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Analyzing Monetary Policy Transmission Mechanism Using Factor Augmented Vector Auto Regression

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Abstract
This study models the transmission mechanism of monetary policy by employing Factor Augmented VectorAuto Regressive (FAVAR) methodology, introduced by Bernanke et al., (2005). We use large data consisting of economic and financial markets for U.S, Canada and U.K. We find strong evidence that factors have additional information. We find that due to tight monetary policy shock output declines and employment decreases. Short term and 10 year interest rates increase due to contractionary monetary policy in these countries.
Keywords: Monetary policy, FAVAR, Financial variables

1. Introduction

Over the last thirty five years there has been huge work and advancement in the area of stationary vector auto regressions (VARs).[1] It would not be wrong to say that empirical analysis of stationary vector auto regressions (VARs) is almost a completed research area. VARs popularly known as work horse models have become benchmark for analyzing impact of monetary policy transmission.

In spite of all this huge advancement, it would not be wrong to say that VAR models have limitations in the practical monetary policy making issues. They have many short comings, apart from the identification problem, one of the most apparent short coming associated with these models is the use of insufficient number of variables, three or four and occasionally more than ten.[2] Monetary policy makers use more variables than normally used in VAR models. Their predictions are not based on formal methods; hence replicating their predictions is not possible. This has two consequences, first monetary policy forecasting is no more considered a scientific act, second VAR models have small impact on everyday monetary policy decisions. In general, FAVAR approach is superior to VAR approach and can be more intuitive for policy makers.

This paper enriches monetary policy literature in many ways by making an extensive cross country investigation beyond U.S to Canada and U.K. using FAVAR approach under the Bayesian framework[3]. Our findings confirms the economic theory that monetary policy impacts major economic and financial variables. Monetary policy tightening results in decrease in industrial production, employment, share prices, housing starts and inflation; however it leads to increase in unemployment, money market rate and 10 year government bond rates. Overall the impact of standardized monetary policy tightening is similar across countries.

2. Literature Review

Questions related to monetary policy tightening and the transmission of these shocks have always remained as a core research area for the researchers and they have tried on different grounds to unriddle these issues. Some researchers have been advanced on the basis of qualitative versus quantitative effects of monetary policy, former try to answer the questions using theoretical approaches as used by Clarida, Gali and Gertler (2000) and Gali (2003) to cite a few. Following the latter approach where there is still no agreement among the researchers comparing to the former approach, a great work has been done on empirical grounds by Sims (1992), Canova and De Nicolo (2002), Uhlig (2005), Scholl and Uhlig (2008), Canova and Gambetti (2009), Forni and Gambetti (2010) and Luciani (2013) among others.

Many researchers tried to answer main questions using vector auto regressions. The anomaly of 'price puzzle', motivated to the inclusions of e.g. commodity price index, output gap, composite leading indicator of economic activity, expected inflation under indeterminacy and use of sign restricted VAR models or imposing long run restrictions in VAR studies, see for example Giordani (2004), Brissmis and Magginas (2006), Castelnuovo and Surico (2010), Krusec (2010), Jaaskela and Jennings (2011) and Rusnak, Havranek and Horvath (2013).

Bjornland and Jacobsen (2010) analyse the role of house prices in the monetary policy transmission mechanism in Sweden, Norway and the UK using structural VARs.

[1] VAR was initially proposed by Christopher Sims (1980) three decades ago to address four macro-econometric tasks: data description and summarization, macroeconomic forecasting, structural inference and macroeconomic policy analysis.
[2] Study by Banbura, Giannone and Reichlin (2010) is an exception to this which uses Bayesian VAR up to 130 variables.
[3] Our study initially was targeted to include all G-7 countries, however complete data was not found for all categories of variables and in some categories of variables the time period was too short to draw consistent conclusions.

