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Abstract

We investigate the impact of financial stress on output, inflation and monetary policy in the UK since 1992 using a nonlinear Bayesian VAR model that distinguishes between regimes of low- and high-financial stress. We find that (a) the UK was in the high-stress regime during the financial crises of 1998-2001 and 2007-2012 but was in the low-stress regime in the rest of the "great moderation" period; (b) positive shocks to financial stress in the high-stress regime lead to sharp and sustained falls in the output gap, inflation and the policy rate; (c) financial stress shocks have little impact in the low-stress regime; (d) the impact of other macroeconomic shocks is stronger in periods of high financial stress; (e) increased financial stress reduced inflation and the output gap by up to 2 percentage points in 2008-2010; (f) financial stress can be monitored against the estimated threshold beyond which it has adverse effects; (g) there is a "policy window" of at least 4 months in which policymakers can respond to increased financial stress before it affects the wider economy.

Keywords: monetary policy, financial stress, financial crisis
JEL Classification: C51, C52, E52, E58

1 Introduction

The financial crisis that began in July 2007 and threatened to bring down banking systems in advanced economies in late 2008 has underlined the reliance of modern economies on well-functioning financial markets. As a result of the crisis, there has been a good deal of work around the concept of "financial stress". Financial stress "can be thought of as an interruption to the normal functioning of financial markets" (Hakkio and Keaton, 2009). It is associated with disruptions of the transmission mechanism that links monetary policy, financial markets and the wider economy. It is widely felt that the financial crisis disrupted the flow of credit from financial markets to households and firms and led to a sharp economic contraction. Recovery from the crisis has been slow: by late 2013, output remained below the peak of summer 2007 in many countries and unemployment remained stubbornly high.

Recent work has focussed on two issues: the best way to measure financial stress and the impact of financial stress on the wider economy, especially output and inflation. On measurement, symptoms of financial stress include: rising interest rate spreads, increased volatility on equity and foreign exchange markets, reduced liquidity, sharp falls in asset values and increased risk and liquidity premia. Measures of financial stress that incorporate these have been developed (Balakrishnan et al, 2009, Hakkio and Keaton, 2009, Hatzius et al, 2010, Oet et al, 2011, Hollo et al 2012) and appear to be useful and informative. Considering the impact of financial stress, there is evidence that shocks that increase financial stress have powerful negative effects on output and inflation. These effects appear to be nonlinear with shocks to financial stress having a larger negative impact when financial stress is already high (Hakkio and Keaton, 2009, Castelnuovo, 2010, Hubrich and Tetlow, 2012, Mittnik and Semmler, 2013, van Roye, 2013, and Aboura and van Roye, 2013).

This paper has three main objectives. The first is to estimate the impact of financial stress in the UK in the period since the introduction of the inflation targeting policy regime in 1992. Mittnik and Semmler (2013) analyse the impact of financial stress on industrial production in the UK as part of a wider multi-country study. We estimate a more complete model, allowing us to assess the impact of financial stress on the output gap, inflation and monetary policy. Second, we will use our model to interpret macroeconomic developments in the UK. In particular, we will estimate the contribution of different macroeconomic shocks to movements in the output gap and inflation in 2008-2010, the height of the financial crisis. Third, we will explore whether there is a "policy window" within which policymakers can offset a rise in financial stress before it affects the wider economy. Our empirical model allows for a delay between an increase in financial stress and the onset of negative effects on the economy. If our estimates detect a significant delay, policymakers may have a window of opportunity within which they can adopt policy responses to financial stress.

We obtain a number of interesting findings. First, we find that the UK economy is best characterised as having two distinct regimes, corresponding to high and low levels of financial stress, where financial stress determines the regime with a four month lag. Second, the UK was largely in the high-stress regime during the financial crises of 1998-2001 and 2007-2012 but was mostly in the low-stress regime in the rest of the "great moderation" period. Third, adverse shocks to financial stress in the high-stress regime lead to sharp and sustained falls in the output gap, inflation and the policy rate, whereas financial stress shocks have little impact in the low-stress regime. Fourth, the impact of other macroeconomic shocks is intensified in periods of high financial stress and weakens in the low-stress regime. Fifth, movements in the output gap and inflation in 2008-2010 were strongly influenced by financial stress.

The remainder of the paper is structured as follows. We discuss measurement of financial stress in section 2). We discuss methodology and alternative econometric approaches in section 3), explaining the two-regime model that allows for differences in behaviour in periods of low and high financial stress that we use. Section 4) presents estimated impulse response functions from our model. Section 5) uses estimates of the two-regime model to relate movements in the output gap and inflation in 2008-2010 to structural shocks. Section 6) explores the "policy window", discussing periods when policy initiatives might have been most effective and possible policy responses to future financial crises. Section 7) concludes.

2 Measuring Financial Stress

The International Monetary Fund (IMF) has calculated a measure of financial stress for the major world economies on a monthly basis from January 1980 to February 2009 (Balakrishnan et al, 2009). This "IMF index" aggregates a range of different indicators of financial stress. Specifically, it uses: (a) the TED spread (the difference between three-month LIBOR and policy rates); (b) the inverted term spread (the difference between short-term and long-term government bond rates); (c) the corporate bond spread (the difference between corporate and government bond yields); (d) the % decline in Stock Prices; (e) the volatility of stock market returns; (f) the volatility of real effective exchange rates and (g) the covariance between changes in banking sector and overall stock market indices. The IMF index is the only consistent measure of financial stress across countries. We will use it to measure financial stress in this paper.

