $\lambda_{1\pi} = 0$) and that the weight on output is reduced during a crisis ($\lambda_{2y} > \lambda_{1y}$).

The implications of our estimates for the explanation of monetary policy during the financial crisis are shown in figure 4) which compares the actual policy rate with the counterfactual policy rates implied by the crisis and no-crisis regimes using the estimates from column (ii) of Table 3a)[8]. The actual policy rate tracks the implied crisis regime rate closely, showing our model fits well over this crucial period. The implied no-crisis rate also falls sharply, but around 3 months later than the fall in the policy rate. Since the no-crisis regime is essentially identical to the simple Taylor rule estimated in section 2), the failure of this regime to predict the most dramatic movement in interest rates in over 30 years explains the poor performance of the Taylor rule during the crisis. The one measure of ω for which we have data beyond early 2009, the US Libor-OIS spread, has a threshold value of around 40 basis points. The spread fell below that value in July 2009 implying a shift back to the no-

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[7] In other versions of the model, we estimated a response to financial stability in no-crisis periods; this effect was always insignificant.

[8] Given by $\hat{i}_t^\phi = \hat{\rho}_i i_{t-1} + (1 - \hat{\rho}_i)\{\hat{\bar{i}} + \hat{\rho}_{1y}\sum_{k=1}^{3}(E_{t-1}y_{t+k}) + \hat{\rho}_{1\sigma}\sigma_t\}$ and

$\hat{i}_t^{1-\phi} = \hat{\rho}_i i_{t-1} + (1 - \hat{\rho}_i)\{\hat{\bar{i}} + \hat{\rho}_{2\pi}\sum_{k=1}^{3}E_{t-1}(\pi_{t+k} - \pi^T) + \hat{\rho}_{2y}\sum_{k=1}^{3}E_{t-1}y_{t+k}\}$ respectively. Results are qualitatively similar using the other estimates in Table 3).

crisis monetary policy regime in the UK around that time. The implied interest rates from crisis and no-crisis regimes were very close at that time, suggesting the transition between regimes has had no discernable impact on interest rates.

6. Conclusions

This paper explores the interest rate setting behaviour of monetary policymakers in the UK during the financial crisis. Our findings are summarised as follows. First, although interest rate setting behaviour is described by a simple Taylor rule in the period before the crisis, the Taylor rule breaks down during the crisis. Second, addition of "spread adjustments" to correct for the widening gap between policy rates and libor and other unsecured borrowing rates that were a prominent feature of the crisis does not solve the problem. Third, we develop a theoretical model in which the objective of policymakers differ between a no-crisis regime, where the objective is to stabilise inflation and a crisis regime in which policymakers also desire to stabilise the financial system and believe this can be done through lower interest rates. Our empirical results offer support for the predictions of the theoretical model as policymakers appear to cease targeting inflation during the crisis and focus instead on setting low interest rates in order to stabilise the financial system.

Our estimates imply that interest rates ceased to respond to inflation during the recent financial crisis. Does this mean that the UK abandoned inflation targeting in this period? If inflation targeting implies setting interest rates according to a policy rule that gives considerable weight to deviations of inflation from the target, the answer must be "yes". We find that policymakers have ignored inflation when setting interest rates during the financial crisis; they have not prevented inflation rising

sharply above the inflation target on occasions since 2007, leading to the first open letters being written by the Governor to explain the overshoot. However if inflation targeting is interpreted in the looser sense of setting interest rates to ensure that deviations of inflation from the target are neither too large not too prolonged, then the answer is arguably "no". The adverse demand shock spawned by the financial crisis put downward pressure on inflation, although the impact on this has been obscured by simultaneous adverse commodity price shocks. The policy response to this, lower interest rates, is the same as the policy response to instability on the financial system. In practice, monetary policy would not have been very different had the UK continued to follow the same policy rule in setting interest rates. Clearly, this issue can be better addressed when more data and with greater hindsight.

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Table 1) Estimates of

$$i_t = \rho_i i_{t-1} + (1 - \rho_i)\{\bar{i} + \rho_\pi \sum_{k=1}^{3}(E_{t-1}\pi_{t+k} - \pi^T) + \rho_y \sum_{k=1}^{3}(E_{t-1}y_{t+k})\} + \xi_t$$

	(i) Sample: 1992M10 2007M4	(ii) Sample: 1992M10 2010M1
ρ_i	0.922 (0.05)	0.932 (0.04)
$\bar{i}$	5.131 (0.19)	4.792 (0.27)
ρ_π	1.453 (0.48)	-0.760 (0.57)
ρ_y	2.424 (0.41)	1.122 (0.39)
J-test (p-value)	0.27	0.26
Breakpoint test (p-value)	0.15 (1998M10)	0.00 (2007M4)
eqn s.e.	0.18	0.23

Notes: Numbers in parentheses are standard errors. J stat is a chi-square test of the model's overidentifying restrictions. The null hypothesis of the Quandt and Andrews breakpoint test is that there are no breakpoints. We report the p-value of the maximum LR F-statistic using 15% observation trimming. The p-value is calculated using Hansen's (1997) method.

