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Dynamic Responses of the Economy to Monetary Shocks in the United Kingdom

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***A*bstract:** We study the dynamic responses of key macroeconomic variables to money supply and bank rate shocks in the UK economy. Our study follows Sims (1992) for recent decades that include the financial crisis of 2008. The Bank of England followed the Fed in taking an active role in managing the bank rate in the UK and employed quantitative easing during and post financial crisis in 2008. Our work isolates the structural shocks to the money supply and the bank rate. We examine the impulse responses of the bank rate, exchange rate, prices levels, and the industrial production deploying a structural vector autoregressive model (SVAR). The variance decomposition results and impulse responses from the VECM and SVAR models show that the industrial production is responsive to monetary actions of the Bank of England.

Keywords: Monetary shocks; Bank rate; Structural VAR; UK economy; Impulse responses
JEL Classifications: E00, E10, E19

1. Introduction

Researchers have studied the relationship and the linkage between monetary policy or announcements, the economy, asset markets, and transmission channels, among other related issues. Notable among pioneering papers are Friedman and Schwartz (1963), Sims (1972), Christiano and Ljungqvist (1988), Lynge (1981), and Pearce and Roley (1983), Cornell (1983) to name a few. Similarly, Federal Reserve discount rate changes and its relationship with financial and asset markets have been the topic of papers by Waud (1970), Smirlock and Yawitz (1985), Pearce and Roley (1985), Cook and Hahn (1988), among others.

In decades of 1990 through 2000s others, including the Jensen *et al*. (1996), Gilchrist and Leahy (2002), Poterba (2000), among others, examine various issues related to monetary actions of the Fed. Other papers along these lines of inquiry are by Gertler and Hubbard (1988), Gertler and Gilchrist (1994), Thorbecke (1997), Perez-Quiros and Timmermann (2000), Ehrmann and Fratzcher (2004), and Gurkaynak, *et al*. (2004), among others.

Inflation targeting in the US in the past few decades has led the policy makers to inform markets of the direction and the stance of the monetary policy based on the announced target inflation rates (see, e.g., Bernanke and Mishkin, 1997). Bernanke and Gertler (2001), employing a simulation approach, find that an aggressive inflation-targeting policy rule under many scenarios stabilizes both output and inflation. Thus, they conclude that inflation-targeting central banks automatically provide a conducive environment for productivity growth.

The Fed and the European Central Bank (ECB), have taken a markedly more active role in the economy in the aftermath of the global financial melt- down of 2008. The unprecedented central bank intervention appears to have prevented a prolonged recession and possible depression in the US and world economies. Following the Fed, the ECB initiated a quantitative easing in late 2014 to remedy the recessionary tendencies in the euro zone economies.

Several researchers, including Bernenke and Mihov (1998), Sousa and Zaghini (2007), among others deploy SVAR modeling to assess the impact monetary aggregates on macroeconomic variables around the globe by examining impulse responses from SVAR models.

The long history and list of papers indicate a continued interest in exploring various aspects of the monetary policy by monetary authorities, policy makers, and researchers. The events of post-2008, the near-zero fed fund rates, and quantitative easing in the US and the eurozone highlights the importance of the effects of monetary policy and its variations on the economies and financial markets.

Monetary Policy Committee of the Bank of England (MPC) is in charge of maintaining inflation target rate. Similar to the US, the committee attempts to affect changes in the Bank of England's official interest rate, Bank Rate. The MPC meets eight times a year to monitor the state of the UK macro economy and take appropriate measures to keep it on track. In the past decade, to confront the deleterious economic effects of the financial market crisis of 2008, the Bank of England also was engaged in quantitative easing to maintain sound economic conditions in UK and the world. Similar to the Fed, the Bank of England considers growth and employment objectives when making monetary decisions. For instance, the inflation target set by the MPC is 2 percent. However, currently the inflation rate is 2.5 percent, which exceeds the target rate. The MPC of BE meets eight times a year. The goal is to manage the bank rate to meet the inflation and economic growth targets. In short, the actions of the Bank of England are like those of the Fed.

At its latest meeting in august 2018, MPC deemed the GDP growth rate slightly above the expected trend. The unemployment rate is low and that the UK economy is near full employment. Given the observed CPI inflation rate of 2.5 percent, the MPC decided to purchase government bonds in order to achieve a twenty- five basis point increase in the bank rate.

In this paper, we attempt to examine the dynamics of the monetary actions in the UK by applying the methodologies that have proven valuable in studying the US market reactions to the Fed's monetary actions.

Our model variables are based on Sims (1992). Sims (1992) examined the dynamic interaction of money supply, interest rate, price levels, commodity prices, exchange rate, and GDP for several countries including Britain using impulse responses from the reduced form VAR estimates. The problem with the reduced form impulse responses is that the forecast errors (shocks) in the reduced form estimates are a linear combination of all the structural shocks in the model. Therefore, it may be impossible to isolate responses to structural shocks to any single variable by using forecast errors. For this reason, Sims (1992) examines correlation coefficients of the structural shocks and finds them to be negligible.

We follow Blanchard and Perotti (2002) by estimating a SVAR rather than a reduced form VAR as in Sims (1992). Impulse responses to structural shocks from an SVAR model will be estimated and presented.

We will examine the impulse responses of the UK bank rate, general prices levels (CPI), global prices of commodities, the exchange rate of the pound, and the UK industrial production to structural shocks to money supply. These findings will be compared with those of Sims (1992).