There are alternative measures of financial stress. For the US, the Federal Reserve and the Federal Reserve Banks of Kansas and St Louis produce their own measures of financial stress. These use broadly similar measures of financial stress but with different methods of aggregation[1] . van Roye

[1] The correlation between the IMF measure of financial stress in the US and the Kansas City index is 0.86 and the correlation between the IMF measure and the St Louis index

(2013) and Aboura and van Roye (2013) develop financial stress indices for Germany and France respectively; movements in these indices over time appear to be similar to movements in the corresponding IMF indices. However there are no alternative measures of financial stress in the UK.

Figure 1a) plots the IMF stress index for the UK since 1992[2] . There are two main periods of elevated financial stress. The first is between 1998-2001, when financial markets were buffeted by, among other events, the Russian crisis and LTCM bailout in 1998 and the bursting of the technology stocks bubble in 2000. The second period began in July 2007, with the onset of the “sub-prime crisis”. Financial stress grew from the second quarter of 2008, greatly intensified in September of that year (when Lehman Brothers collapsed) and remained at an elevated level until December 2009. This was followed by further episodes of heightened stress associated with recurrent Eurozone crises, between May 2010 and January 2011 and for most of the period between August 2011 and August 2012.

3 Methodology

The literature on the impact of financial stress uses regime-switching Vector Autoregression (VAR) models. These models assume that the economy is in one of two regimes[3], labelled the “high-“ and “low-stress” regimes, where

is 0.80.

[2] We thank Selim Elekdag of the IMF for providing us with updated data.

[3] The literature assumes there are two regimes, with the exception of Hubrich and Tetlow (2012), who consider three.

the regime is indicated by $s_t \in \{h, l\}$, where h and l denote the high- and low-stress regimes respectively. The model is

$$(1) \qquad A_0(s_t)X_t = \overline{A}(s_t) + \sum_{k=1}^{p} A_k(s_t)X_{t-k} + u_t$$

where X_t is a $(k \times 1)$ vector containing the endogenous variables, u_t is a $(k \times 1)$ vector containing structural shocks and A_0 , A_k $(k = 1, .., p)$ and $\overline{A}$ are $(k \times k)$ matrices of parameters that respectively describe the contemporaneous relationships between the variables, the impact of lagged endogenous variables and the constant. The structural relationships in (1) differ between regimes. The covariance matrix of the structural shocks, $\Sigma = Eu_t u_t'$ is assumed to be diagonal.

Part of the existing literature (eg Castelnuovo, 2010, Davig and Hakkio, 2010, Hubrich and Tetlow, 2012, Aboura and van Roye, 2013) uses a Markov-switching VAR (MS-VAR). This model assumes that the economy moves between regimes following a stochastic Markov process, so

$$(2) \qquad \Pr\{s_t = n/s_{t-1} = m\} = p_{nm}$$

for $n, m \in \{h, l\}$ and where p_{nm} is a constant transition probability. In this model, s_t is an unobserved latent variable. The rest of the literature uses a Threshold VAR (TVAR) (Tsay, 1998, Balke, 2000). This model assumes that the regime depends on financial stress, so

$$(3) \qquad \begin{Bmatrix} s_t = h \\ s_t = l \end{Bmatrix} \; if \; \begin{Bmatrix} \sigma_{t-d} > \overline{\sigma} \\ \sigma_{t-d} \leq \overline{\sigma} \end{Bmatrix}$$

where σ is financial stress, $\overline{\sigma}$ is the threshold value of financial stress and d is the the delay parameter.

In this paper, we will use the TVAR methodology, since it allows us to address issues concerning the detection and policy response to financial stress. To do this, we exploit two features of the TVAR model. First, we can estimate $\overline{\sigma}$, the threshold value of financial stress above which the economy is in the high-stress state. Since financial stress can be measured accurately in real time, policymakers can monitor the risk of financial stress and, if necessary, take pre-emptive action. Second, we can estimate the "delay parameter", d. This measures the width of the "policy window", during which policymakers can respond to financial stress before it affects the wider economy.

Correct specification of the variables to be included in the model is clearly critical. Part of the literature (eg Davig and Hakkio, 2010, Hollo et al, 2010, Mittnik and Semmler, 2013) includes just two variables in X_t: output and financial stress. This seems inadequate, not least because it does not enable analysis of the impact of financial stress on the transmission mechanism. We follow the rest of the literature (eg Castelnuovo, 2010, Aboura and van Roye, 2013, van Roye, 2013) and analyse four variables: inflation (π_t), the output gap (y_t), the policy rate (i_t) and financial stress (σ_t)[4].

Given these assumptions, we can express (1) as[5]

(4a) $$X_t = B_0(h) + B_1(h)X_{t-1} + B_2(h)X_{t-2} + .. + B_p(h)X_{t-p} + v(h)_t$$

and

(4b) $$X_t = B_0(l) + B_1(l)X_{t-1} + B_2(l)X_{t-2} + .. + B_p(l)X_{t-p} + v(l)_t$$

where $X_t = (\pi_t, y_t, i_t, \sigma_t)'$ is the (4x1) vector of endogenous variables, $B_0(s) = A_0(s_t)^{-1}\overline{A}(s_t)$, $B_j(s) = A_0(s_t)^{-1}A_j(s_t)$, for $j = 1, .., p$ are (4x4) parameter matrices and $v(s)_t = A_0(s_t)^{-1}u_t$ are (4x1) vectors of errors for $s_t \in \{h, l\}$.

Analysis of the TVAR model proceeds in three steps. First, the null of a linear VAR model is tested against the alternative of a TVAR model using the test statistic proposed by Tsay (1998). Then the threshold value ($\overline{\sigma}$) and the delay parameter (d) are estimated. Finally the remaining parameters of the TVAR model in (4a) and (4b) are estimated. There are two approaches to estimation in the literature: the TVAR model is estimated using classical techniques, whereas the MS-VAR model is estimated using Bayesian techniques. We will break with this tradition by estimating the parameters of (4) using Bayesian techniques.