Table 2) Estimates of

$$i_t = \rho_i i_{t-1} + (1 - \rho_i)\{\bar{i} + \rho_\mu \mu_t + \rho_\pi \sum_{k=1}^{3}(E_{t-1}\pi_{t+k} - \pi^T) + \rho_y \sum_{k=1}^{3}(E_{t-1}y_{t+k})\} + \varepsilon_t$$

	Pre-crisis sample			Full sample		
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
	Sample: 1992M10 2007M4	Sample: 1996M1 2007M4	Sample: 1992M10 2007M4	Sample: 1992M10 2009M6	Sample: 1996M1 2010M1	Sample: 1992M10 2009M2
μ measured as	Liquidity index	Libor-Gilt Repo spread	Financial Stress	Liquidity index	Libor-Gilt Repo spread	Financial Stress
ρ_i	0.941 (0.06)	0.931 (0.05)	0.933 (0.06)	0.931 (0.07)	0.941 (0.06)	0.931 (0.07)
$\bar{i}$	5.331 (0.18)	4.951 (0.42)	5.052 (0.24)	5.022 (0.23)	5.122 (0.25)	4.232 (0.24)
ρ_π	1.214 (0.46)	1.121 (0.44)	1.021 (0.47)	0.173 (0.31)	0.062 (0.17)	-0.171 (0.40)
ρ_y	2.620 (0.48)	2.293 (0.50)	2.503 (0.48)	0.783 (0.29)	1.582 (0.23)	1.532 (0.31)
ρ_μ	0.052 (0.41)	2.341 (2.29)	-0.192 (0.10)	1.933 (0.25)	-7.021 (0.66)	-0.531 (0.07)
J-test (p-value)	0.27	0.23	0.27	0.24	0.23	0.22
Breakpoint test (p-value)	0.22 (2001M2)	0.21 (1998M10)	0.33 (1998m10)	0.14 (2001M2)	0.12 (1998M10)	0.19 (1998m10)
eqn s.e.	0.16	0.16	0.16	0.22	0.19	0.20

Notes: See the notes of Table 1.

Table 3) Estimates of

$$i_t = \rho_i i_{t-1} + (1 - \rho_i)\{\bar{i} + \phi_t[\rho_{1\pi}\sum_{k=1}^{3}(E_{t-1}\pi_{t+k} - \pi^T) + \rho_{1y}\sum_{k=1}^{3}(E_{t-1}y_{t+k}) + \rho_{1\sigma}\sigma_t]$$

$$+ (1 - \phi_t)[\rho_{2\pi}\sum_{k=1}^{3}(E_{t-1}\pi_{t+k} - \pi^T) + \rho_{2y}\sum_{k=1}^{3}(E_{t-1}y_{t+k})]\} + v_t$$

3a) Financial crisis indicator: US Libor-Overnight Federal Funds spread

	(i) Sample: 1992M10 2009M6	(ii) Sample: 1996M1 2010M1	(iii) Sample: 1992M10 2009M2
ω measured as	US Libor-Overnight Federal Funds spread		
σ measured as	Liquidity index	Libor-Gilt Repo spread	Financial Stress
ρ_i	0.931 (0.08)	0.934 (0.08)	0.942 (0.08)
$\bar{i}$	5.101 (0.20)	5.449 (0.25)	4.754 (0.26)
financial crisis regime			
$\rho_{1\pi}$			
ρ_{1y}	0.814 (0.35)	1.349 (0.40)	0.923 (0.46)
$\rho_{1\sigma}$	2.211 (0.28)	-7.924 (0.72)	-0.623 (0.12)
no financial crisis regime			
$\rho_{2\pi}$	1.762 (0.43)	1.540 (0.64)	1.247 (0.46)
ρ_{2y}	1.073 (0.42)	1.744 (0.60)	1.064 (0.50)
ω^0	0.391 (0.08)	0.401 (0.09)	0.382 (0.08)
J-test (p-value)	0.30	0.27	0.29
Eqn s.e.	0.20	0.17	0.18
$H_0: \rho_{1\pi} = 0$ (p-value)	0.97	0.23	0.31