This paper is organized as follows. Section 2 explains the data, sources, and the main methodology of the research. Empirical results are presented and discussed in Section 3. Section 4 offers a variance decomposition analysis, and Section 5 summarizes and presents conclusions.

2. Data and Methodology

This paper examines monetary intervention in the UK economy from January 1988, through August 2016. All data series are obtained from the International Monetary Fund's (IMF) International Financial Statistics except for the global commodity prices and the expenditure on technology. The latter two are derived from the Federal Reserve Bank of St. Louis database, FRED. The SVAR model variables are the money supply, bank rate, the dollar exchange rate of the pound, the global commodity prices, consumer prices indices, and the industrial production. To account for technological innovations and its role in real business cycles, we enter a variable that is called Future Technology Spending Diffusion Index for New York. This variable is a monthly index provided by Federal Reserve Bank of St. Louis starting in 2001. We use it as a proxy for investments on technology assuming that British firms are also investing in new technology according to this index. In the absence of any other measure this index may serve as a fairly useful proxy. Following Sims (1992) we use logarithms of all variables except the bank rate (BR).

2.1 Vector autoregressive formulation

We formulate a structural vector autoregressive model (SVAR) for nominal macroeconomic variables in the logs of variable levels as follows

$$\boldsymbol{AX}_t = \beta_0 + \sum_{i=1}^{s} \beta_i \boldsymbol{X}_{t-i} + \boldsymbol{u}_t \tag{1}$$

The 6×6 coefficient matrix $\boldsymbol{A}$ is given by

$$\boldsymbol{A} = \begin{pmatrix} 1 & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} \\ a_{21} & 1 & a_{23} & a_{24} & a_{25} & a_{26} \\ a_{31} & a_{32} & 1 & a_{34} & a_{35} & a_{36} \\ a_{41} & a_{42} & a_{43} & 1 & a_{45} & a_{46} \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & a_{56} \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 \end{pmatrix},$$

And a_{ij} stands for element in the ith and jth rows and columns, respectively. The Structural innovations are assumed to be uncorrelated across SAVR equations. Thus, shocks to each structural variable such as the money supply are independent of all other variables in the SVAR and not influenced by them.

Vector $\boldsymbol{X}$ consists of the global commodity price index, money supply, bank rate, the dollar exchange rate of the pound, the consumer prices index, and the industrial production. Initially we leave out the technology index in order to follow the Sims (1992) model.

Sims analyzes the dynamic responses to the reduced form shocks. As shown by Blanchard and Perotti (2002) the dynamic path of variables may be traced more accurately by examining the structural shocks to the model variables. SVAR coefficients and the structural shocks vector ($\boldsymbol{u}_t$) cannot be recovered from the estimated reduced form SVAR due to the identification problem. Imposing reasonable *a priori* restrictions on the SVAR coefficients is necessary to render the SVAR identifiable. We impose 6×(6-1)/2 restrictions on the off-diagonal upper triangle elements of matrix $\boldsymbol{A}$.

$\boldsymbol{\beta}_0$ is a 6×1vector of intercepts. $\boldsymbol{\beta}_\mathrm{i}$ is the coefficient matrix of lagged endogenous variables on the right-hand-side of equation (1). There are 6×6×s (s is the lag order) parameters to be estimated in the matrix $\boldsymbol{\beta}_\mathrm{i}$.

Multiplying both sides of the equation (1) by the matrix $\boldsymbol{A}^{-1}$, we arrive at the reduced form of the VAR, i.e.

$$\boldsymbol{X}_t = \boldsymbol{G}_0 + \sum_{\mathrm{i}=1}^{\mathrm{s}} \boldsymbol{G}_i \boldsymbol{X}_{t-i} + \boldsymbol{e}_t \ ,$$

where, $\boldsymbol{G}_0 = \boldsymbol{A}^{-1}\boldsymbol{\beta}_0$, $\boldsymbol{G}_i = \boldsymbol{A}^{-1}\boldsymbol{\beta}_i$ and $\boldsymbol{e}_t = \boldsymbol{A}^{-1}\boldsymbol{u}_t$. It should be noted that the elements of vector $\boldsymbol{e}_t$, which, are referred to as forecast errors, are a linear function of the model structural shocks, i.e., elements of vector $\boldsymbol{u}_t$. Once a reduced form VAR is estimated, the structural shocks would have to be recovered to examine the effects of exogenous structural shocks to a model variable on the remaining variables. Thus, multiplying the vector of forecast errors by matrix $\boldsymbol{A}$, one recovers the vector of the structural shocks $\boldsymbol{u}_t$ as $\boldsymbol{u}_t = \boldsymbol{A}\boldsymbol{e}_t$.

The problem of identification arises because the number of equations derived from the reduced form estimation are not sufficient to solve for and obtain the coefficients of the structural model and to recover the structural shocks. Therefore, prior to estimating the reduced form parameters, some identification restrictions on the off diagonal elements of the matrix $\boldsymbol{A}$ in equation (1) are necessary. In this paper, we follow the identification strategy suggested by Sims (1992), and more recently applied by Blanchard and Perotti (2002), among others. This strategy calls for imposing some restrictions on the contemporaneous relationships among the elements of matrix $\boldsymbol{A}$ based on their role in the model.

For instance, it is plausible that the money supply is not contemporaneously correlated with the remaining model variables because it is determined by the BE. Therefore, in the first equation, the coefficient of the money supply will be set at one and the remaining coefficients, which represent the contemporaneous association of the money supply with the rest of the SVAR variables, are zero. Thus, $a_{12} = a_{13} = \ldots = a_{16} = 0$.