[4] Hubrich and Tetlow (2012) also use money growth.

[5] This model can be derived from a structural Threshold Regime Switching Rational Expectations model (Kazanas et al, 2011).

4 Threshold VAR Model

We use UK monthly data for the period January 1993- January 2013. We use the annual change in the widely-used RPI price index as our measure of inflation. The output gap 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 the average of two alternative measures of equilibrium output: the Hodrick and Prescott (1997) trend[6] and a simple quadratic trend. The UK output gap in the post-2007 period is a subject of some controversy (Giles, 2011). In our judgement, the output gap implied by the Hodrick and Prescott (1997) filter underestimates the severity of the post-2007 recession whereas the output gap constructed using a quadratic trend overstates this. Using the average of these alternative measures gives an output gap that is similar to that estimated by the Office for Budget Responsibility (OBR) in its quarterly measure[7]. For the nominal interest rate we use the policy rate of the Bank of England. Figure 1b) plots the output gap, RPI inflation and the policy rate. Selecting the length of the VAR using the AIC results in $p = 2$.[8]

The Tsay (1998) procedure tests the null of a VAR model against the

[6] To tackle the end-point problem in calculating the Hodrick-Prescott trend (see Mise et al, 2005), we applied an autoregressive AR(n) model (with n set at 4 using the Akaike Information Criterion (AIC)) 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.

[7] Available from: http://budgetresponsibility.independent.gov.uk/data/

[8] Other criteria place a heavier penalty on the number of parameters and so result in smaller values of p; this does not materially affect the estimates reported below.

alternative of a TVAR model. The null hypothesis is $H_0 : B_k(l) = B_k(h)$ for $k = 0, 1, ..., p$. To implement the test, the data are re-ordered according to ascending values of the threshold variable. A single regime linear VAR model for X_t is then estimated using the first m_0 observations of the re-ordered sample. These estimates are then used to test for parameter stability across the full sample.[9] We calculate the test statistic for a range of possible values of the delay parameter d and for differing values of m_0. However we restrict the set of possible break points by insisting that at least 20% of the sample is in each regime (cf Balke, 2000). If there is evidence of a break, we select the values of $\overline{\sigma}$ and d that maximise the test statistic, following Tsay (1998). Having done so we perform a grid search over a range of values of $\overline{\sigma}$ selecting the value that maximises the log likelihood function of the model.

Table 1) presents significance levels of the Tsay test for a range of values of $\overline{\sigma}$ and d. The null hypothesis is rejected at the 5% level in 29 out of 36 cases and rejected at the 1% level in 19 cases. The strongest rejections occur for $d = 4$ and this is chosen as the delay parameter.[10] Given this estimate of d, we estimate the regime threshold is $\overline{\sigma} = -0.99$ (this threshold is superimposed on the financial stress index in figure 1a). This estimate classifies the major episodes of financial stress in the UK into the high-stress regime. The remainder of the sample, covering the period of the "Great

[9] With the MS-BVAR model this can be done, less conveniently, using likelihood ratio tests.

[10] However, the null is also rejected by every test with $d = 5, 6, 7$ and $d = 10, 11$, suggesting that our point estimate of d is at the lower end of possible values.

Moderation" is mainly classified into the low-stress regime.

We next estimate the parameters in (4) using Bayesian techniques. We follow the literature in using the Minnesota prior (Doan et al, 1984, Koop and Korobilis, 2010). This shrinks the model towards a random walk, by assuming a prior of unity on the first own-lag of each endogenous variable and a prior of zero on subsequent own-lags and on the cross-effects between variables.[11] Following the literature, we identify our model by assuming that A_0^{-1} is lower-triangular.[12] The ordering of variables in the VAR reflects evidence that the response of inflation to shocks is slower than the response of output and evidence that both respond more slowly than monetary policy. Financial stress is treated as the most endogenous variable since it reflects events on highly responsive financial markets. In practice, classical and Bayesian estimates gave similar impulse response functions, however Bayesian estimates gave more precisely defined error bounds for the impulse responses.[13]

The estimated impulse response functions documenting the median re-

[11] We assume that the standard deviation of the prior distribution for the coefficient on lag l of variable j in equation i is given by $\sigma_{ij}(l) = \frac{\gamma s_i}{s_j}$ where γ is the tightness parameter governing the overall size of the standard deviations of the priors (we set $\gamma = 0.05$) and s_k is the estimated standard error in an AR(1) regression for variable k. Given that we use relatively high-frequency monthly macroeconomic data, we do not assume that the standard deviations of the priors decline with lag length, nor do we assume that the standard deviations are smaller when $j \neq i$; we balance these assumptions by using a relatively small tightness parameter.

[12] We explored alternative identification strategies. We reversed the ordering of variables in the VAR, following Sims (1992). We also used generalized impulse responses (Pesaran and Shin, 1998) that do not require orthogonalization of shocks and are invariant to the ordering of the variables in the VAR. These alternatives gave similar results, suggesting that our estimates are robust.