In macroeconomics to characterize the variables it is possible to extend factor models for dynamic properties resulting into Dynamic Factor Models (DFMs). In DFMs it is hard to recognize shocks to quantify impulse response functions. This inspires the application of Factor Augmented VARs (FAVARs), which is an extension of DFMs with an implicit restriction which permits for impulse response analysis which is more economically sensible[1].

3. Econometric Model

3.1FAVAR Model

Let Y_t be a (M × 1) vector of observable time series macroeconomic variables assumed to have persistent effects on the economy. However in many instances additional information is required that is not fully explained by Y_t to depict the dynamics of series, Y_t contains the policy instrument (possibly contains other policy variables not contained in X_t) so Y_t can be considered as subset of X_t. Mostly in VAR analysis these limited number of variables (normally four to eight variables) are used for estimation, additional variables required to depict the dynamics can be written as F_t here F_t is the (K × 1) vector of unobserved factors. For identifying monetary policy shocks we employ the FAVAR approach as follows

$$\begin{bmatrix} F_t \\ Y_t \end{bmatrix} = \Phi(L) \begin{bmatrix} F_t - 1 \\ Y_t - 1 \end{bmatrix} + \upsilon_t \qquad (1)$$

Where Φ(L) is a lag polynomial of finite order d and the error term υ_t is identically independently distributed with mean zero and with covariance matrix Q. lll

It is possible to reduce the above system to standard VAR if terms of Φ(L) that relate Y_t to F_t are zero. The system described above enables to assess the marginal contribution of additional information in F_t. Hence if the true system is a FAVAR, the standard VAR suffers from omitted variable bias; hence FAVAR is a more realistic depiction of economic dynamics and outperforms the results from VAR model ; as it includes more variables.

The results are analyzed in terms of impulse response functions. The responses are considered significant at horizons where median and percentile bands of impulse response functions of selected variables do not fall on the base line.

In our analysis FAVAR model with 5 and 3 factors is analyzed for each country. FAVAR with 5 factors is considered as our benchmark model.

Mainly we are interested to test following three hypothesis in our benchmark model (FAVAR with 5 factors).

Hypothesis 1: Output declines due to contractionary monetary policy shock.
Hypothesis 2: Employment rate decreases due to contractionary monetary policy shock.
Hypothesis 3: Money market rates and 10 year interest rates rise in response to tight monetary policy.

4. Data

The data for the analysis is taken from the data sources: Ecowin database, the Federal Reserve Bank of the U.S. and OECD General Statistics. We try to include similar variables for each country to add the comparisons. Depending on data availability, the estimation period differs from country to country. Xt includes all stationary variables and in other case are subject to transformation. All the data is standardized, i-e, every variable has zero mean and unit standard deviation. Further detail on the variables and transformation used is provided in the appendix.

5. Empirical Results

We present our results in Figures 1-6, for U.S., Canada and U.K. for 9 major macroeconomic and financial variables encompassing our broad data-set. We use 3 and 5 factors for each country in order to investigate how the addition of factors impact the reaction of economy and financial markets in the form of impulse responses. FAVAR with 5 factors is considered as our benchmark model.

We use 12 lags as the frequency of data is monthly however using 8 lags provide the same results. In

[1] Please refer Stock and Watson (2005), they define FAVAR by writing DFMs in VAR structure. The insight behind this approach is that by combining the factor methods which have the ability to extract information in large data set with VAR which lays down the theoretical insight one can be better able to analyze the effects of monetary policy.

the figures the dotted lines are the 10th and the 90th percentiles and the posterior median is given by the solid line. Innovations in central banks rates are standardized to 1 standard deviation hence figures are interpreted in terms of standard deviation units.

Increasing the number of factors leads to more logical responses in the form of reduction in industrial production and prices. Principle component analysis employs Gibbs related 16000 iterations from which we reject initial 5000 draws for accuracy of outcomes. In FAVAR frame work we only consider that Y_t contains only central bank rate that means that is the only variable that is considered to have effects on the economy.