For similar reasons, the remaining upper triangle elements of matrix $\boldsymbol{A}$ are et equal to zero, reducing it to a lower triangular matrix with identifiable number of unknown parameters. These conditions result in fifteen restrictions, i.e., $(6^2\text{-}6)/2$, imposed on the elements of matrix $\boldsymbol{A}$.

The structural shocks, i.e., the innovations of the SVAR given by the vector

$\mathbf{u}_t = (u_t^{ms}, u_t^{br}, u_t^{xr}\ u_t^{ppi}, u_t^{cpi}, u_t^{ip})'$, are also retrievable as the product of the reduced form residuals and the recovered elements of matrix $\boldsymbol{A}$.

The identified and estimated structural model in equation (1) may be written in an infinite moving average representation (Wold representation) of the structural variables as follows:

$$\boldsymbol{X}_t = \boldsymbol{\Omega} + \sum_{j=0}^{\infty} \boldsymbol{\Phi}_j \, \boldsymbol{u}_{t-j} \qquad (2)$$

where $\boldsymbol{\Omega}$ and $\boldsymbol{\Phi}$ are the vector of intercepts (means of SVAR variables) and the coefficient matrix of infinite structural shocks, respectively.

In equation (2), the elements of matrix $\boldsymbol{\Phi}$ at lag 0 are the impact multipliers. For instance $\phi_{ij}(0)$ is the instantaneous impact of a structural shock or innovation ion endogenous variable j. Similarly, $\phi_{ij}(t)$ are the one-period impact of shocks to variable i on variable j in time period t . In a similar way one can examine the forecast error variance by innovation accounting, i.e., variance decomposition. If a structural innovation of variable i explains none of the forecast error variance of endogenous variable x_j, then the series x_j is not responsive to innovations in variable i .

3. Empirical Results

Prior to estimation of the SVAR model, we determine the lag order of the reduced form SVAR. Several lag order determination criteria are computed for unrestricted reduced form SVAR. Schwarz (SC) and Hannon-Quinn (HQ) criteria indicate lag orders of 3 and 4, respectively. The SC tends to underestimate the number of lags. Too few lags could result in non-stationary VAR system and residuals that are not white noise. The Akaike Information Criterion (AIC), The Forecast Prediction Error (FPE), as well as the log likelihood ratio test (LR), point to the lag order of two. Therefore, we choose the lag order of two for the reduced form VAR estimation. We follow Sims (1992) and estimate the reduced form VAR and the SVAR models in levels. However, Table 1 shows that according to the ADF test, the model variables are non-stationary in their levels. ADF tests indicate that once the drift, trend, and break- point in the time series accounted for, all variables are stationary. Thus, two additional exogenous variables are also included in the estimation of the reduced form VAR. We include an exogenous deterministic trend variable in the VAR estimation because in addition to ADF test, graphic observations indicate that some variables demonstrate deterministic trend.

A break point dummy variable is also included to capture the financial crisis and the quantitative easing by the Bank of England for the period of late 2008 through late 2011. The post estimation test of the inverse of the roots of the reduced form characteristic polynomial shows that they are within the unit circle ensuring the system stationarity. Furthermore, the portmanteau Q statistic (p-value test of VAR residuals autocorrelation up to 10 lags) rejects the null of autocorrelation in the VAR system residuals.

Some variables of the SVAR model are non-stationary by the Augmented Dickey Fuller (ADF) as shown in Table 1. Lütkepohl (2005) among others suggest transforming SVAR variables to stationary in order for the SVAR to be stationary and stable. However, we followed Sims (1992) who estimates VAR without this transformation. Non-stationary variables could result in a non-stationary VAR system and impulse responses that are spurious and do not die down with time.

Table 1. Diagnostics and Summary (1974:1--2017:3)

Panel A: Levels

	GCP	TEC	M1	BR	CPI	XR	IP
ADF	-1.400	-5.700[a]	-0.847	-0.946	-1.489	-1.953	-1.672
ADF (trend, intcp)	-1.749	-5.897[a]	-1.394	-2.920	-4.036[a]	-2.239	-1.706
ADF (trend, intcp, BP)	-3.409[a]	-6.703[a]	-3.695[a]	-5.371[a]	-4.754[a]	-3.843[a]	-4.044[a]

Panel B: Summary descriptive statistics for model variables, all in level

	GCP	TEC	M1	BR	CPI	XR	IP
Mean	4.487	2.446	6.036	5.177	4.428	4.738	4.634
Stand Dev	0.488	0.687	0.766	3.898	0.190	0.084	0.054
Skewness	0.340	-1.437	-0.174	0.741	-0.249	-0.476	-0.014
Kurtosis	1.610	5.291	1.675	3.169	2.458	1.905	1.428
J-B	29.526	96.902	26.909	31.928	7.759	30.212	35.432

Panel C: Johansen-Juselius Cointegration Test, unrestricted VAR lag order = 6

	λ_m	**P-value**	**λ_t**	**P-value**
r=0	49.591	0.003	120.293	0.000
r≤1	31.795	0.089	70.702	0.042
r≤2	21.085	0.271	38.907	0.264

r is the number of co-integrating vectors among the four variables.