[13] These estimates are available on request, as are estimates of alternatives specifications of the model, discussed below.

sponse of the endogenous variables to a one standard deviation shock to the financial stress index are depicted in figure 2) (with one standard deviation error bounds) based on 1000 Monte Carlo draws. The shock to financial stress has a powerful effect on output, inflation and the policy rate in the high-stress regime but not in the low-stress regime. In the high-stress regime, a shock to financial stress leads to a sharp reduction in the output gap that reaches a maximum after one year and remains significant for nearly three years. By contrast, a shock to financial stress has no effect on the output gap in the low-stress regime. The impulse responses of inflation are similar. In the high-stress regime, there is a reduction in inflation that reaches a maximum in month 10 and remains significant for two and a half years. In the low-stress regime, the response is very small and never significant. A shock to financial stress reduces the policy rate in the high-stress regime; this reduction reaches a trough after 15 months and remains significant for over three years. The response in the low-stress regime is small and insignificant. The differences between the impact of a shock to financial stress in the high-stress and low-stress regimes are highlighted by the respective variance decompositions. In the high-stress regime, shocks to financial stress explain 37%, 35% and 29% of the variances of the output gap, inflation and the policy rate, respectively, at a 2 year horizon; in the low-stress regime, the corresponding figures are 2%, 0.1% and 3.1%.

The other impulse responses are reported in figure A1) in the appendix.

Shocks to the output equation result in higher output and inflation and so might be interpreted as aggregate demand shocks. Shocks to the inflation equation result in higher inflation and a reduction (after a delay of some months) in the output gap; they might therefore be seen as supply shocks. There is a significant increase in the policy rate in response to both demand and supply shocks. There is no evidence of a "price puzzle", as positive shocks to the policy rate do not result in significantly higher inflation.[14] It is apparent that the impact of all shocks is significantly larger in the high-stress regime than the low-stress regime. As a result, the economy is more vulnerable to shocks in periods of elevated financial stress. By contrast, the economy appears to be more resilient in the face of shocks in periods of lower stress.

We considered alternative specifications of our model. We used Consumer Price inflation (CPI) rather than RPI inflation. The pattern of impulse responses is broadly similar (although the impact of financial stress shocks are less well determined in the high-stress regime). In contrast to the results with RPI, the response of inflation to the policy rate using CPI is significantly negative in the low-stress regime but insignificant in the high-stress regime. The responses of the output gap and policy rate to financial stress in the high-stress regime are shorter-lived with CPI. We also used GDP growth rather than the output gap. The impulse responses are similar, although the

[14] There is a price puzzle if we allow the standard deviations of the priors to decline with lag length and assume the standard deviations of the priors are smaller when $j \neq i$.

response of GDP growth to financial stress in the high-stress regime is less persistent. We also used the nominal 10-year government bond rate rather than the policy rate. The impulse responses are again similar, although in this case, in the high-stress regime, inflation does not fall in response to a contractionary monetary policy shock.

5 The Impact of Shocks, 2008-2010

The impulse response functions reported in the previous section show the impact of hypothetical one-standard deviation structural shocks. Although useful in illustrating the properties of the estimated model, they are not directly informative about movements in the endogenous variables in the sample period. In this section, we investigate the impact of shocks on the UK economy in $2008 - 2010$, the period when the financial crisis was most intense.

Using our estimated value of p and assuming that the UK would have been in the high-stress regime in the absence of shocks[15] throughout $2008 - 2010$, we can use the identity

$$X_t = \widehat{\beta}_0(h) + \widehat{\beta}_1(h)X_{t-1} + \widehat{\beta}_2(h)X_{t-2} + \widehat{v}(h)_t \tag{5}$$

where $\widehat{\beta}_k$, for $k = 0, 1, 2$, denotes matrices of estimated parameters and

[15] Financial stress was well above the regime threshold throughout 2008-2009. There was a period of lower stress in early 2010, so the estimated impact of shocks in this period might be viewed more sceptically.

$\widehat{v}(h)_t$ is a vector containing estimated residuals, to estimate the effect of structural shocks. To do this, we first use the estimated covariance matrix of the estimated residuals and the assumed diagonality of the covariance matrix of the structural shocks to estimate $A_0(h)$ (Enders, 2010) and obtain the estimated structural shocks at time t as $\widehat{u}\,(h)_t = \widehat{A}_0\,(h)\,\widehat{v}\,(h)_t$. To isolate the impact of the structural shock to the ith variable we pre-multiply by a selection matrix $\tau(i)$ (an identity matrix with the ith column replaced with zeroes) giving $\widehat{u}\,(h)_t^{-i} = \tau\,(i)\,\widehat{u}\,(h)_t$ as the vector of estimated structural shocks with the ith shock removed. We can then generate the counterfactual values of the endogenous variables as

$$X_t^{-i} = \widehat{\beta}_0(h) + \widehat{\beta}_1(h)X_{t-1}^{-i} + \widehat{\beta}_2(h)X_{t-2}^{-i} + \widehat{v}\,(h)_t^{-i} \tag{6}$$

where $\widehat{v}\,(h)_t^{-i} = \widehat{A}_0\,(h)^{-1}\,\widehat{u}\,(h)_t^{-i}$ are the estimated residuals adjusted by the removal of the ith structural shock. The impact of the ith structural shock on the endogenous variables is then given by $X_t - X_t^{-i}$.

The estimated impact of structural shocks on the output gap is shown in Figure 3a). Movements in the output gap mainly reflect shocks to financial stress and to aggregate demand. Financial stress shocks have a large and persistently negative impact on the output gap. The negative effect becomes apparent in February 2009, exceeds -100 basis points (b.p) by November 2009 and reaches a peak effect of -190 b.p between November 2009 and February 2010. Thereafter the effect is gradually reduced, but still exceeds

-100 b.p at the end of December 2010. These finding are consistent with Florackis et al (2012), who find that a sharp increase in stock market illiquidity reduced UK output growth during the financial crisis, with a peak effect of 230 bp in 2009. The output gap is also affected by aggregate demand shocks, which have stronger but shorter-lived effects. The impact of demand shocks is apparent by June 2008, exceeds -100 b.p by November 2008 and reaches a peak of -250 b.p in March 2009. Thereafter, the impact is reduced, falling below -100 b.p in September 2009 before becoming positive in May 2010. Shocks to inflation have a smaller effect and policy rate shocks have little discernible impact.

