Monetary Policy Effects on Output and Exchange rates: Results from US, UK and Japan

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Abstract

We investigate the effects of "contractionary" monetary shocks on three developed economies by imposing sign restrictions on the impulse responses of macroeconomic variables up to six months while allowing industrial production and exchange rate to be completely determined by the data. We show that i) the effect of monetary policy shock on industrial production is ambiguous; ii) there is evidence for price puzzle for Japan and UK; iii) there is delayed overshooting puzzle for Japan and the exchange rate puzzle for the UK and the US. The results from structural Markov regime-switching VAR approach provide support for our findings.

JEL: C3, E1, E3

Key words: monetary shocks, business cycles, exchange rate puzzle, price puzzle, vector autoregression

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1 Introduction

The fundamental theoretical and empirical question in monetary economics centers on understanding whether money and monetary policy affect real economic activity. To that end monetary economists have been particularly interested in investigating the validity of the benchmark theories and examining the impact of monetary policy shocks on the economy over the business cycles. In their investigation researchers often implement the vector autoregressive (VAR) framework, developed by Sims (1980), to describe and understand the behavior of prices, monetary aggregates, interest rates and output, as well as to conduct policy experiments.

The popularity of the VAR methodology can be attributable to the fact that VAR models validate dynamic stochastic general equilibrium (DSGE) models under certain sign restrictions.[1] In fact, it is well known that linear or log linear approximations of Markovian DSGE models around the steady state yields VAR(1) solutions which are complicated functions of the underlying preference, technology and policy parameters.[2] Hence, extracting meaningful results from a reduced form VAR is a difficult task and requires cross-equation restrictions which should be credible and uncontroversial. To overcome this problem, researchers generally proceed with one of the two potential approaches. The first approach, followed by Bernake and Blinder (1992) and Bernake and Mihov (1998) among others, uses a recursive identification scheme where policy shock affects output with a lag. The second approach (see Blanchard and Quah (1989) and Gali (1992) among others) achieves identification by imposing zero restrictions on the long-run impact of monetary disturbances.

However, researchers have been stressing that the identification of shocks based on either of the above methods presents various shortcomings. Cooley and Leroy (1985) argue

[1] The first order conditions of a DSGE model and log-linearisation around the steady state lead to a system of rational expectations (RE) model. Ireland (1999) shows how a real business cycle model can be written as a VAR(1). Also note that the conventional solution to RE models using Blanchard and Kahn (1980) method gives a VAR(1).

[2] See, for instance, Leeper, et al. (1996) Christiano et al. (1999) and Canova (2007) who discuss the developments in the literature.

that identification based on the Cholesky decomposition is unsatisfactory because this approach is not consistent with the DSGE models. Canova and Pina (1999) show that DSGE models do not imply the recursive structure imposed by the Cholesky decomposition. Cooley and Dwyer (1998) show that the long-run restrictions used by Blanchard and Quah (1989) rely on weak instruments and lead to unreliable conclusions concerning the differentiation of permanent shocks from transitory shocks. Further researchers (see, for instance, Giordani (2004) and Benati and Surico (2009)) point out that for a certain class of DSGE models, VARs are unable to trace out both the true dynamics of state variables and the true shocks even if the appropriate identification restrictions were used. This is so because the log-linearization of DSGE models around the steady state, leads to a VARMA data generating process (DGP). [3] If one of the roots of the MA component is large then a finite order VAR would not necessarily capture the true DGP.

Given the criticism regarding the use of zero restrictions in identifying parameters of a VAR structure and the fact that DSGE models do not exhibit zero restrictions, researchers began to use sign restrictions to validate DGSE models. To that end Canova (2007) argues that a log-linearized DGSE model rarely delivers zero restrictions, but often embodies sign restrictions which could be used to identify the model.

In this paper, taking into account the developments in the field, we empirically investigate the impact of monetary shocks on the behavior of industrial production and the exchange rate along with several other variables using monthly data for three developed countries including the UK, the US and Japan. In our investigation, which covers the period between January 1988-December 2009, we implement a Bayesian structural VAR model as suggested by Uhlig (2005) and Mountford and Uhlig (2009). This methodology identifies structural monetary shocks by imposing sign restrictions on the impulse responses of (some) variables while allowing the other variables to be completely determined by the data. In our case, we impose no restrictions on the responses of industrial

[3] Benati and Surico (2009) using a New-Keynesian model show that if there is a structural change in the policy rule (i.e., from passive to active) then a VAR analysis will detect this as the variance of the shocks has changed. However, their approach can be criticized on the grounds of omitted variables problem which induces biased coefficients and overestimated variance of shocks. To that end, Canova (2006) states that an augmented VAR model including a proxy for the omitted variable (i.e. expected inflation), may uncover the true DGP. Along the same lines also see and Canova and Gambetti (2010).

production and exchange rate to monetary policy shocks as they are the key variables of interest in this study and we want the data to determine their path. As a result, we examine, compare and contrast the effects of a contractionary monetary policy shock on these two variables across all three countries in our dataset.

It is worth stressing at this point that although most of the results in the VAR literature are consistent with the economic theory, Sims (1992) using a recursive identification approach observed a positive relationship between prices and the interest rate.[4] Sims in his investigation argues that the price puzzle is possibly an artifact of omitted variables which are correlated with variables used in the VAR model. Hence, once the omitted variables are incorporated into the model, the price puzzle should be resolved. In other words, he suggests that the central bank has more information concerning the expected inflation than a researcher can incorporate in a VAR model.

The price puzzle has attracted the attention of several researchers. For instance, in explaining this problem Clarida et al. (2000), Lubik and Schorfheide (2004) and Boivin and Giannoni (2006) argue that monetary policy in the pre-Volker regime was passive and led to self-fulfilling inflation expectations. However, this observation is not shared by other researchers including Canova et al. (2005) and Sim and Zha (2006) who found no evidence of instability in the postwar US monetary policy. These researchers argue that the price puzzle was the outcome of bad luck rather than bad policy. More recently, Castelnuovo and Surico (2010) suggest that the price puzzle is a by-product of passive monetary policy. That is if a central bank accommodates instead of fighting inflation, then this would generate indeterminate multiple equilibria and expectations become self-fulfilling. Thus, a passive monetary policy may lead to higher inflation expectations. This implies that the Sims' argument is correct only when monetary policy is passive.

Our empirical findings can be summarized as follows. First, similar to Uhlig (2005), we find that a contractionary monetary policy shock, does not necessarily lead to a fall in real GDP. For instance, in the US, we find that the real industrial output growth stays positive for the entire 5 year period following a contractionary monetary shock.

[4]Eichenbaum (1992) named this anomaly as the "price puzzle".

In Japan the real industrial production growth does not respond much to the monetary shock for several months but then it slightly increases after the middle of the second year following the shock; however, this response is small and negligible. In contrast, the real industrial production growth in the UK declines for the entire period following the negative shock. Second, although the response of prices is tainted due to the sign restriction, it is interesting to note that we do observe the price puzzle for the UK and Japan when we consider the full sample. However, on the basis that the price puzzle disappears for both countries after the period of crises is removed from the analysis, we suggest that the price puzzle in these two countries is not an outcome of passive monetary policy but it is related to adverse developments in the financial markets.[5] Third, when we inspect the behavior of the real exchange rates, we observe delayed overshooting in Japan and exchange rate puzzle in the UK and in the US.[6]

To examine the robustness of our results we implement a structural Markov regime-switching VAR (SMRS VAR) model. Different from the linear VAR models, this approach allows us to account for nonlinearities in the data. The results obtained from this approach are qualitatively similar to our earlier findings providing support to our initial modeling strategy and findings.