3b) Financial crisis indicator: US financial stress index

	(i) Sample: 1992M10 2009M5	(ii) Sample: 1996M1 2009M5	(iii) Sample: 1992M10 2009M2
ω measured as	US financial stress index		
σ measured as	Liquidity index	Libor-Gilt Repo spread	Financial Stress
ρ_i	0.921 (0.06)	0.932 (0.06)	0.924 (0.06)
$\bar{i}$	5.455 (0.18)	5.161 (0.23)	5.382 (0.23)
financial crisis regime			
$\rho_{1\pi}$			
ρ_{1y}		1.751 (0.30)	1.412 (0.37)
$\rho_{1\sigma}$	2.636 (0.22)	-7.661 (0.66)	-0.798 (0.07)
no financial crisis regime			
$\rho_{2\pi}$	1.292 (0.45)	1.391 (0.60)	1.281 (0.52)
ρ_{2y}	1.701 (0.43)	2.292 (0.70)	2.031 (0.55)
ω^0	1.110 (0.28)	1.071 (0.29)	1.012 (0.27)
J-test (p-value)	0.26	0.28	0.24
Eqn s.e.	0.18	0.16	0.16
$H_0 : \rho_{1\pi} = \rho_{1y} = 0$ (p-value)	0.29		
$H_0 : \rho_{1\pi} = 0$ (p-value)		0.93	0.37

3c) Financial crisis indicator: G7 financial stress index

	(i) Sample: 1992M10 2009M5	(ii) Sample: 1996M1 2009M5	(iii) Sample: 1992M10 2009M2
ω measured as	G7 financial stress index		
σ measured as	Liquidity index	Libor-Gilt Repo spread	Financial Stress
ρ_i	0.931 (0.05)	0.932 (0.07)	0.932 (0.07)
$\bar{i}$	5.534 (0.16)	5.529 (0.22)	5.461 (0.23)
financial crisis regime			
$\rho_{1\pi}$			
ρ_{1y}		2.202 (0.33)	1.232 (0.36)
$\rho_{1\sigma}$	3.470 (0.27)	-8.257 (0.61)	-0.839 (0.07)
no financial crisis regime			
$\rho_{2\pi}$	1.338 (0.40)	1.710 (0.64)	1.248 (0.58)
ρ_{2y}	2.115 (0.40)	2.919 (0.65)	2.392 (0.55)
ω^0	0.981 (0.10)	0.991 (0.20)	1.010 (0.20)
J-test (p-value)	0.30	0.30	0.30
eqn s.e.	0.16	0.15	0.17
$H_0 : \rho_{1\pi} = \rho_{1y} = 0$ (p-value)	0.31		
$H_0 : \rho_{1\pi} = 0$ (p-value)		0.74	0.98

Notes: See the notes of Table 1.