Figures 1-6 present the impulse response functions of major economic and financial variables to monetary policy shocks under FAVAR approach. These impulse response functions help in understanding the evolution and size of monetary policy shocks and their transmission to key variables of interest in U.S., Canada and U.K.

The results show that under the 3 factor FAVAR frame work 100 basis points tightening of monetary policy in each country leads to the initial positive response of output in U.S. and U.K. Extending the numbers of factors from 3 to 5 in our analysis show that output declines immediately in US and U.K. which is according to the conventional wisdom, the output effects of a monetary policy shock commence within months of the shock. In UK output declines significantly during first 3 months in response to contractionary monetary policy shock. However the most negative impact on output is noticed during 5th, 7th and 18th month in U.S., Canada and U.K. respectively though only significant for U.S. and Canada. Our this finding is in line with the theoretical constructs and qualitatively supports the findings of Kazi et al. (2013). They find a delayed most negative response of output due to the slow moving nature of the variable. This can be supported by the reason that due to the rise in interest rates aggregate demand falls resulting in decrease in the level of production, employment rate and rising level of unemployment in the U.S., U.K and Canada. This is evident from figures 2, 4 and 6 where additions of factors helps in depicting the true response of these variables.

These results confirm our first and second hypothesis that output falls and employment rate decreases in our benchmark model due to tight monetary policy shock.

In our preferred specification of FAVAR (with 5 factors) following contractionary monetary policy shock stock prices (posterior median) fall immediately by 60, 18 and 10 percent in the United States, Canada and United Kingdom respectively. This is qualitatively in line with the findings of Bjornland and Lateimo (2009) who focus on short-run and long run restrictions but quantitatively much larger than those found in their study.

Figure 1-6 shows that when monetary authority raises policy rate, short-term interest rates tend to rise because money market rates closely follow policy rate. Long term interest rates increase as a result of increase in short term interest rates. Increase in borrowing cost results in decline in demand for housing. Housing construction declines due to fall in demand for housing.

Hence it is confirmed that short term and long term interest rates rise in response to contractionary monetary policy shock.

The contractionary monetary policy in the form of higher interest rates will decline the demand for housing and construction resulting in lower house prices leading to lower residential investment. We find that this decline in housing starts as a response to contractionary monetary policy is more evident for U.S. than Canada and U.K.

One interesting finding also emerges from our study is that the negative response of housing starts is more pronounced than the decline in share prices. As house prices are considered much less volatile than stock prices hence any change in housing wealth might be viewed as much longer lasting than change in stock market wealth, another reason that housing wealth should have a greater effect on consumption than stock market wealth. All these findings confirm the theoretical priors provided by Mishkin (2007).

We also estimate the impulse response function of inflation to contractionary monetary policy shock where it takes 3, 2 and 6 months in U.S., Canada and U.K. respectively to fully pass through to prices.

Many studies found a persistent positive response of inflation to monetary policy shock where it takes several years for permanent aggregate shocks to fully affect prices, Romer and Romer (2004), Primiceri (2005) are a few of the many examples. Our findings present a challenge to existing explanations for business cycles and conform the findings of Mark bill (2009) where they find that over the last two decades US inflation persistence has fallen markedly.

The impulse response functions discussed above provide an overview of the effects of monetary policy shocks on major macroeconomic and financial variables and show the importance of FAVAR methodology in capturing the additional information, it provides comprehensive view of the effects of monetary policy and can be more intuitive for policy makers. Overall the effect of monetary policy tightening is same across the countries and results are quite convincing.

6. Conclusion

There is a large body of literature that examines the transmission of monetary policy to major economic and financial variables. The FAVAR approach can account for important changes in the responses of output, employment, share prices, inflation and interest rates to monetary policy shocks. Our findings suggest that factor models can play an important role in analyzing monetary policy transmission mechanism.