The remainder of the paper is organized as follows. Section 2 explains the methodology. Section 3 provides information on the data and illustrates our results. Finally, Section 4 concludes the investigation.

2 The Bayesian VAR model and identification

We construct a VAR system that consist of real industrial production, exchange rate, money market rate, total reserves and consumer price index and follow the identification approach suggested in Uhlig (2005) by imposing sign restrictions. By construction, the growth rate of real industrial production and that of the real exchange rate are the focus of interest and we do not impose any sign restrictions on these variables. However, we

[5]Early 90s are poor years for both countries as well as the 2007-09 financial crises period.

[6]Scholl and Uhlig (2008) report the presence of the exchange rate puzzle for US-Germany, US-UK, US-Japan.

restrict the impulse responses of monetary and price variables to identify monetary policy shocks.

2.1 VAR model

Consider the reduced form VAR model:

$$\begin{aligned} Y_t &= \Phi_1 Y_{t-1} + \Phi_2 Y_{t-2} + ... + \Phi_p Y_{t-p} + \epsilon_t & (1) \\ &= \Phi(L) Y_t + \epsilon_t & (2) \end{aligned}$$

where Y_t is a $n \times 1$ vector of data at time t, $\Phi(L)$ is a polynomial in the lag operator L of order p and ϵ_t is the error term. Furthermore, let $u_t = A^{-1}\epsilon_t$ is a $n \times 1$ vector of independent structural shocks such that:

$$E(uu') = \Sigma_u = I_n$$

where I_n is an identity matrix of order n and A is an $n \times n$ matrix. Here, identification of u_t requires the researcher to impose $n(n-1)/2$ restrictions on matrix A. In the VAR literature this is done through the recursive ordering of variables:

$$\begin{aligned} \Sigma_\epsilon &= E(\epsilon_t, \epsilon_t') & (3) \\ &= AA' \end{aligned}$$

where A is the Cholesky factor of Σ_ϵ.[7]

2.2 Sign-Restriction Approach

Instead of using the standard approach which we briefly discussed above, Uhlig (2005) and Mountford and Uhlig (2009) achieve the identification of the VAR model by imposing sign restrictions on the impulse responses of a group of variables. These two

[7] Recursive identification imposes short-run restrictions based on an ad-hoc ordering. This method was used by Sims (1986). Alternatively, Blachard and Quah (1989) identified structural shocks by imposing $n(n-1)/2$ long-run restrictions on $C(1) = [I - \Phi(1)]^{-1}$.

papers demonstrate that any impulse vector $a \subseteq R^n$ can be restored if there exists an $n-$dimensional vector q of unit length such that $a = \tilde{A}q$ where $\Sigma_\epsilon = AA' = \tilde{A}\tilde{A}'$, and $\tilde{A}$ is the lower triangular Cholesky factor of the covariates matrix, Σ_ϵ. Note that $\widetilde{A} = AQ$ where Q is an $n \times n$ orthogonal matrix.

We implement the estimation and the inference following Uhlig (2005). We construct the prior and draw the posterior from the Normal-Wishart family for $(\widehat{\Phi}(L), \widehat{\Sigma}_\epsilon)$. After estimating $\Phi(L)$ and Σ_ϵ from the posterior draws, we draw $\widehat{q_j}$ from a uniform distribution, divided by its length. Then, we construct a candidate impulse response vector $\widehat{\alpha}_j = \tilde{A}\widehat{q_j}$ and compute its impulse responses by:

$$r_s = [I - \widehat{\Phi(L)}]^{-1}\widehat{\alpha}_j \tag{4}$$

where r_s is the vector of the impulse responses at horizon s. We account for only those draws of $\widehat{q_j}$ where the sign restrictions are not violated. We repeat this procedure until we obtain 1000 draws that satisfy the sign restrictions. Next, using these draws we construct the error bands.

The advantage of using sign restrictions to identify policy shocks is that results are not affected by the ordering of the variables. That is changing the order of the variables in a system would not render any difference in the observed impulse response functions. In addition Bayesian VAR (BVAR) is not subject to parameter uncertainty. This is so because the BVAR allows us to compute the reduced-form parameters and the impulse vector simultaneously.

3 Data and Results

In this section, we first present some basic information on the data that we use in our investigation followed by a discussion of the results that we obtain using the pure sign-restriction approach.

We carry out our analysis using monthly data for the US, the UK and Japan. Our data cover the period between January 1988 and December 2009. We specifically compare and examine the results gathered from these three countries to understand how monetary policy shocks affect output, exchange rate and prices. Our empirical model is similar to that of Bernanke and Mihov (1998) and it is well studied in the literature. Our investigation makes use of real industrial production, commodity price index, total reserves, the real exchange rate and short-term interest rate. The data on the interest rate are taken from line 60b of the *International Financial Statistics*. Data for total reserves are taken from line 12 of the same source and it represents total reserves minus gold. Data on the consumer price index (CPI) and the industrial production are extracted from lines 64 and 66, respectively. The real effective exchange rate is taken from line 42. Note that the real effective exchange rates of the UK and Japan are measured with respect to the US dollar. The real exchange rate for the US is constructed with respect to the SDR. Given the definition of the real exchange rate series, an increase indicates a real depreciation whereas a decline indicates a real appreciation. We use the logarithmic first difference of each variable in our VAR system with the exception of the short-term interest rates which is used in levels.

We built our VAR model allowing for 12 lags in the logarithmic difference form of the series with the exception of the short-term interest rate which is used in levels. To achieve identification of the VAR system, we impose that the response of inflation and growth of total reserves would not increase and that of money market rate would not decrease for the first six months following the monetary policy shock; i.e. $s = 6$.

3.1 General Observations

We have three key results. The first one is about the effect of monetary policy shocks on real output. We find that a negative monetary policy shock does not necessarily lead to a contractionary effect on real industrial production. It is possible that the ambiguous effect of monetary policy on economic growth is related to the response of the financial sector to changes in monetary policy. In particular, achieving a transparent and a well functioning financial sector can restore confidence so that the uncertainty surrounding the future economic growth and inflation can be avoided to a large extent.

Second, when we consider the full data, we find evidence of a price puzzle for the UK and Japan. The presence of the price puzzle begs for an answer to the question regarding the underlying factors that generate this indeterminacy. Although, Castelnuovo and Surico (2010) argue that the indeterminacy is due to violation of the 'Taylor principle'[8], their suggestion is not consistent with the adoption of inflation targeting by the BoE or the inflation averse policies followed by the BoJ.[9] Here, we show that the price puzzle for both countries disappears once we remove the crises periods from the analysis. This observation provides the basis of our suggestion that without establishing a well functioning and a well regulated financial sector, it would be hard to achieve economic recovery.

Our third result relates to the behavior of the real exchange rate of the countries in our sample. We find that the reaction of the exchange rate to monetary policy shocks is not identical across all three countries. In particular, there is evidence of a delayed overshooting for Japan. In contrast, for the UK and the US we find evidence for the exchange rate puzzle; depreciation of the real exchange rate in response to a contractionary monetary policy.