Figure 1: UK policy rate, inflation and output gap

Interest rate

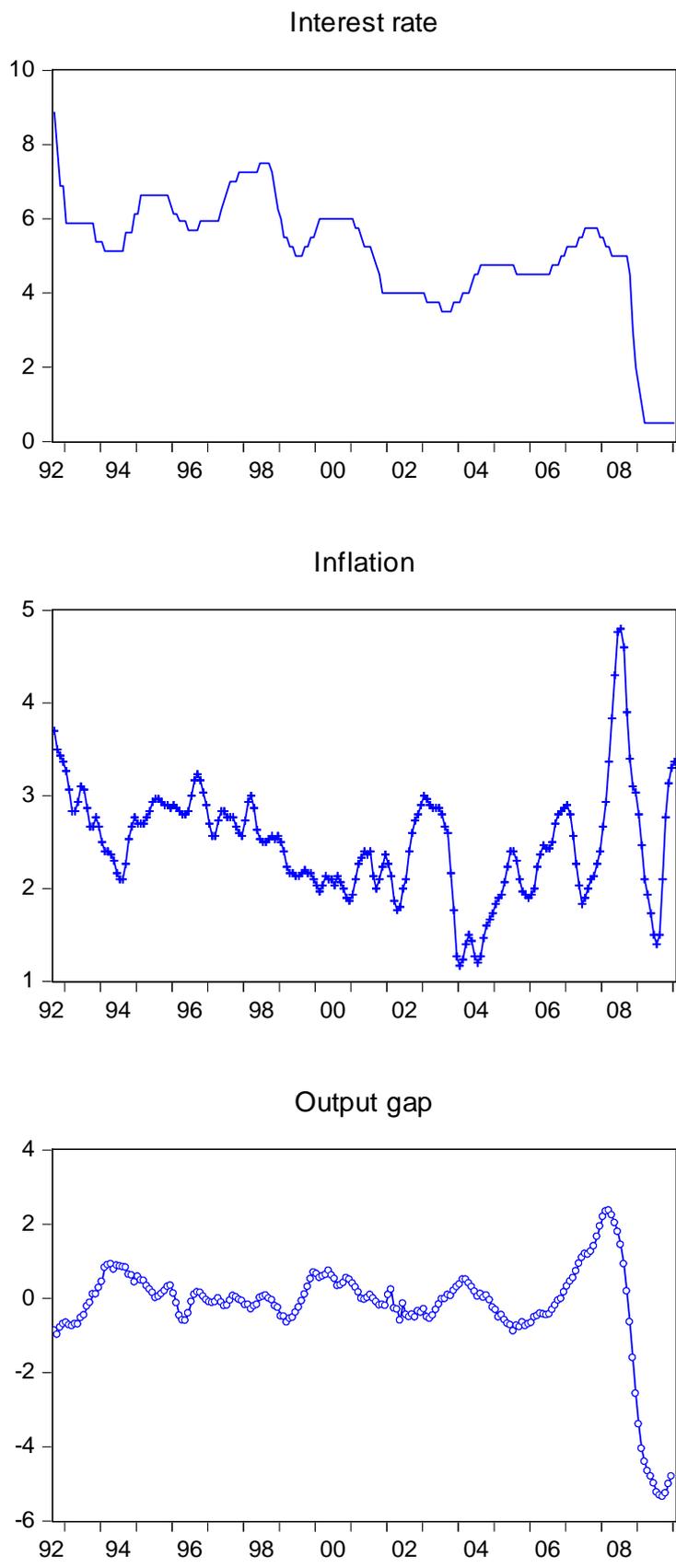
Inflation

Output gap

Figure 2: Liquidity index, 3-month Libor minus 3-month Repo and Financial Stress Index