Notes: VAR variables are global commodity price (GCP), Investment in technology (TEC), money supply (M1), bank rate (BR), consumer price index (CPI), pound exchange rate (XR), and industrial production (IP). All are in natural logs except for the bank rate. BP stands for break point in unit root tests. Order of lags in the VAR for cointegration test is 2, determined by the AIC, SC, the log likelihood ratio test (LR), and FPE. Cointegration with unrestricted intercepts and no trends in the co-integrating VARs. P-values from MacKinnon-Haug-Michelis (1999) for both λ_m and λ_t reject no or one co-integrating vector. Maximum eigenvalue and traces tests suggest 2 co-integrating vectors at 5% significance level.

The marks a, b, and c , represent statistical significance at 0.01, 0.05, and 0.10 levels, respectively.

The test of cointegration among model variables shows at least one co-integrating vector among the variables. Therefore, we also estimate a vector error correction model (VECM) and examine the impulse responses of both SVAR and VECM. In VECM estimation, we include the dummy exogenous variable that accounts for the financial crisis during the 2008 through 2011 period.

Figure 1 below shows the impulse responses to one standard deviation structural shock to the money supply. The solid line traces the point estimates of the impulse response and the dotted line represents the two-standard error confidence band of the impulse responses. Impulse responses show the size of the impact of a shock as well as the rate at which the response tapers off. Impulse responses in almost all periods are statistically insignificant indicating that the responses to monetary shocks are quite weak. However, as Sims and Zha(1999) explain, conventional significance tests may be misleading in the case of impulse responses. Therefore, our attention will be focused mostly on the direction and the duration of the impulse responses. The global commodity price rises and then trails downward in roughly five to ten months. The rise in global commodity prices due to a monetary stimulation in the economy of the UK may show that the monetary policy in a major world economy may have a short-term expansionary effect on its trading partners and the global price levels.

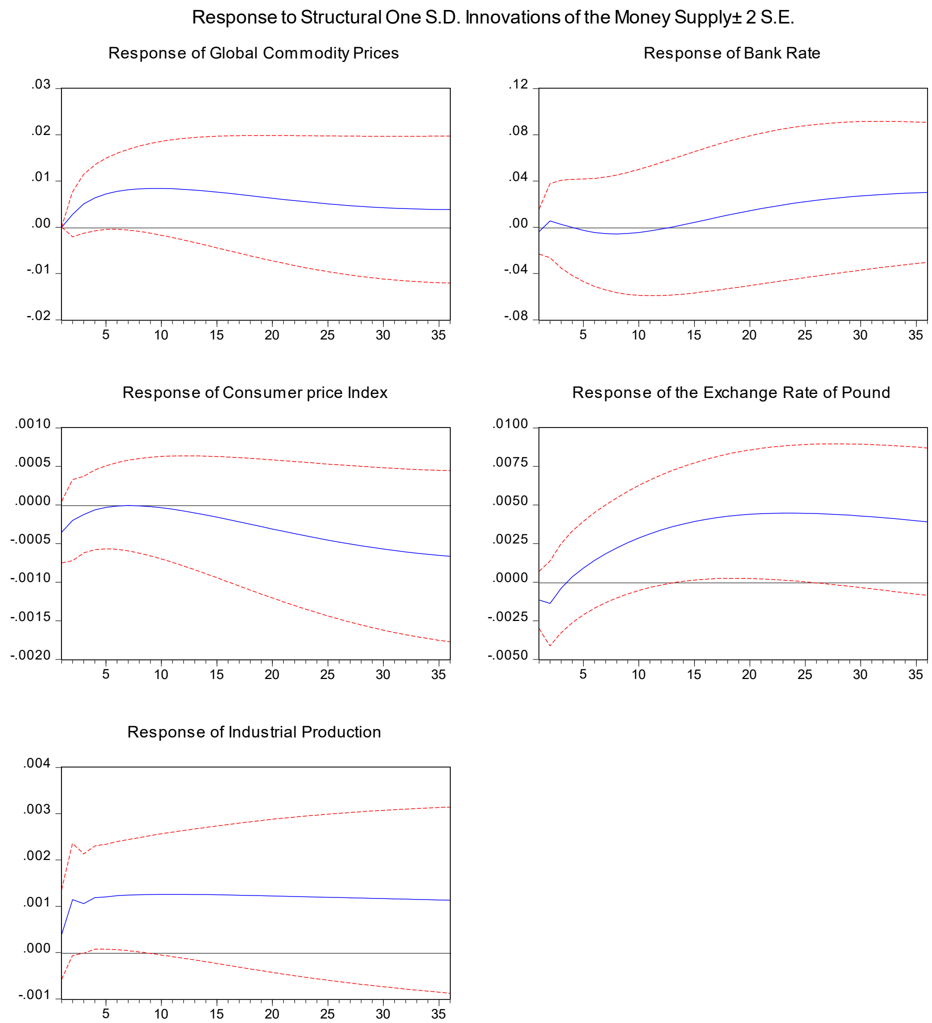

Figure 1. Responses of the bank rate and the natural logarithms of the global commodity prices, consumer price index, the exchange rate of the pound, and the industrial production to one standard deviation shock to the natural logarithm of the money supply. Estimates and two-standard deviation confidence band. SVAR lag order is 2. Dummy variables for financial crisis and trend are included as exogenous variables. 1988:01--2016:08.

The short-term bank rate shows a small spike in the first month, falls for several month and begins to rise in about 12 months. This pattern may indicate that the monetary expansion reduces the bank rate in the short-run. With rising demand for credit, interest rates respond and the short-term bank rates rise signaling a tightening in the credit market. The conclusion may be that the effects of one-time expansionary money supply on interest rates are temporary.