It is worth noting that within the framework of a typical delayed overshooting model, as demonstrated in empirical studies including that of Eichenbaum and Evans (1995) and Grilli and Roubini (1995, 1996), the value of exchange rate overshoots its long-run level in response to a monetary shock and reaches its peak after one to three years rather than instantaneously as the Dornbush's overshooting model suggests.[10] Hence, there is a disagreement between the standard theory and the baseline evidence regarding the effects of monetary policy shocks on the behavior of exchange rates.[11] To that end, Faust

[8]The Taylor principle states that if the coefficient of inflation in the standard Taylor rule is smaller than one, then the rational expectations model has multiple equilibria and the expectations become self-fulfilling.

[9]Lubik and Schorfheide (2004) argue that the association of indeterminacy with passive monetary policy is model specific. Dupor (2001) shows that in a continuous time model with endogenous investment passive monetary policy is consistent with determinacy. However, the New-Keynesian literature suggests that passive monetary policy generates indeterminacy.

[10]The delayed overshooting puzzle is also named as the forward discount puzzle due to the violation of uncovered interest rate parity. It is worth noting that a forward discount puzzle might exist even if there is no delayed overshooting. See also Leeper et al. (1996), Clarida and Gali (1994) and Kim (2001).

[11]Dornbusch's (1976) overshooting model predicts that an increase in the domestic interest rate relative to the foreign interest rate leads to an immediate appreciation followed by a depreciation of the domestic currency to its long-run equilibrium level.

and Rogers (2003) argue that the delayed overshooting is an artifact of the recursive identification scheme. In particular, they show that there is no evidence of delayed overshooting once mild sign or shape restrictions are imposed to identify monetary policy shocks. Yet, Scholl and Uhlig (2008) restore the delayed overshooting puzzle when they implement sign restrictions on the impulse response functions.

3.2 Empirical Results

Figures 1 to 5 show the impulse responses for Japan, the UK and the US to a contractionary monetary policy shock for different sample periods. Figures 1, 3 and 5 plot the impulse responses for the full sample for each country, respectively. Figure 2 presents the impulse responses of the state variables to a contractionary monetary policy for Japan when we use the data over 1992-2007 as we remove the periods of crises from our analysis. Likewise, in Figure 4 we present the response of state variables to a contractionary monetary policy shock for the UK when we examine the data between 1995-2007 as we exclude the period of crises from the analysis. Figure 5 presents results for the US over the full sample.

The Case of Japan

When we inspect Figure 1, we observe that a contractionary monetary policy shock has unclear effects on the real industrial production of Japan. Although the real industrial production growth does not respond to the shock for the first two and a half years, it starts to increase afterwards. This observation that adverse monetary shock is not an important source of fluctuation in Japan's economy is consistent with the fact that Japanese monetary authorities faced near-zero interest rates for most of the period that we explored in this study. Hence, monetary policy authorities did not have much latitude to reduce the interest rates to push the economy back to a higher equilibrium when there was a significant drop in the aggregate demand. In this context, Baba et al. (2004) also discuss the ineffectiveness of monetary policy in Japan by showing that deflation has persisted after 1995 even though the ratio of money base to GDP doubled.

We next examine the behavior of consumer prices. By construction inflation cannot increase in the first 6 months following the negative monetary policy shock. But then although inflation remains below the baseline level for almost two years, it becomes positive and increases for the rest of the period presenting a mild evidence of the price puzzle. We presume that the price puzzle is surfacing here due to factors that led to the economic crises that Japan went through over the late 1980s and early 1990s. In particular, recall that the Bank of Japan (BoJ) during this period followed an expansionary monetary policy to mitigate the impact of Yen's appreciation in compliance with the 1985 Plaza Accord. The expansionary monetary policy, along with the current account surplus, led to excess liquidity in the financial system fueling the value of financial assets and property prices. However, the Japanese monetary policy authorities were also concerned about the possibility that inflation would surge as a consequence of the developments in the economy. To counteract a potential surge in inflation, BoJ doubled the bank rate. Yet, they were then slow to reduce it. The increase in the bank rate exerted a negative impact on real estate and stock prices resulting in an increase in the number of loan defaults. The negative impact of loan defaults on the economy was further exacerbated as Japanese banks ended up with the final bill in the form of bad loans. The damage was done: bad loans, continuous increases in the number of defaults and reduction in real estate and stock prices paved way to a deflationary environment making demand side policies ineffective.

Given the nature of the crises in Japan, we conjecture that the presence of the price puzzle is due poor bank regulation which led to excessive lending over this period. To provide evidence for our conjecture, we generate impulse responses for the state variables after removing the period of crises from our examination. The new set of impulse response functions for the period 1992-2007 are given in Figure 2. As the figure shows, while the reaction of the other variables to monetary policy shock does not change, inflation stay below the baseline and do not increase following the adverse monetary shock, providing support for our claims.

When we turn to examine the movements in the real exchange rate, we observe in Figure 1 that the Japanese Yen appreciates following the monetary policy shock for a year and then settles around its baseline as the value of the currency does not appear to change much (although there is some evidence of depreciation following a year and a half of the shock, this is mild). Thus, there is evidence of delayed overshooting following the contractionary monetary policy shock. However, the delayed overshooting in Japan might be mirroring the price puzzle. More specifically, exchange rate initially appreciates to mitigate the effects of expected inflation and then depreciates. Once we exclude the periods of financial crises the delayed overshooting becomes milder.

The Case of the UK

We next inspect the results for the UK. Figure 3 plots the impulse responses of the variables when we use the full data. In general, we observe that the industrial production growth falls following a contractionary monetary policy shock. However, this drop is not too large. As expected, inflation initially falls due to the restriction that we impose for the first 6 months. Afterwards inflation increases reaching a peak by the end of the first year while it remains above the baseline for the rest of the period. Yet, the deviation of inflation from the baseline is negligible after the four years following the shock.

Similar to the case of Japan, the positive relation between inflation and interest rate could be due to the fact that the UK economy went through a period of crises in the early 90s. In this period, in conjunction with the German unification and the subsequent contractionary monetary policy that Germany implemented, the UK economic outlook deteriorated and unemployment increased substantially. To reduce unemployment, the British government could not stimulate the economic growth by devaluating the British pound due to the Exchange Rate Mechanism (ERM).[12] The option for the government at that time was either to opt out of the ERM and achieve higher economic growth by devaluing the domestic currency or to remain in the ERM and suffer a severe recession. The market bet in favor of the former option leading to a speculative attack on the British pound in September 1992. Given this panorama of the UK economy, speculative attack on the currency which led to heightening of devaluation and inflation expectations could as well be the underlying reason for the price puzzle that we observe in the data. To

[12] The UK joined the ERM on October 1990 and opt out of the ERM in September 1992.

examine for this possibility, we repeat the analysis concentrating on the period between 1995-2007 as we remove the periods of financial crises from the analysis. The new set of impulse response functions are given in Figure 4. As the figure shows, while the reaction of the other variables do not change, the price puzzle disappears, similar to the case of Japan.

Our results are consistent with Benati (2008) who using a time-varying coefficient structural VAR (TVC-SVAR) system shows that there is a violation of the Taylor principle during the entire decade of the 80s. During the ERM, the interest rate differential between the UK and Germany declined from 2.3 to 0.4 (see Gross and Thygesen 1998). In line with the empirical regularities, Benati (2008) estimates a temporary decrease in the long-run coefficients on inflation and output growth over the period leading to ERM. In particular, the long-run inflation coefficient was estimated to be around 0.7 before the UK joined the Exchange Rate Mechanism ERM. Following the suspension of the ERM membership and the introduction of inflation targeting in October 1992, the long-run coefficients on inflation and output estimated to be 1.4 and 0.9, respectively. That is, although there was a violation of the Taylor principle before the ERM crisis, this was not the case for the period until the recent financial crisis.