Liquidity

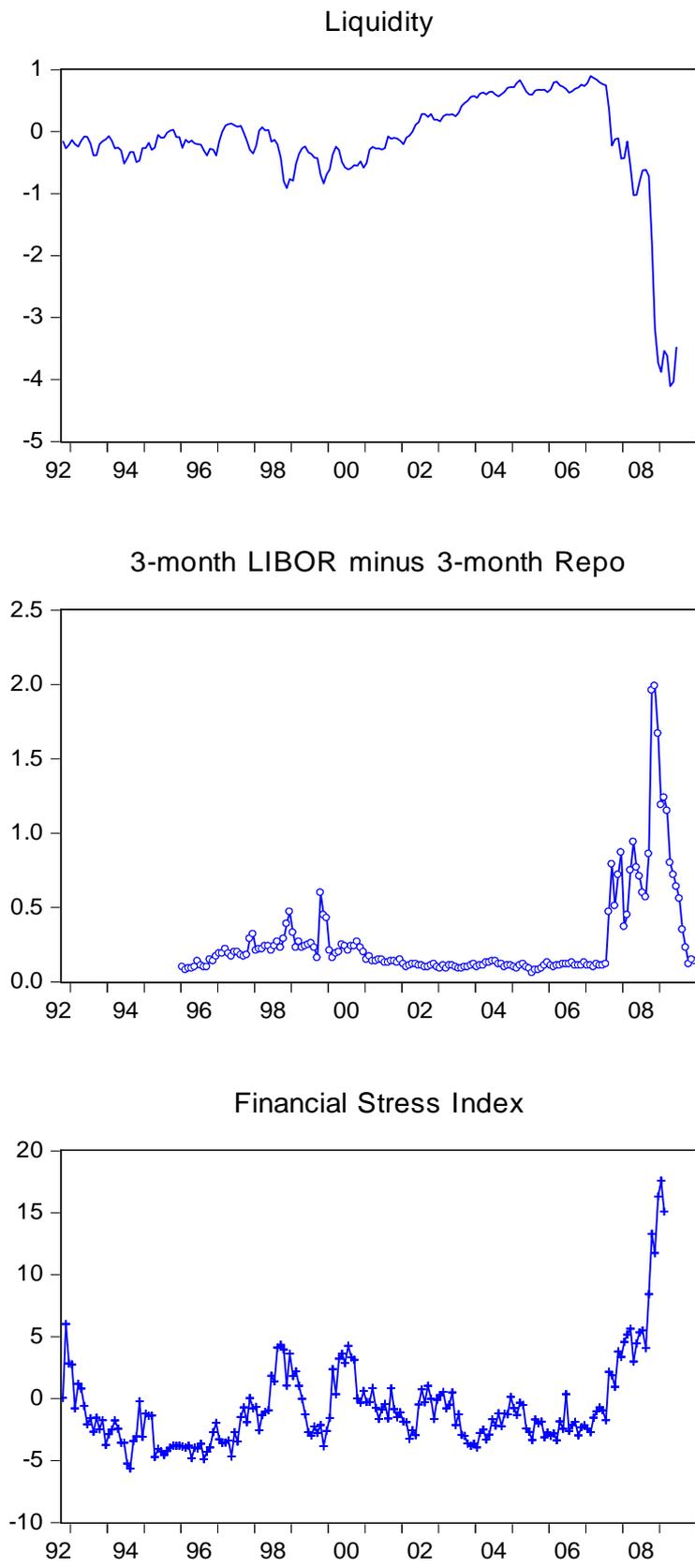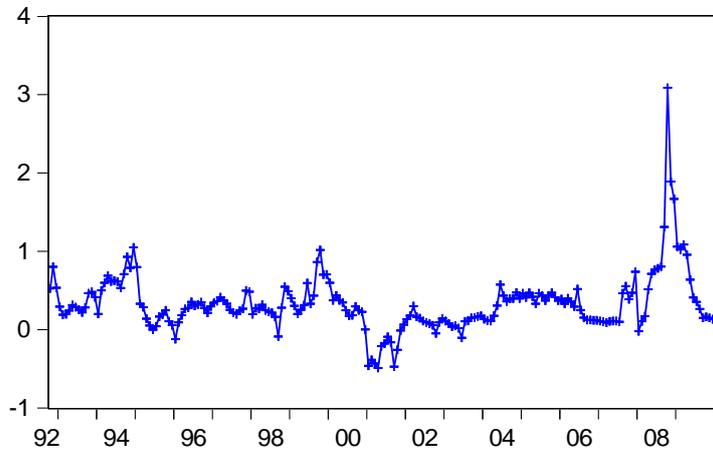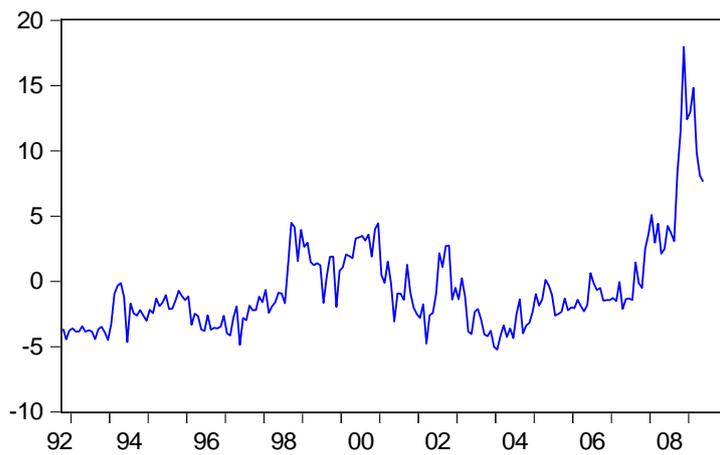3-month LIBOR minus 3-month Repo

Financial Stress Index

28

Figure 3: Spread between 3-month Libor and overnight Federal Funds rates, US Financial Stress Index and G7 Financial Stress Index

3-month LIBOR minus overnight Federal Funds Rate in the US

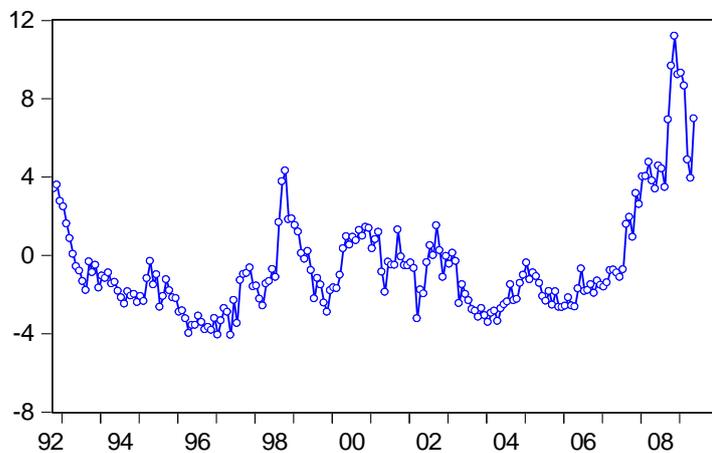Financial Stress Index (US)

Financial Stress Index (G7)

Figure 4: Actual and implied regime-specific policy rates