The consumer price index rises in response to the monetary expansion and its immediate stimulative effect on the economy. Consumer prices decline after about ten months and tend toward their original level. Rising interest rates and improved economic activity following the monetary shock is associated with the strengthening to the exchange rate for close to two years. Beyond that period the exchange rate of the pound trends downward.

The industrial production reacts positively to positive innovations of the money supply. However, as expected the positive response of the industrial output is short-lived.

Impulse responses of the key model variables, i.e., bank rate, exchange rate, global commodity prices, and the industrial production presented in Figure1, are qualitatively similar to those obtained by Sims (1992). Confirming his results for a sample of more recent time and a SVAR versus his reduced form VAR model results indicates that the dynamic association among these variables has been stable for years.

Sims (1992) discusses the ramification of the real business cycle theory (RBC). RBC holds that business cycles follow innovations in production or other technologies. Robert Gordon (2016), for instance, argues that the modern world economies have experienced multiple innovation revolutions in the past several decades. He mentions information technology and the advent of internet as factors that have triggered structural changes in the labor market and contributed to economic cycles.

In the next set of empirical tests, we include a variable to account for the dramatic advances in the information technology that has been underway. The most reliable variable that we could find is the expenditures on the technology that the Federal Reserve Bank of the St. Louis provides. This index shows the investments on technology in New York. In the absence of a similar variable for the UK, we use the US variable as a proxy. We estimate the seven-variable structural VAR that includes this variable. In the following, we report the results of this estimation. Figure 2 reports these results. The findings reported in Figure 1 did not change noticeably. Thus, we concluded that accounting for the effects of the information technology, did not alter the findings of shocks to the money supply in the UK. Investment in technology might be reasonable to deduct that while the introduction of technological advances may affect the life or the frequencies of business cycles, however the underlying dynamics of money supply shocks are not affected.

Having observed that impulse responses are statistically insignificant, we turn our attention to the main instrument of monetary policy, i.e., the bank rate in UK. Much like the Fed the Bank of England target the short- term bank rate by open market operations. Therefore, monetary shocks should enter the economy through the bank rate. In the following, we report the impact of negative shocks to the bank rate on the macroeconomic variables in the UK from the SVAR. We have set the shocks as negative to see the impulse responses to drops in the bank rate. Figures 3 and 4 present impulse responses to structural shocks to the bank rate and their cumulative effects from the SVAR without the technology investment proxy variable.

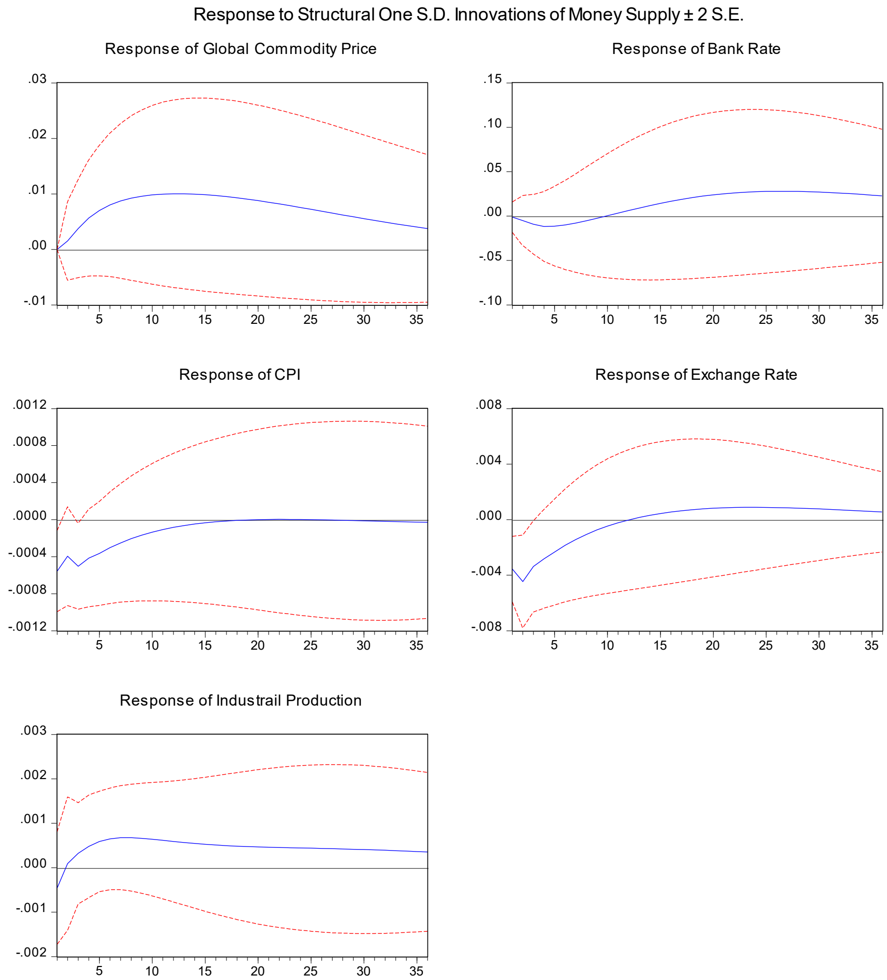

Figure 2. Responses of the bank rate and the natural logarithms of the global commodity prices, consumer price index, the exchange rate of the pound, and the industrial production to one standard deviation shock to the natural logarithm of the money supply. Estimates and two-standard deviation confidence band. SVAR lag order is 2, and includes expenditures on technology. A trend and dummy for financial crisis are included as exogenous variables. 1988:01--2016:08.