The estimated impact of structural shocks on inflation is shown in Figure 3b). Movements in inflation largely reflect the interplay of two shocks, financial stress shocks and aggregate supply shocks. Shocks to financial stress have a large and persistently negative impact on inflation. The negative effect is apparent at the start of 2008, reduces inflation by more than 100 b.p by February 2009 and by around $190-200$ b.p between May-December 2009. The effect is then somewhat reduced but shocks to financial stress continue to reduce inflation by more than 100 b.p until November 2010. The effect of aggregate supply shocks on inflation has three distinct phases. Aggregate supply shocks increase inflation between January-November 2008, with a peak effect of 200 b.p in September 2008. There is then a sharp reversal with the impact of aggregate supply shocks exceeding -100 b.p by December 2008, with a peak effect of -200 b.p in September 2009 (this reversal follows movements in crude oil prices, which peaked in October 2008 and fell rapidly for the next 12 months). This is followed by another sharp reversal, with aggregate supply shocks increasing inflation by more than 150 b.p by December 2009 and by more than 350 b.p by April 2010 (these movements again closely follow movements in the price of crude, which grew rapidly between November 2009-May 2010). This positive effect then tapers off but remains positive at the end of 2010.

6 The Policy Window

Our estimates suggest there is a “policy window” of at least 4 months in which policymakers can respond to increased stress before it affects the wider economy. From figure 1), we can identify a policy window at the start of the financial crisis between July-October 2007. There were no significant policy initiatives in the UK in this period, in contrast to the US where deeps cuts in the Federal Funds rate began in August 2007. There were subsequent policy windows in April-July 2010 and August-November 2011. The second wave of Quantitative Easing in the UK began in this latter policy window in October 2011 (swiftly followed by a third wave in February 2012, Martin and Milas, 2012).

Our estimates highlight the damage that can be caused by financial stress and emphasise the importance of actively monitoring the level of financial stress relative to the estimated regime threshold. What might the appropriate policy responses be? Our estimates suggest that policy responses involving inflation, the output gap and the policy rate may not be directly effective as we cannot reject the hypotheses that these variables fail to Granger-cause financial stress in either regime.[16] They also suggest that financial stress is highly persistent[17] suggesting that any reductions in financial stress arise from negative structural shocks to financial stress rather than reversion to the mean.

Our estimates suggest, albeit indirectly, that Quantitative Easing (QE) may be associated with negative shocks to financial stress. Negative structural shocks to financial stress (the final column of $\widehat{u}\,(h)_t$), whose size exceeds one-standard deviation, are estimated to have occurred in (i) March-April 2009, which may reflect the launch of QE in the US and UK in March 2009; (ii) September 2010, following the announcement that redemptions of assets purchased in earlier rounds of QE in the US would be re-invested (and Governor Bernanke's late August speech that paved the way for further QE; (iii) December 2010, arguably following the November launch of QE2 in the US; (iv) October 2011, following the £75 bn expansion in UK QE (also the launch of US "Operation Twist" in late September); (v) February 2012, following

[16] The p-values for these tests are 0.14, 0.76 and 0.68 for inflation, the output gap and the policy rate respectively in the high-stress regime and 0.85, 0.51 and 0.99 respectively in the low-stress regime. However, the impulse responses do suggest that high inflation is associated with higher stress at some horizons.

[17] The estimates on the lags of financial stress in the financial stress equations are 0.916 and 0.003 in the low-stress regime and 0.968 and 0.005 in the high-stress regime.

further purchases of £50 bn; (vi) in September 2012,following the launch of open-ended monthly purchases of agency debt in the US (and the speech by Mario Draghi in August, committing the ECB to defending the Euro) and finally (vii) January 2013, following the expansion of US open-ended QE to reach monthly purchases of $85bn.[18]

These residuals are suggestive of an impact of QE in reducing financial stress. Given this, future policy responses to increased financial stress might include changes to the policy rate (perhaps with forward guidance linked to financial stress), liquidity support to financial markets, changes to capital requirements for financial institutions, with the option of escalating to pre-emptive Quantitative Easing (possibly with forward guidance).

7 Conclusions

This paper has estimated the impact of financial stress in the UK. We have argued that the UK economy is best characterised as having two distinct regimes, corresponding to high and low levels of financial stress. We have also documented the adverse impact of heightened financial stress when the economy is in the high-stress regime. In doing so, we have extended typical findings in the literature to the case of the UK. We would argue that our other findings extend the literature, in two ways. First, we have estimated

[18]Sizeable negative shocks are also estimated in July 2009, February 2010, June 2011 and June 2012. Positive shocks to financial stress that exceed one standard deviation are estimated in April-May and August 2010, August and November 2011 and in May and July-August 2012. These dates are largely associated with the crisis in the Eurozone.

the contribution of structural macroeconomic shocks during the financial crisis; we find that increased financial stress in $2008-2010$ reduced the output gap, by around 200 b.p in November 2009-February 2010, at the height of the financial crisis, and by around 100 b.p for the rest of the 2008-2010 period. We also find that financial stress reduced inflation by around 200b.p in May-December 2009 and by 100 b.p in the rest of $2008-2010$. Second, we have argued that there is a delay of at least four months before increased financial stress begins to impact on the wider economy. This opens a "policy window" for corrective action to be taken.