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Appendics

Data Description

The data sources for this article are Ecowin database, the Federal Reserve Bank of the U.S. and OECD General Statistics. Though there are slight variations from country to country, the variables are chosen from following broad categories: output, employment, unemployment, share prices, housing starts, interest rates and inflation. Some of the variables (Industrial Production Index, Consumer Price Index and All Share Price Index) are taken in growth rates which are all found stationary. Following transformations are carried out: 5 (first difference of logarithm), 4 (logarithm), 2 (first difference) and 1 (levels).

We divide the variables into fast moving variables and slow moving (represented by *).

Table 1. Data Description and Transformation

S. No	Description	Data Span			T Code
		U.S.	Canada	U.K.	
1	Industrial Production Index*	1995:1-2015:12	1996:1-2015:12	2003:1-2015:12	1
2	Employment Rtae*	1995:1-2015:12	1996:1-2015:12	2003:1-2015:12	1
3	Unemployment Rate*	1995:1-2015:12	1996:1-2015:12	2003:1-2015:12	1
4	All Share Price Index	1995:1-2015:12	1996:1-2015:12	2003:1-2015:12	1
5	Housing Starts	1995:1-2015:12	1996:1-2015:12	2003:1-2015:12	4
6	Short Term Interest Rate	1995:1-2015:12	1996:1-2015:12	2003:1-2015:12	1
7	Long Term Interest	1995:1-2015:12	1996:1-2015:12	2003:1-2015:12	1
8	Consumer Price Index*	1995:1-2015:12	1996:1-2015:12	2003:1-2015:12	1
9	Central Bank Rates	1995:1-2015:12	1996:1-2015:12	2003:1-2015:12	1

Figures (1-6) Mnemonic: (OUTPT: Industrial production index, EMPRAT, EMP, EMPR: Employment Rate, UEMPRAT, UEMP, UEMPR: Unemployment Rate, SHP: Share Price, HS: Housing Starts, TB3MS: 3 Months Treasury Bill Rate, LTR: Long Term Interest Rate, CPI: Consumer Price Index, FEDFUDRAT: Federal Funds Rate, POLCYRAT: Bank of Canada Policy Rate, EOBR: Bank of England Official Bank Rate).

Figure 1. The U.S. impulse response functions to Federal Funds Rate, (FFR), from FAVAR (Y = FFR, 3 factors), the dashed lines are the 10th and the 90th percentiles and the posterior median is given by the solid line.