When we examine the behavior of the British pound, we observe that the real exchange rate, as shown in Figure 3, depreciates after a contractionary monetary policy shock providing evidence in favor of an exchange rate puzzle which might be consistent with the presence of the price puzzle. More specifically, considering Frankel's (1979) overshooting model, an increase in the interest rate will lead to depreciation only if the expected inflation is higher than the nominal interest rate.[13] In Figure 4 where we exclude the periods of crises from our analysis we still observe the exchange rate puzzle: the currency depreciates following the adverse shock for the first 40 months but then it stays around

[13] Frankel's overshooting model suggests that the deviation of exchange rate from its equilibrium value depends on the real interest rate differential:

$$s_t = \overline{s} - \frac{1}{\theta}[(i_t - \Pi^e) - (i_t^* - \Pi^{*e})]$$

where s_t is the current exchange rate, $\overline{s}$ is the equilibrium exchange rate i_t, is domestic nominal interest rate, i_t^* is foreign nominal interest rate, Π^e is the expected domestic inflation rate and Π^{*e} is the foreign expected rate.

the baseline. But, these movements are much milder than that presented in Figure 3.

The Case of the US

Finally, we concentrate on the behavior of the US economy in response to a contractionary monetary policy shock. Our findings, given in Figure 5, in general support earlier observations reported in the literature. We first notice that the industrial production growth in the US increases at first and then falls towards the baseline supporting Uhlig (2005) that a contractionary monetary policy does not necessarily lead to a contraction in the economy. When we turn to observe the behavior of prices, we see that inflation falls for the first six months reflecting the restrictions that we impose. Furthermore, inflation remains below the baseline for most of the time and it does not appear to have a tendency to increase although it exhibits some cyclicality. We also observe that there is a mild evidence of exchange rate puzzle where exchange rate depreciate for the first eight periods after which remains slightly above zero. This might be due to a forward discount puzzle where violation of uncovered interest rate parity (UIP) is driven by the existence of forward risk premium. Here, the risk premium implies that the forward premium is higher than the expected devaluation. This result along with the behavior of other variables in our VAR are in line with Scholl and Uhlig (2008) and Fratzscher at al. (2010) who found strong evidence for a forward discount premium in four developed countries.

3.2.1 An Evaluation of the Results

To understand the overall impact of monetary policy shocks on the state variables we provide the variance decomposition of all the variables in response to an interest rate shock. These results are given in Table 1. Interestingly, the results show that movements in monetary policy is responsible only for a small fraction of the state variables' movements for each of these countries. More concretely, monetary policy explains about 20 percent of the variability of any of the variables included in the VAR system. Given this observation, it must be the case that there are other factors at work affecting the behavior of the state variables. This issue, which is beyond the current investigation, needs careful attention in future research. One possibility could be to examine the simultaneous impact of financial policy shocks and monetary policy shocks on the state variables. Alternatively, it might be useful to introduce financial markets into the model while examining the effects of monetary policy shocks on the economy. This is sensible as transmission of monetary policy depends on the financial markets.[14]

4 Robustness tests

Stock and Watson (2001) argue that SVAR modeling is very sensitive to the assumptions concerning the breaks in the sample. Therefore, to account for the robustness of our results, we use structural Markov regime-switching VAR (SMRS VAR) approach as we allow for the possibility that over time the economy switches between high and low volatility regimes. In this section, we present the impulse responses of the state variables to a contractionary monetary policy shock obtained from the SMRS VAR model.

An SMRS VAR can be considered as a two-step procedure which introduces Markov regime-switching and identification into the VAR approach. In the first step we estimate the following MRS VAR model:

$$Y_t = \sum_{j=1}^{p} \Phi(s_t) Y_{t-j} + \epsilon(s_t) \tag{5}$$

where all parameters are assumed to be state-dependent. The unobserved state variable s_t takes values from the finite set $\Omega = \{1, ..., n\}$ and follows a Markov process with transition probability $P = (p_{ij})'_{i,j\in\Omega}$ where $p_{ij} = P(s_{t+1} = j|s_t = i)$. In the second step the state-dependent structural shock $u(s_t) = A(s_t)\epsilon(s_t)$ is identified by imposing sign restrictions on the impulse responses of the state variables to the monetary policy shock. Note that impulse responses are regime-dependent and computed based on the QR decomposition of an $n \times n$ random matrix K and the Choleski factor of

$$\Sigma_\epsilon(s_t) = E_t[\epsilon(s_t)\epsilon(s_t)'] = A(s_t)A(s_t)'.$$

[14] See Bernanke and Gertler (1995), Kashyap and Stein (2000), Baum et al. (2012) among others.

In particular, we draw an $n \times n$ random matrix K from the N(0,1) where $K = QR$ and compute the structural impact matrix as $\widetilde{A}(s_t) = A(s_t)Q'$.[15] If the draw satisfies the restriction we keep it or otherwise we discard it. The lag structure of the variables in the model is based on the BIC criterion. Hence, we allow for 2 lags in the case of the UK and 3 lags in the case of US.[16] The model considers two states based on the difference in volatilities across the two regimes. Regime 1 depicts the high volatility state and regime 2 depicts the low volatility state.

Figure 6 plots the smooth probabilities of the low volatility state (regime 2) for the UK. Looking at this figure we see that late 80s and the period pre-1992 crises are included in the high volatility regime; i.e., regime 1. We can also observe that the probability of being in regime 1 is high between 2001 and 2003 as well as during the post-2008 period. Note that Groen, Kapetanios and Price (2009) implementing a multivariate extension of the CUSUM test show that the UK RPI inflation was subject to structural breaks after 2001, 2003 and 2005. They argue that there may have been temporary breaks induced by the large volatilities in house and energy prices after 2000. Hence, our observations within the context of SMRS VAR model is consistent with their findings.

Given our observations for the state of the economy, we focus on the impulse responses for the low volatility regime where we can properly trace the response of the economy to macroeconomic shocks rather than that for the high volatility regime during which the response of the variables will be erratic by definition. The results given in Figure 7 for the UK provide evidence that the price and exchange rate puzzles exist even in the low volatility regime. This is a strong result and support our earlier findings shown in Figure 3. Next, we estimate the model for the UK after the period of crises is removed from the analysis, We present the resulting impulse responses of the state variables to a contractionary monetary policy for the stable regime in Figure 8. Here, we observe that there is no evidence of the price puzzle. The response of prices and exchange rate to an adverse monetary policy shock is very close to zero across all horizons supporting

[15] Q is a unitary matrix and R is an upper triangular matrix.

[16] It is well known that linear models overstate the persistence in the data when regime changes are overlooked.

our findings depicted in Figure 4. Differently, the results also provide evidence that the exchange rate puzzle also dissolves. Furthermore, the response of the remaining variables are generally in line with our earlier observations and we do not make any further comments.

Our last set of results present evidence on the US. Figure 9 provides the smooth probabilities for the low volatility regime. This figure depicts that only few observations are drawn from the high volatility regime. In other words, the model does not provide evidence for regime switching. This is consistent with the view that monetary policy authorities acted consistently with the appointment of Paul Volker as the FED Chairman. In fact our sample correspond to the period of great moderation which might be the outcome of good policy as several economists including Clarida et al. (2000) and Benati and Surico (2009) argue. Figure 10 presents the corresponding impulse responses of the state variables for the US. Looking at the impulse responses we observe no evidence for the price puzzle. Inflation follows a path near the baseline showing some cyclicality (which is quite subdued) as we observed earlier in Figure 5. In a similar context we do not observe evidence for the exchange rate puzzles. The interpretation of the remaining impulse responses are similar to those we observed in Figure 5 providing support to our earlier claims.