However our work is far from definitive. We obtain some evidence that unconventional monetary policy is associated with a reduction in financial stress, but this is tentative and lacks statistical precision. Extension of the analysis to incorporate unconventional monetary policy would be valuable.

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Table 1			
p-values for the Tsay test			
	$m_0 = 100$	$m_0 = 140$	$m_0 = 180$
$d = 1$	0.00283	0.00113	0.09778
$d = 2$	0.01141	0.03815	0.10848
$d = 3$	0.02004	0.06375	0.05746
$d = 4$	0.00001	0.00057	0.00024
$d = 5$	0.00022	0.00482	0.01288
$d = 6$	0.00047	0.00665	0.02267
$d = 7$	0.00004	0.00065	0.03474
$d = 8$	0.00010	0.00171	0.13515
$d = 9$	0.01577	0.01732	0.12799
$d = 10$	0.00247	0.00042	0.00261
$d = 11$	0.02674	0.00763	0.00786
$d = 12$	0.00690	0.02851	0.22708

Figure 1a

IMF Financial Stress Index for the UK

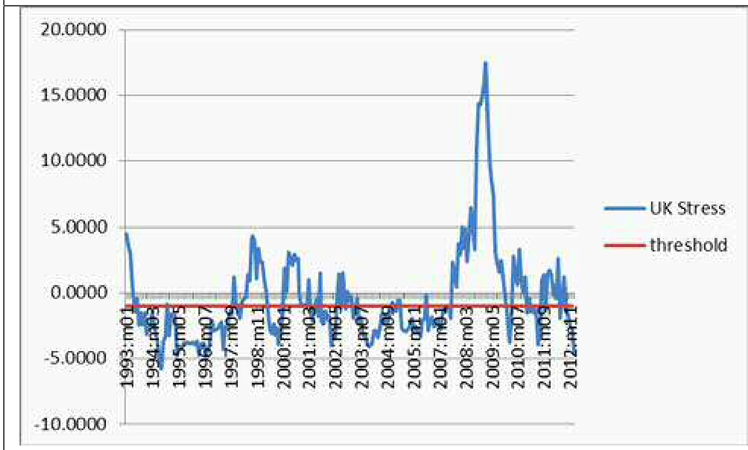


Figure 1b

Output gap, RPI inflation and policy interest rate