Figure 3 shows that the downward structural shocks to the bank rate in the UK stimulate the economy. They trigger an increase in the global commodity prices, the exchange rate of the pound, and the industrial production. However, the CPI does not show a statistically significant response to shocks to the bank rate. This may indicate that the stimulative effects of negative shocks to the bank rate are on the real production and GDP growth rather than inflation, a plausible scenario during economic downturns and times that monetary policy may be most effective. Furthermore, it is plausible that the appreciations in the exchange rate of the pound may help lower general price levels by lowering import prices of raw materials and other input products.

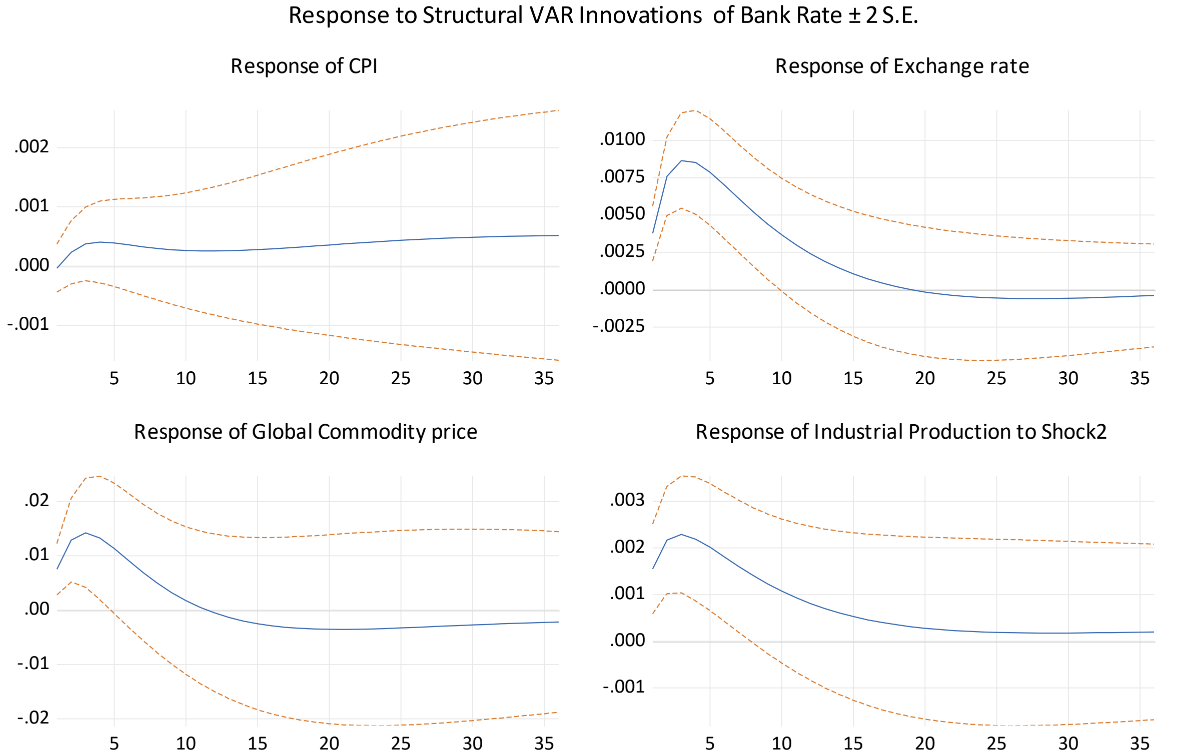

Figure 3. Responses to bank rate innovations of the natural logarithms of the global commodity prices, consumer price index, the exchange rate of the pound, and the industrial production to one structural shock to bank rate. Estimates and two-standard deviation confidence band. SVAR lag order is 2. Dummy variables for financial crisis and trend are included as exogenous variables. 1988:01--2016:08.

The bank rate shock instigates a rise in the exchange rate that lasts around 10 months before dying down. This is consistent with the economic theory that a rise in the domestic economic growth, raises the expectation that the aggregate demand and domestic yields will improve. This may raise the future interest rate spread between the domestic and foreign interest rates stimulating higher demand for the pound due to capital inflow to the UK.

The rise in the global commodity prices could conceivably occur due to higher demand for commodities stemming from economic stimulation in the UK economy. However, the response to shocks dissipates in around five months. The industrial production responds to the bank rate negative shocks, showing positive impulse response for around eight months.

Figure 4 shows the cumulative effects of downward bank rate innovations on the variables of interest. All macroeconomic variables of the model with the exception of CPI are exhibiting the expected reaction to bank rate innovations. The exchange rate of the pound and the industrial production show a cumulative positive response to bank rate shocks up to twenty and fifteen months, respectively. Thus, the economic stimulation of the industrial production is achieved by as predicted by the Keynesian aggregate demand model. Contrary to the monetarist views and Taylor's rule of nondiscretionary monetary policy, prices do not show an accumulated inflationary effect. This could be due to the particular sample period. For instance, while the Fed in the US was aggressively engaged in the quantitative easing for several years after the 2008 recession, inflation remained benign for years. In the meanwhile, the economy recovered and unemployment rates dropped steadily from the peak of around fourteen percent to current levels of four percent, which is below the natural rate.