5 Conclusion

In this paper we investigate the impacts of monetary policy shocks on output, exchange rate and prices using data from the UK, the US and Japan. We carry out our investigation implementing an identification method proposed by Uhlig (2005). In this framework, to achieve identification we impose sign restrictions on domestic short-term interest rates, prices and total reserves for the first six months following the contractionary shock. We apply no restrictions on real exchange rate and output so that the impulse responses of these variables are completely determined by the data. Regarding the restrictions that we impose, we follow the conventional wisdom and assume that a contractionary monetary policy shock does not lead to a fall in domestic short-term interest rates, does not increase domestic prices and does not increase total reserves. Our observations can be summarized as follows.

First, the response of real output to adverse monetary policy shocks is ambiguous in a way that in most cases it does not have a specific effect on output as the response can be positive as well as negative. Therefore, we cannot be as comfortable as before when commenting on the impact of a contractionary monetary shock on the output. Second, although not significant, we observe price puzzle for Japan and UK when we use the full sample period during which both countries experienced two distinct periods of crises. We argue that the price puzzle maybe a consequence of adverse developments in financial markets which led to heightened inflation expectations rather than being a by-product of passive monetary policy, as the central banks were active throughout the sample period. Third, we show that the exchange rate puzzle occurs in the UK and the US. This might be due to a forward discount puzzle where violation of uncovered interest rate parity (UIP) is driven by the existence of forward risk premium as discussed in Scholl and Uhlig (2008) and Fratzscher at al. (2010). Differently, we observe delayed overshooting for Japan in response to a contractionary monetary policy. To check for the robustness of our observations, we implement structural Markov regime-switching VAR approach. The results gathered from this exercise provide support for our observations.

Last but not least, we examine the overall impact of monetary policy shocks as we examine the variance decomposition of the variables in response to an interest rate shock. The results show that movements in monetary policy is responsible only for about 20 percent of the variability of any of the variables included in the VAR system. Hence, for future research, it would be fruitful to further develop the model by incorporating proxies that capture changes in financial policy and the state of the financial markets.

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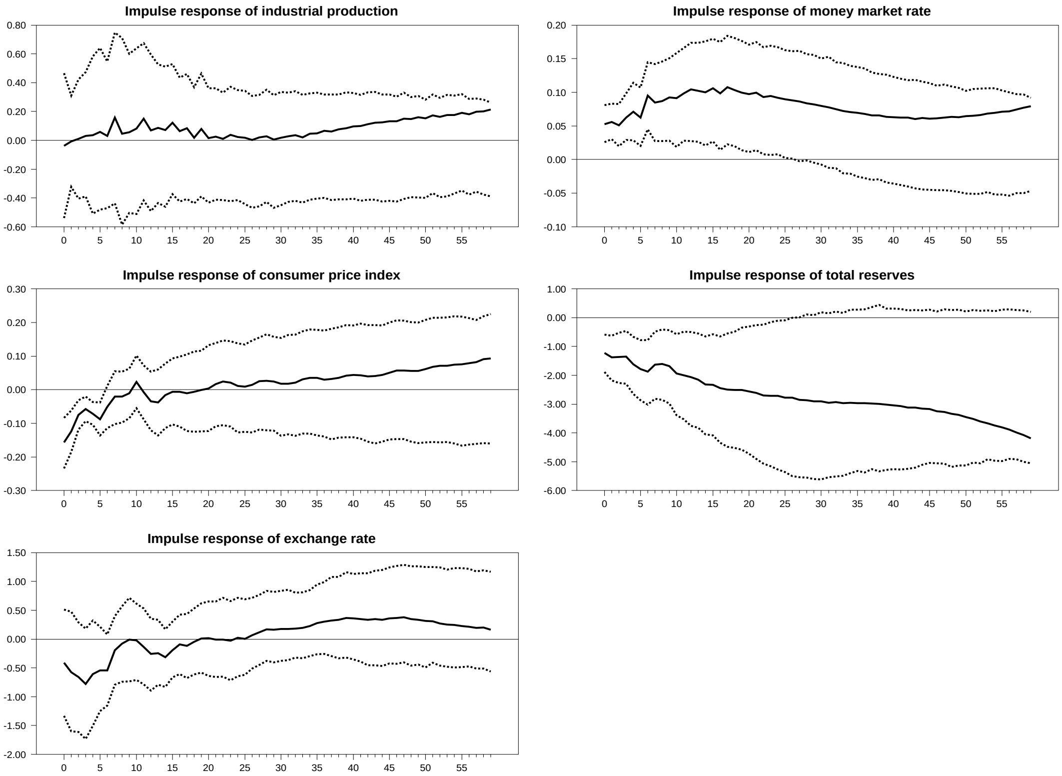
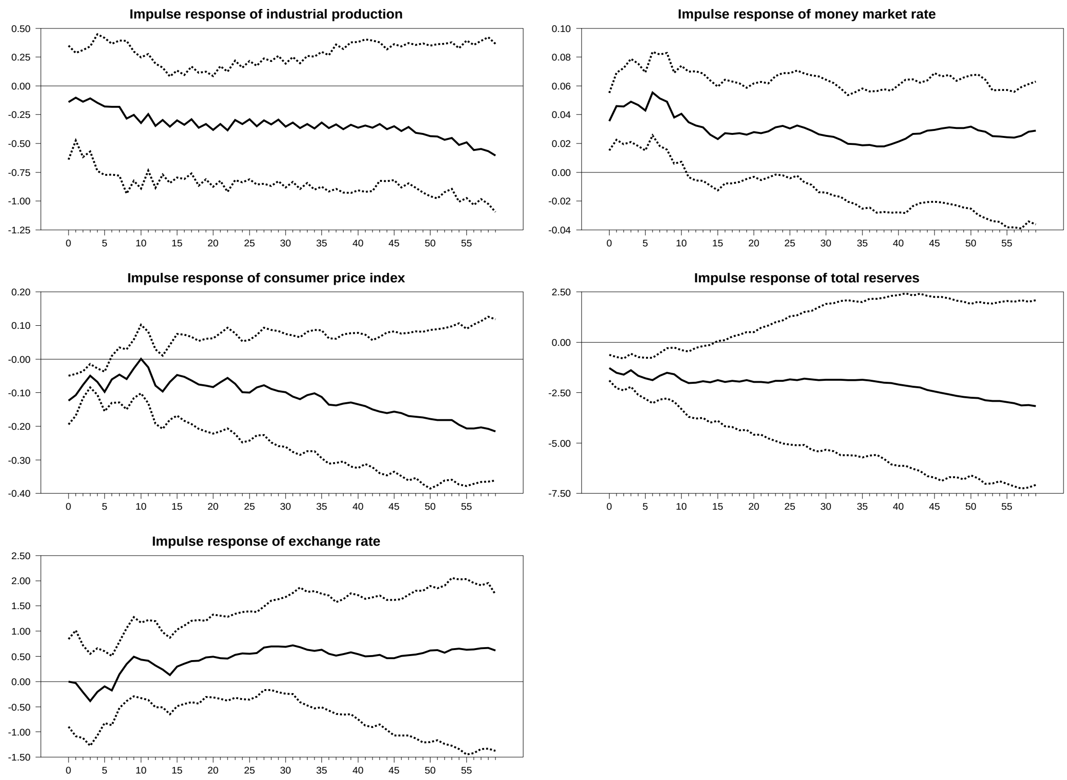
Figure 1: The impulse response functions for Japan: Full Sample (1988m1-2009m12)