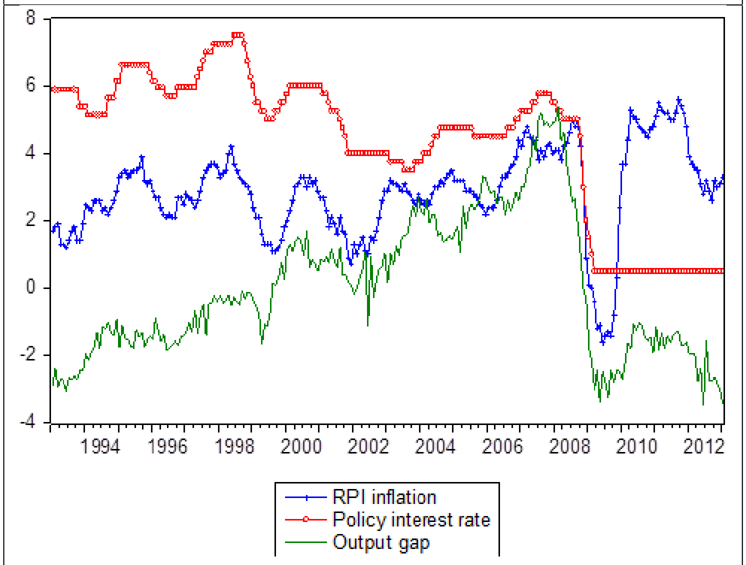


Figure 2a

Estimated Impact of Financial Stress Shock, High-Stress Regime, 1993-2013

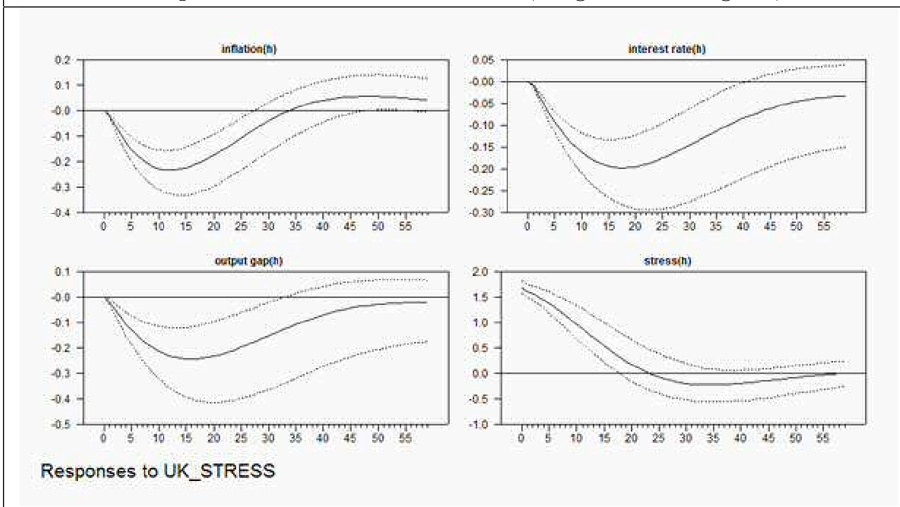


Figure 2b

Estimated Impact of Financial Stress Shock, Low-Stress Regime, 1993-2013

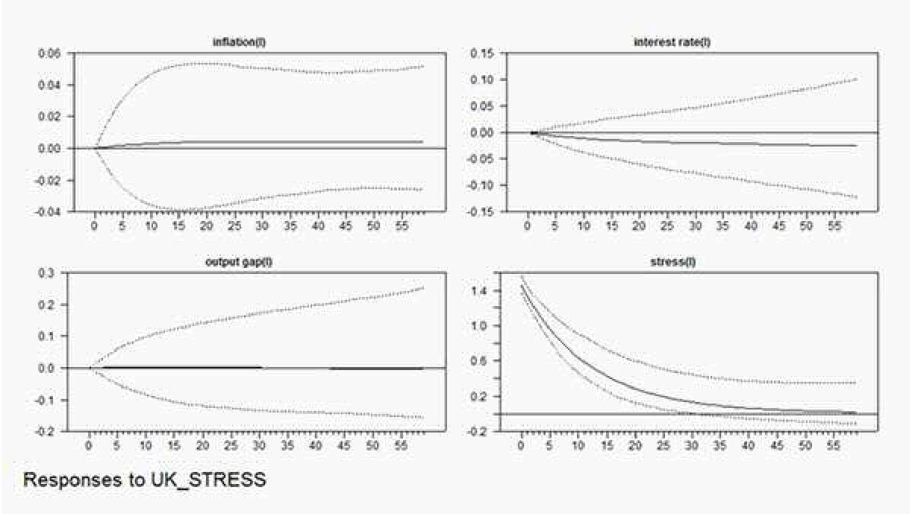
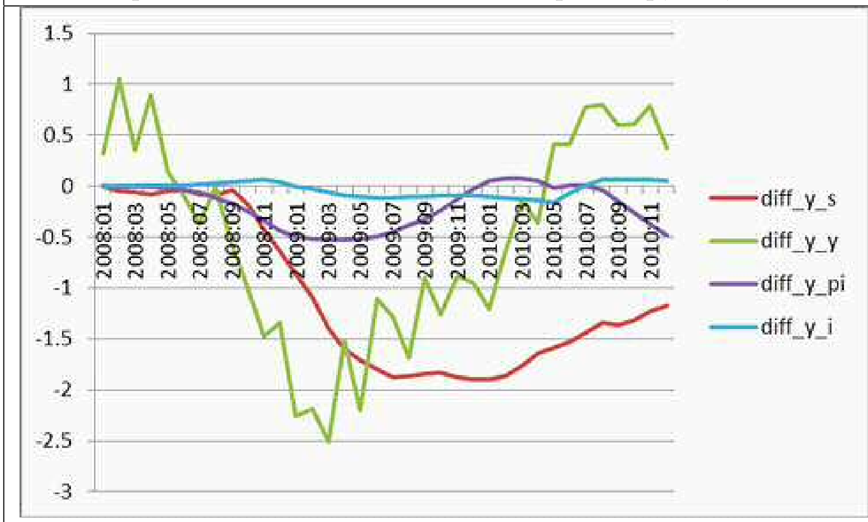


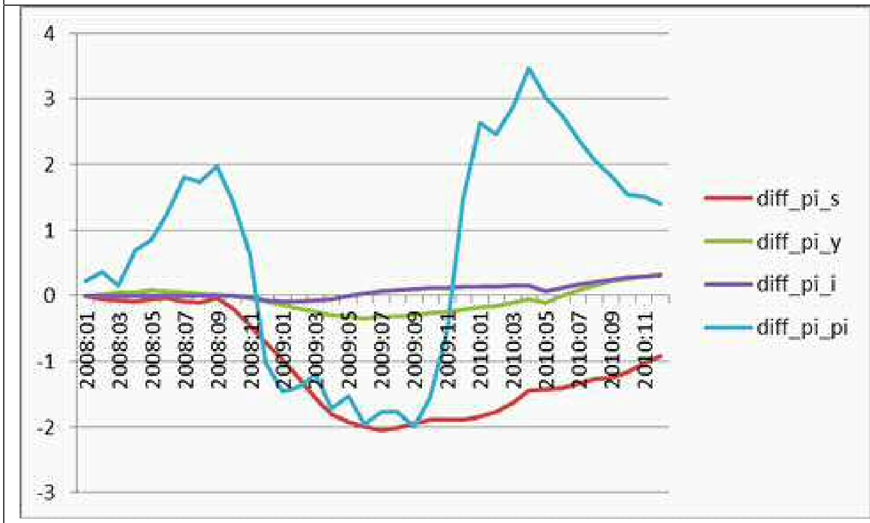
Figure 3a

Impact of Structural Shocks on Output Gap, UK, 2008-2010



Note: diff_y_s, diff_y_y, diff_y_pi and diff_y_i refer to the impact of a financial stress structural shock, an output structural shock, an inflation structural shock and an interest rate shock, respectively.

Figure 3b
Impact of Shocks on Inflation, 2008-2010

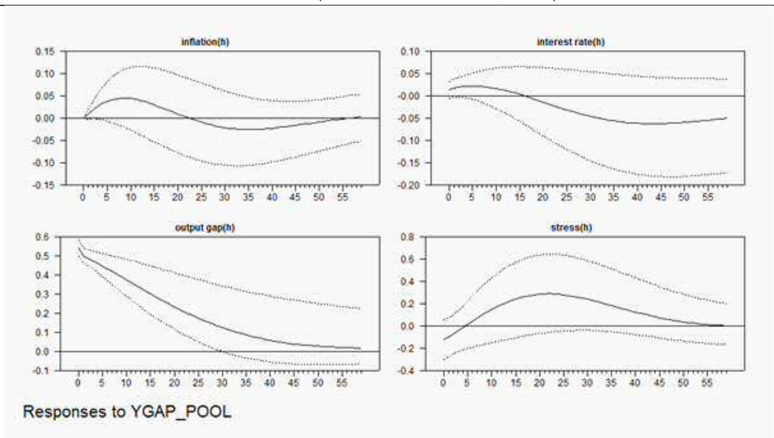


Note: diff_y_s, diff_y_y, diff_y_pi and diff_y_i refer to the impact of a financial stress structural shock, output structural shock, an inflation structural shock and an interest rate shock, respectively.