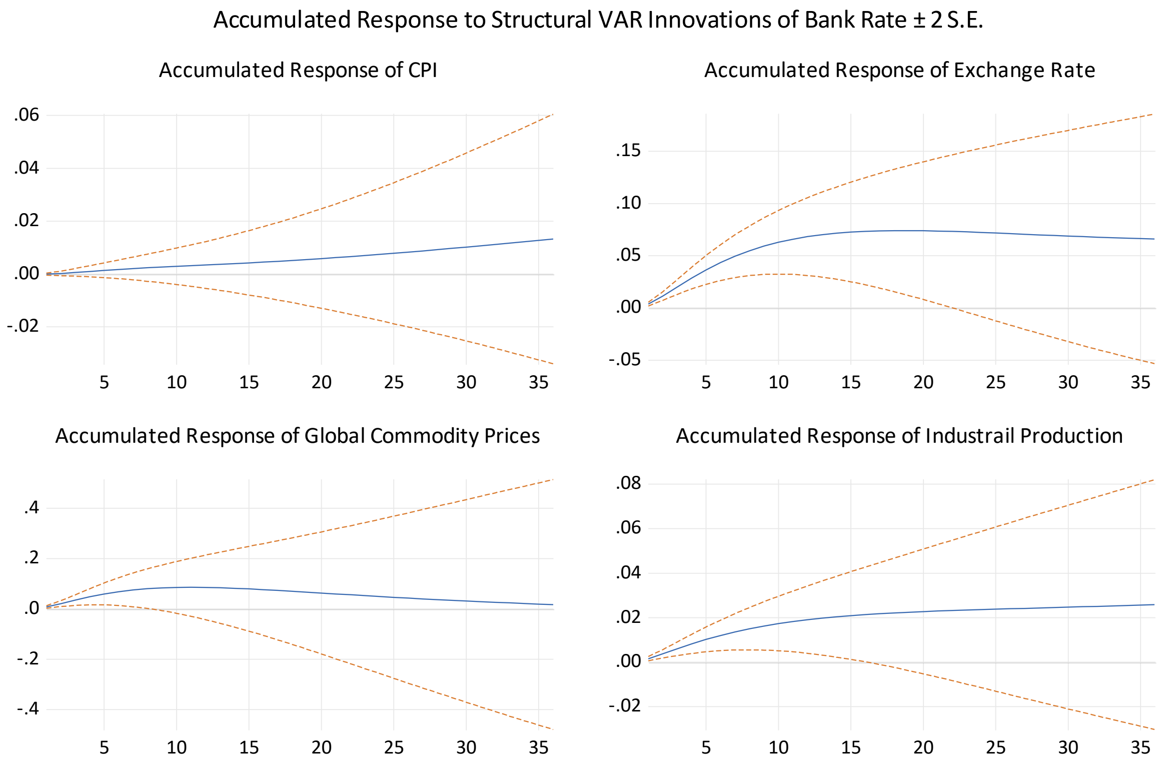

Figure 4. Accumulated responses to bank rate innovations of the natural logarithms of consumer price index, the global commodity prices, the exchange rate of the pound, and the industrial production to one structural shock to bank rate. Estimates and two-standard deviation confidence band. SVAR lag order is 2. Dummy variables for financial crisis and trend are included as exogenous variables. 1988:01--2016:08.

The cumulative effect of the UK bank rate on the global commodity prices has the shortest duration as expected. The UK demand for commodities globally is relatively small.

The findings seem to lend support the Keynesian view of the monetary policy. The monetary stimulus imparts short-term positive responses in the industrial production consistent with the Keynesian view.

As shown in Figure 5, the VECM impulse responses confirm the findings from the SVAR, indicating that the findings are robust and not model dependent. The exception is the CPI. The CPI rises for a few months and levels off afterwards. The Exchange rate, global commodity prices, and industrial production rise for about five months and die down in around ten months.

In summary, impulse responses confirm that impact of a one- time shock to bank rate on the economy are relatively temporary and fade in two years. These findings lend support to the approach taken by the Bank of England and the Fed for their policy of quantitative easing. The sustained multi-year infusion of the money into the banking system shored up the financial structure of the British and US economies. These steps gradually reversed the meltdown of the late 2008 due to the financial crisis. Unemployment subsided and the economic growth was restored while the inflation remained benign. This experience was a significant deviation from the experiences. Non-discretionary monetary policy was completely abandoned during the quantitative easing in contrast to the tenets of monetarism or the Taylor's rule. In the following section, we discuss the variance decomposition findings.