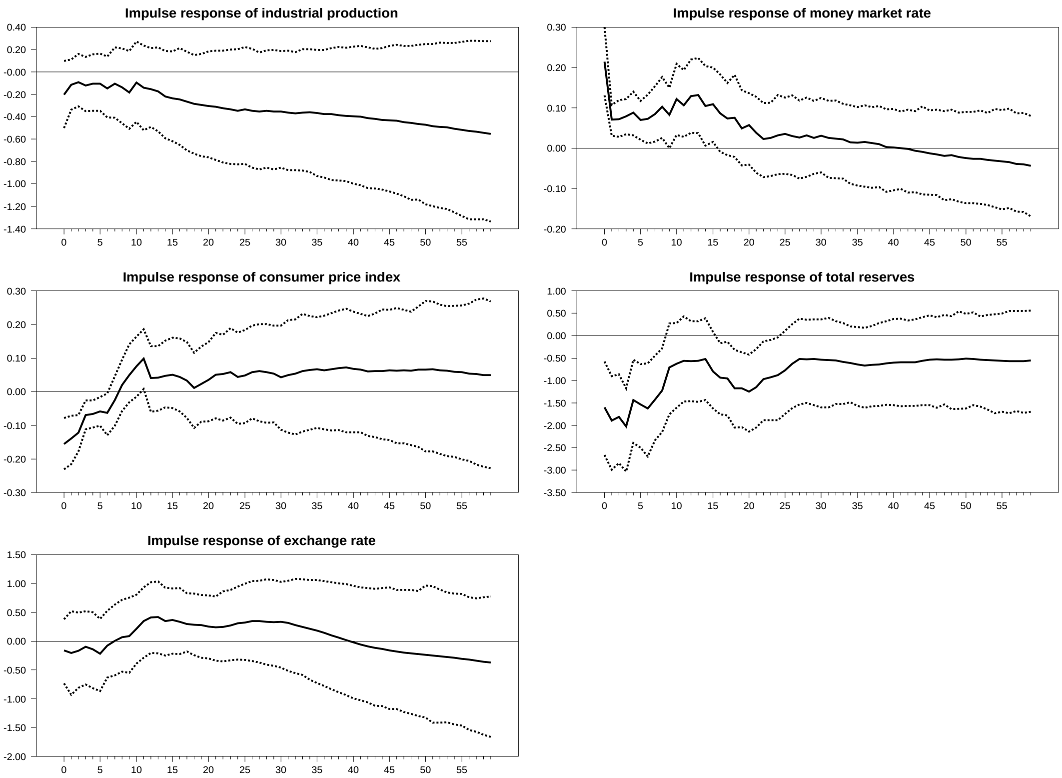
Note: Impulse responses with pure sign approach.

Figure 2: The impulse response functions for Japan: 1992m1-2007m12



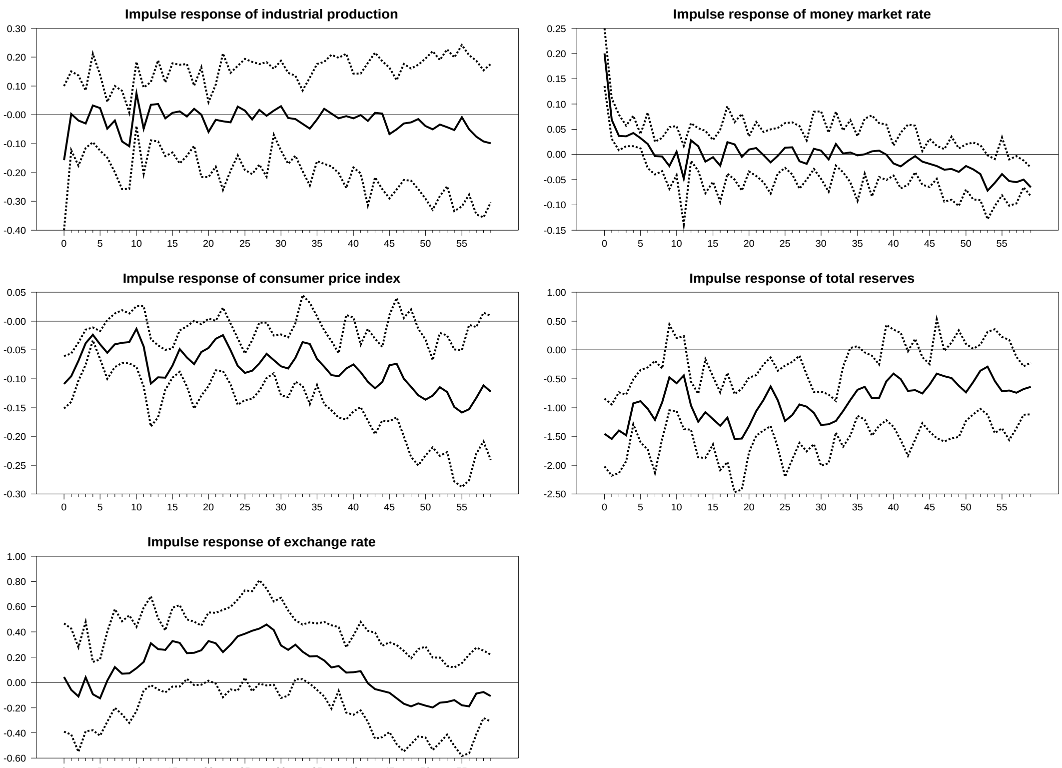
Note: Impulse responses with pure sign approach.

Figure 3: The impulse response functions for the UK: Full Sample (1988m1-2009m12)



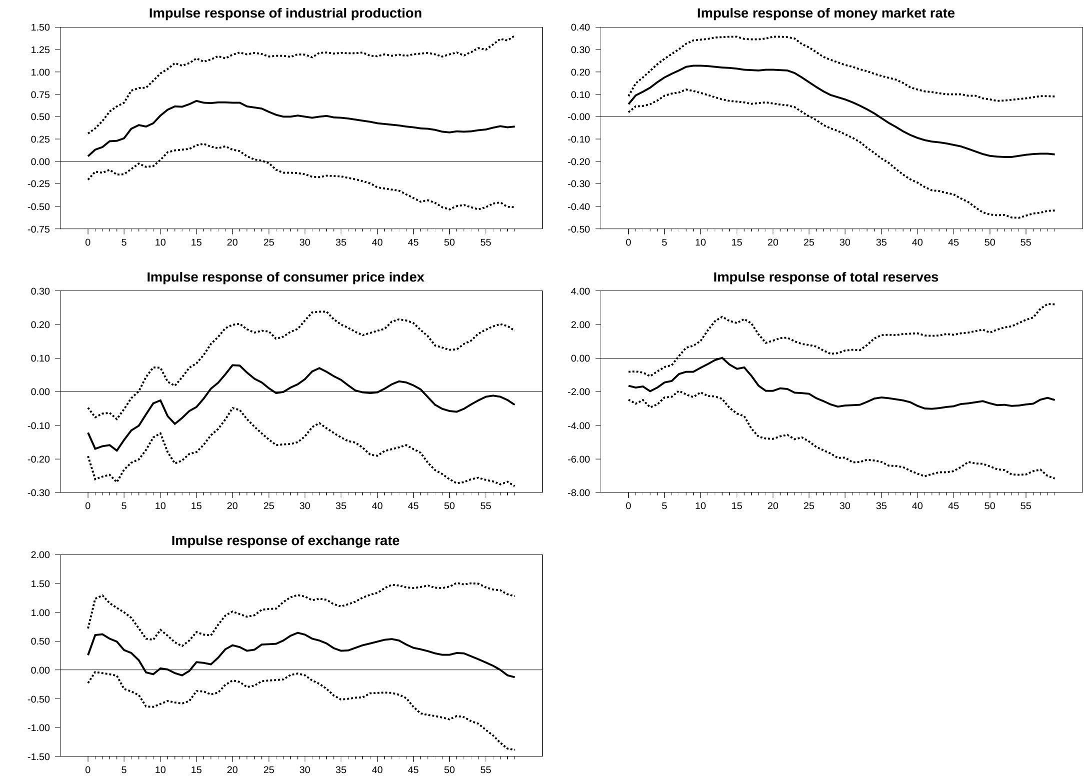
Note: Impulse responses with pure sign approach.