Figure A1

Other Estimated Impulse Responses, TVAR, 1993-2013

Responses to output gap (high stress regime)



Responses to output gap (low stress regime)

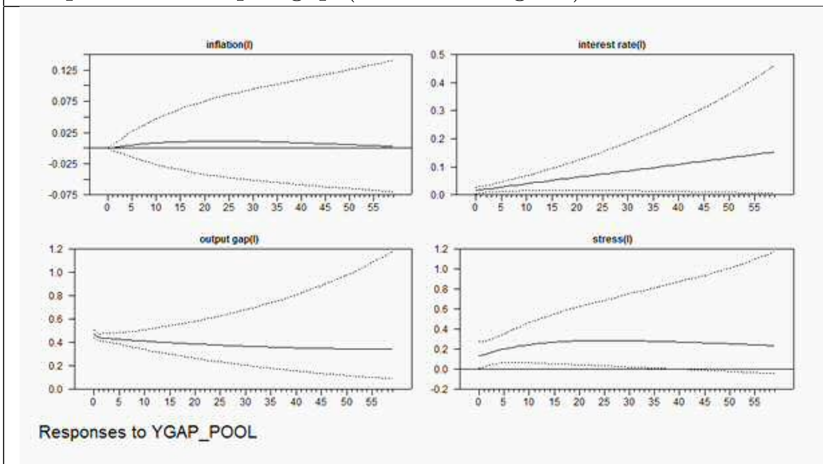
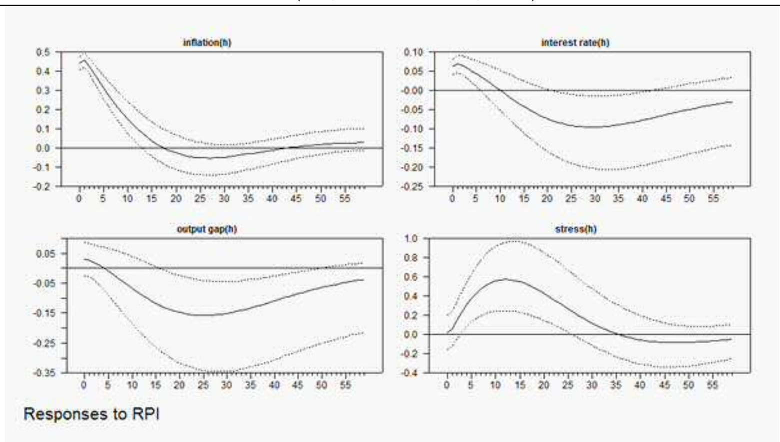


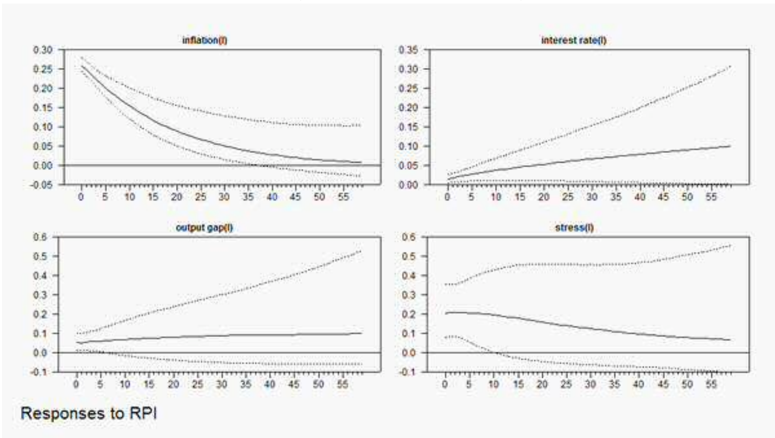
Figure A1 continued

Other Estimated Impulse Responses, TVAR, 1993-2013

Responses to inflation (high stress regime)



Responses to inflation (low stress regime)



Responses to policy rate (high stress regime)

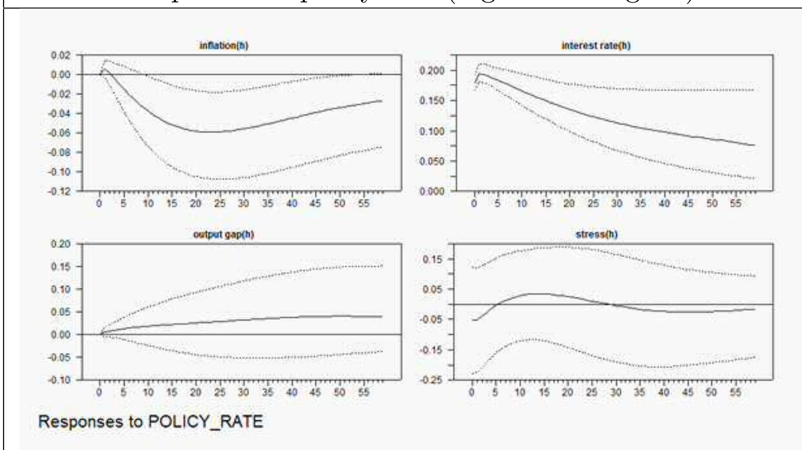


Figure A1 continued
Responses to policy rate (low stress regime)