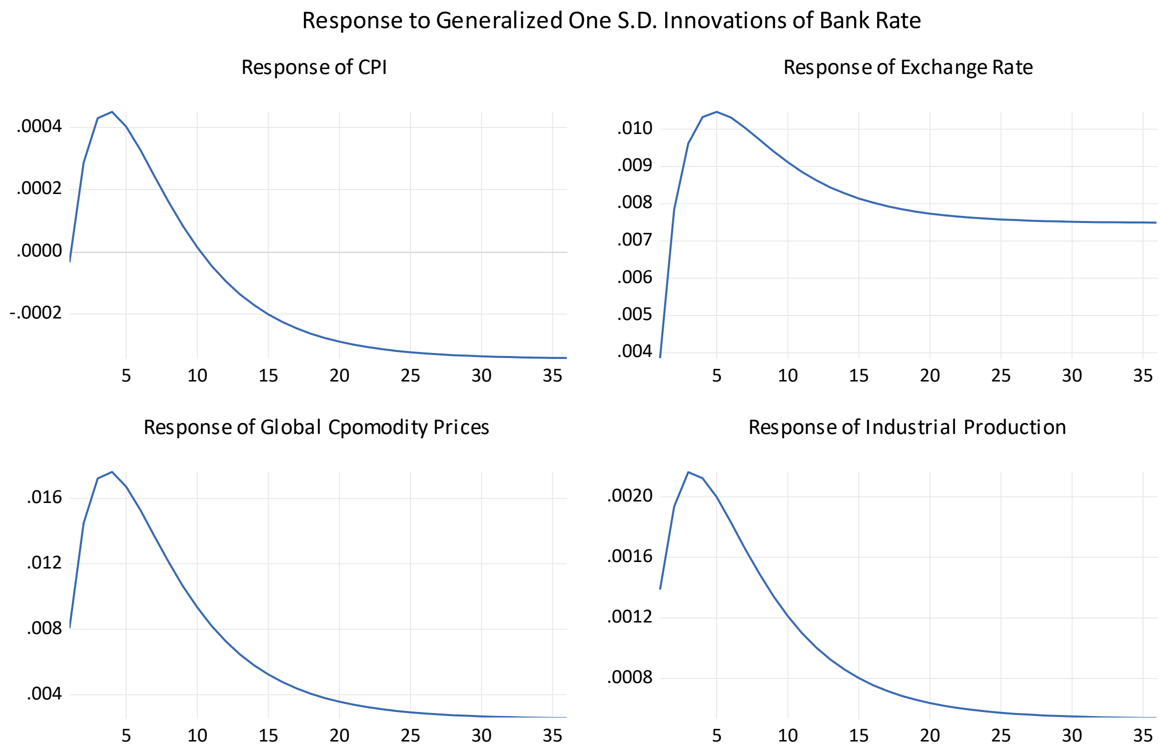

Figure 5. VECM Impulse responses of the natural logarithms of the global commodity prices, consumer price index, the exchange rate of the pound, and the industrial production to shocks to the bank rate. Estimates are based on Cholesky ordering. A dummy variable for financial crisis is included as an exogenous variable. 1988:01--2016:08.

4. Variance Decomposition Analysis

The variance decomposition analysis from SVAR, SVAR with the addition of investments in technology, and the VECM are qualitatively similar. In the interest of brevity, we only present and discuss these results from the SVAR.

Tables 2 shows the contribution of each variable to explaining the forecast error of the industrial production in the SVAR model including an exogenous dummy variable for the financial crisis, a trend variable, and the technology investment. In this model, the M1 money supply and bank rate appear to explain around sixteen percentage of the forecast error of the industrial production. This may be viewed as the importance of the role of the money and monetary policy in the economic cycle. The shocks to money supply are a counterbalance to further rapid decreases in interest rates and may be helpful to the growth in the industrial production. Consequently, up to seventeen percent of the industrial production forecast error is determined by the bank rate in three years.

Table 2. Variance decomposition of industrial production from the structural VAR model

Period	S.E.	M1	BR	CPI	XR	GCP	IP
1	0.011	0.267	2.121	0.886	0.461	0.165	96.099
2	0.014	0.333	6.737	1.109	0.349	1.415	90.055
3	0.016	0.714	9.521	1.528	0.345	1.725	86.164
4	0.018	1.527	11.633	1.805	0.813	1.735	82.485
5	0.019	2.498	13.125	2.001	1.866	1.588	78.922
6	0.021	3.525	14.187	2.122	3.641	1.486	75.039
12	0.027	6.780	16.161	2.048	23.448	1.485	50.077
18	0.033	6.399	15.597	1.733	41.856	1.064	33.350
24	0.039	5.734	14.144	1.595	52.789	1.255	24.483
36	0.049	5.852	11.368	2.015	61.254	2.142	17.369

Factorization: Structural

Notes: Six SVAR variables are money supply (M1), bank rate (BR), consumer price index (CPI), pound exchange rate (XR), global commodity price (GCP), and industrial production (IP). All are in natural logarithms except for the bank rate. Exogenous variables are a dummy for financial crisis and a trend variable.

Surprisingly, around 61 percent of the forecast error in industrial production is explained by the exchange rate of the pound. One explanation may be that the exchange rate variations may reflect the effects of capital inflow due to investment opportunities. Increase in foreign investment in the UK economy could partially bolster the growth in the industrial production.

5. Summary and Conclusions

Inspired by Sims (1992), we study the dynamic responses of key macroeconomic variables to money supply shocks in the UK economy. One of the main motivations of the study is to see if the findings of Sims (1992) hold for a time period that witnessed the gravest challenge of the financial meltdown in 2008. The Bank of England followed the Fed in taking an active role in managing the bank rate in UK and employing quantitative easing. Our structural vector autoregressive model (SVAR) estimation is different from the approach in Sims (1992) in that we isolate the structural shocks to the SVAR variables.

We estimate and report the responses of the SVAR variables to structural shocks to the money supply and the bank rate. Our impulse responses to money supply shocks are similar to those reported by Sims (1992) with the exception of consumer price index. Impulse responses show a temporary rise in CPI following a positive money supply shock. Impulse responses are not sensitive to the presence of a technology investment that capture real business cycle effects. However, the statistical insignificance of many impulse responses may indicate that the monetary shocks in the UK economy are not the main reason behind changes in other macroeconomic variables. Negative innovations of the bank rate from the SVAR model lend support to the notion that monetary policy is effective in boosting growth in the industrial production in the short-and medium-run. The impulse responses to downward shocks to the bank rate from the VECM model support the findings from the SVAR. The variance decomposition results are qualitatively similar for the Vector Error Correction model (VECM), and the SVAR models. Examining the SVAR model variance decomposition shows that around 17% of the forecast error in industrial production is due to the money supply and the bank rate.

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