Figure 4: The impulse response functions for the UK: 1995m1-2007m12



Note: Impulse responses with pure sign approach.

Figure 5: The impulse response functions for the US: Full sample (1988m1-2009m12)



Note: Impulse responses with pure sign approach.

Figure 6: The smooth probabilities of the low volatility state for the UK: Full Sample (1988m1-2009m12)

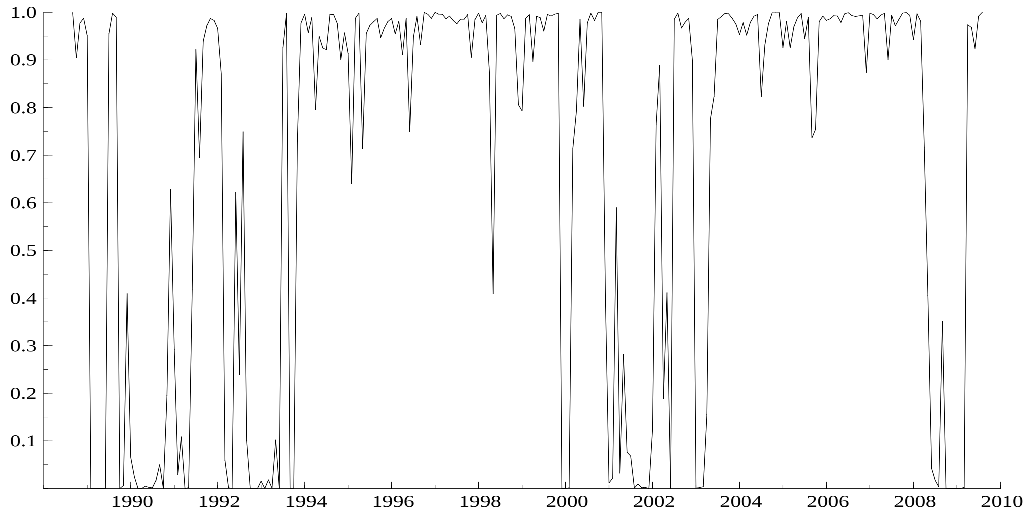
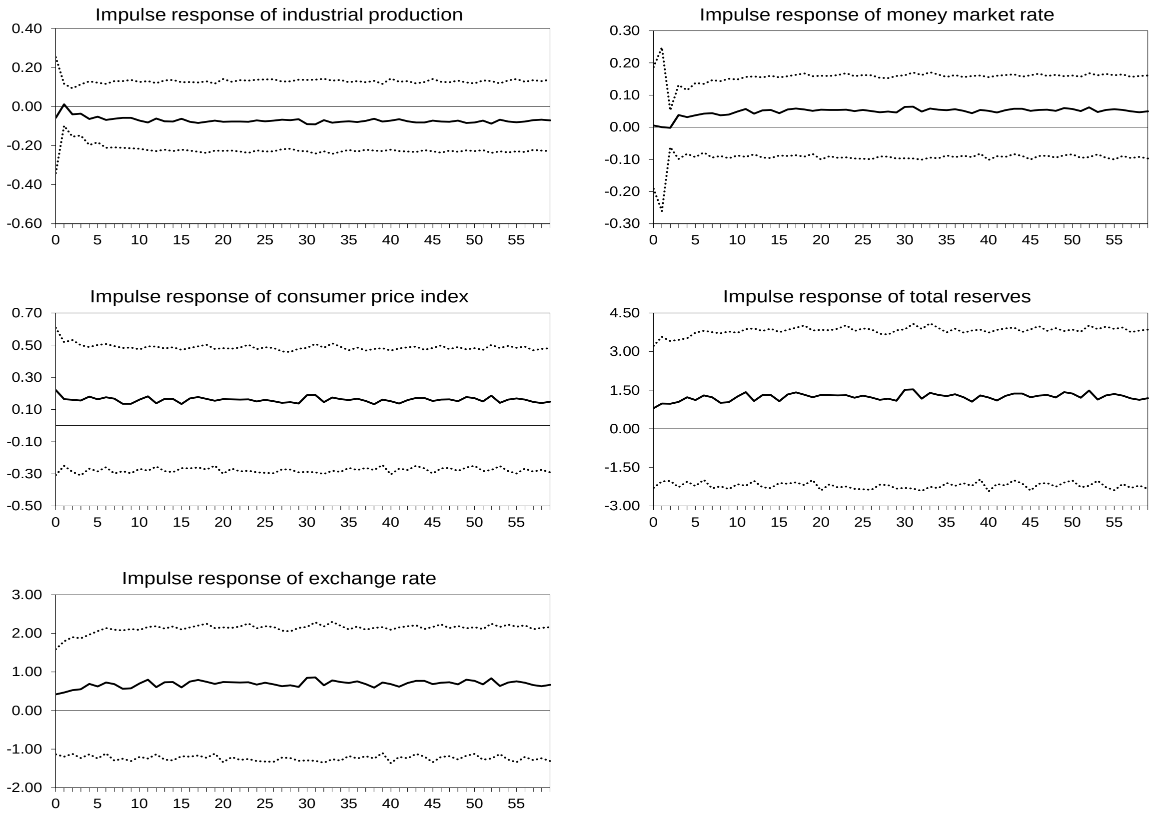
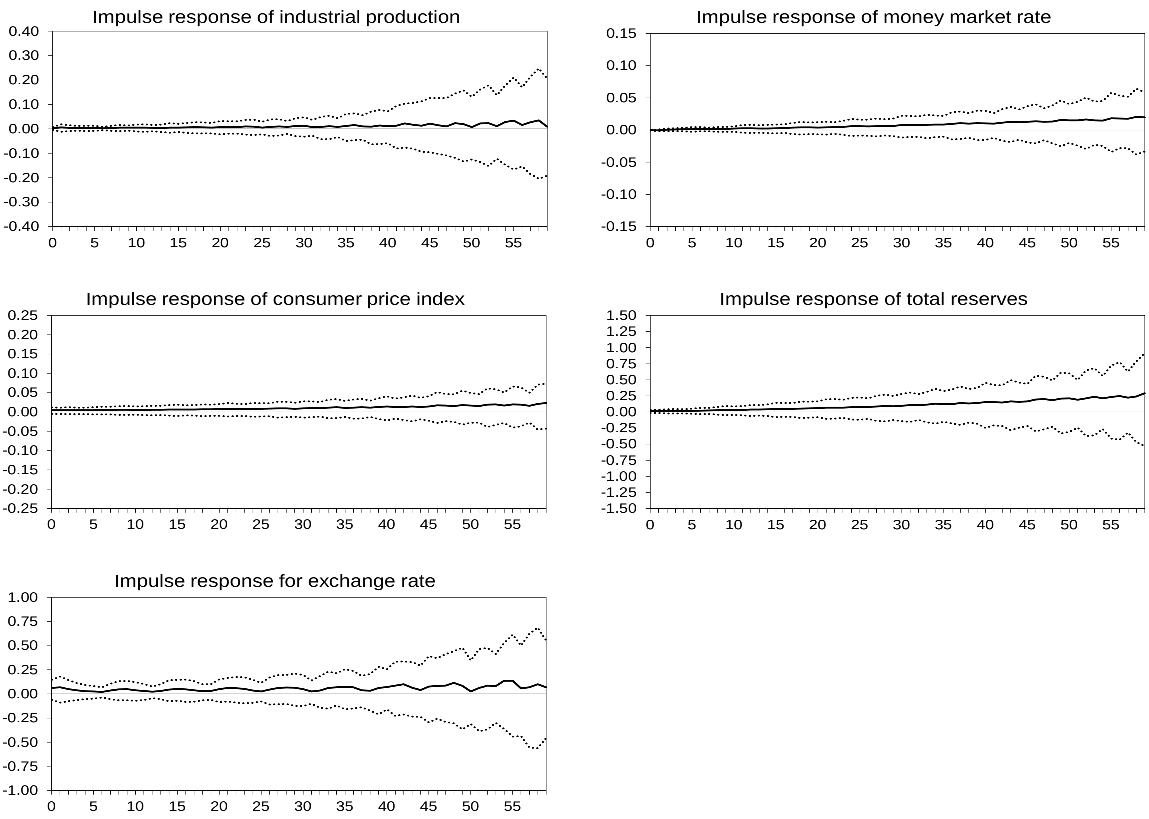


Figure 7: The impulse response functions for the UK: Full Sample (1988m1-2009m12)



Note: Impulse responses from SMRS VAR.

Figure 8: The impulse response functions for the UK: 1995m1-2007m12



Note: Impulse responses from SMRS VAR.

Figure 9: The smooth probabilities of the low volatility state for the US: Full Sample (1988m1-2009m12)

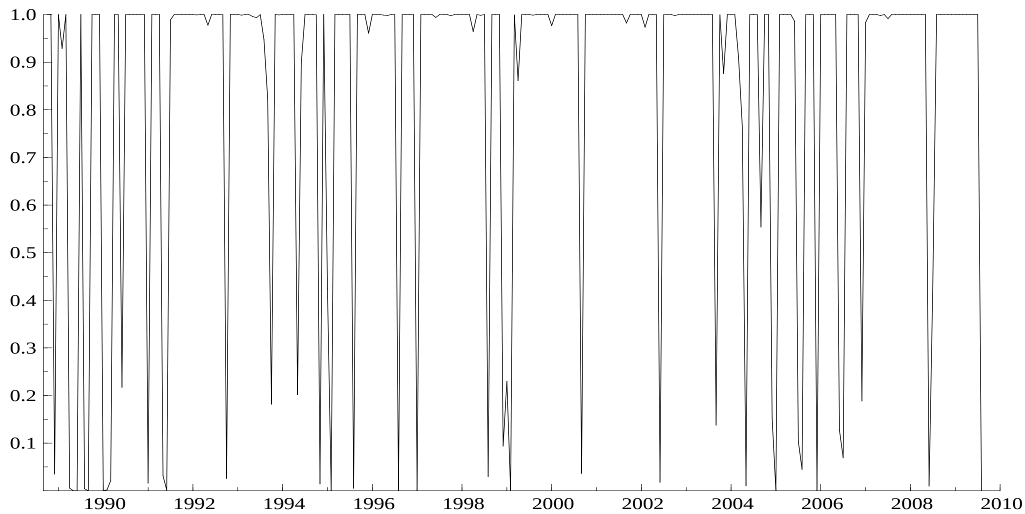
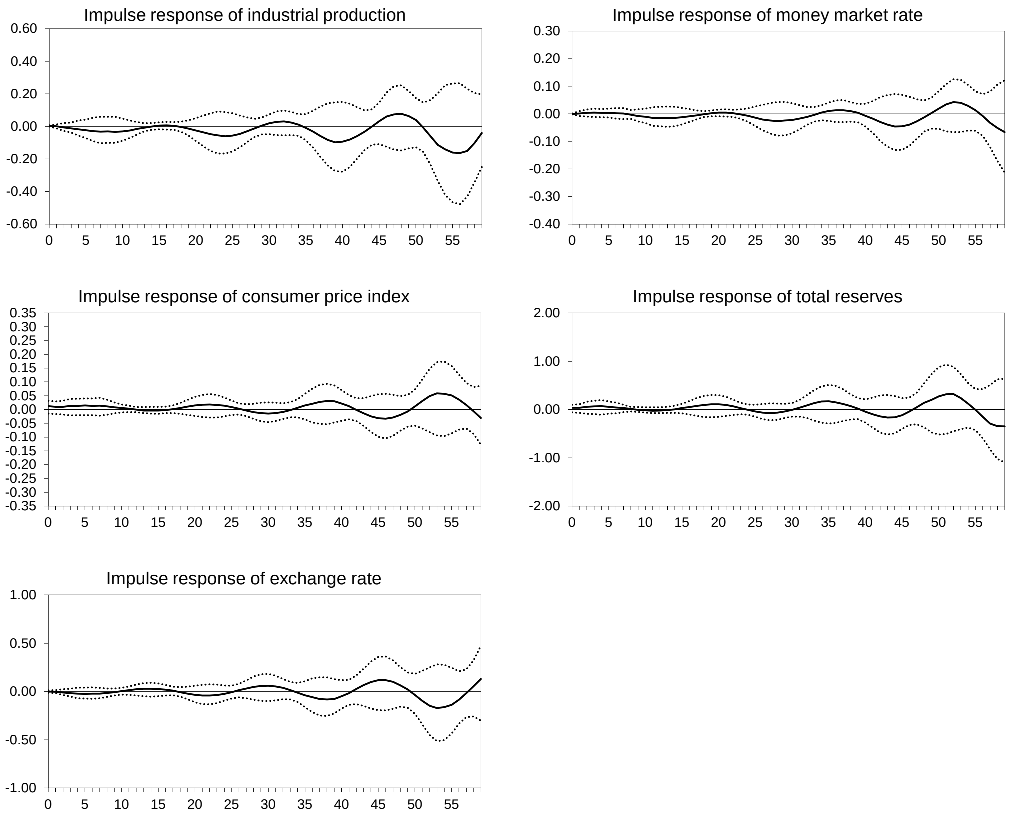


Figure 10: The impulse response functions for the US: Full Sample (1988m1-2009m12)



Note: Impulse responses from SMRS VAR.

Table 1: Variance decomposition

Fraction of Variance for IP Growth	6 month	12 month	24 month
Japan	10 %	14 %	16 %
United States	10 %	14 %	16 %
United Kingdom	11 %	17 %	20 %
Fraction of Variance for Inflation			
Japan	22 %	21 %	20 %
United States	15 %	20 %	18 %
United Kingdom	18 %	22 %	23 %
Fraction of Variance for Exchange Rate Growth			
Japan	11 %	13 %	17 %
United States	16 %	20 %	22 %
United Kingdom	12 %	15 %	20 %