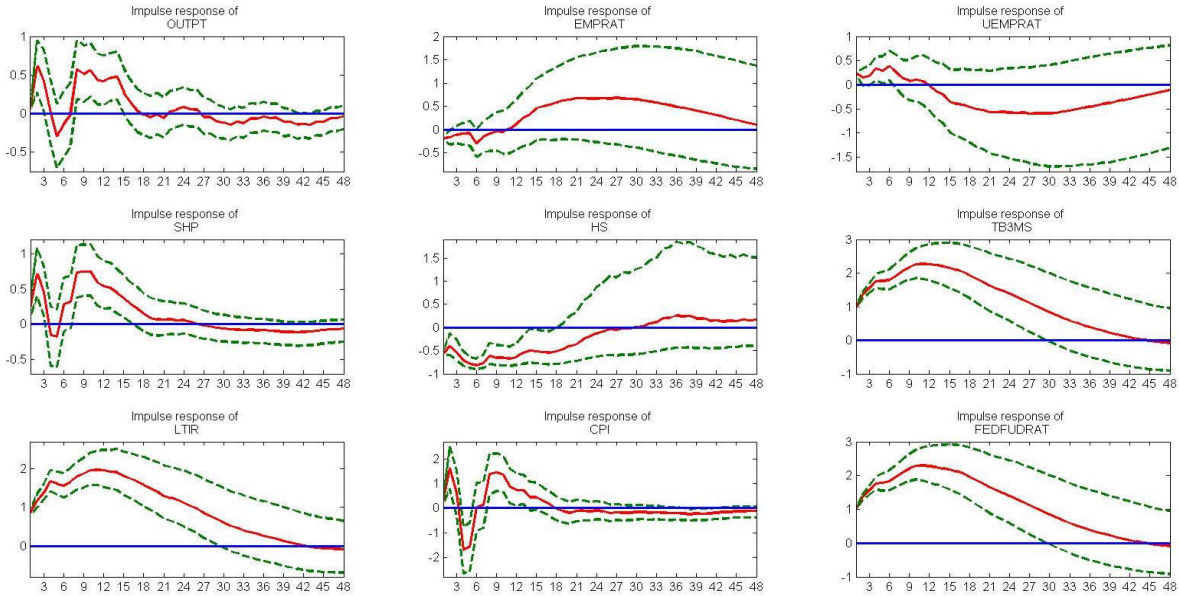

Figure 2. The U.S. impulse response functions to Federal Funds Rate, (FFR), from FAVAR (Y = FFR, 5 factors), the dashed lines are the 10th and the 90th percentiles and the posterior median is given by the solid line.

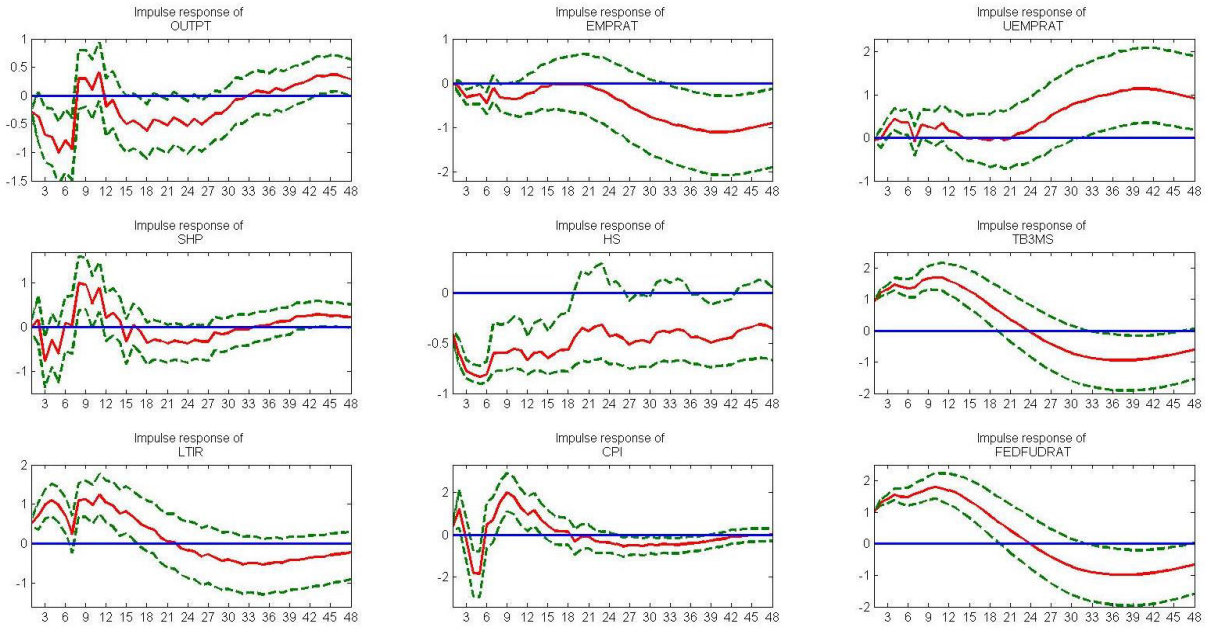

Figure 3. The Canada impulse response functions to Policy Rate, (POLICYRAT), from FAVAR (Y = POLICYRAT, 3 factors), the dashed lines are the 10th and the 90th percentiles and the posterior median is given by the solid line.

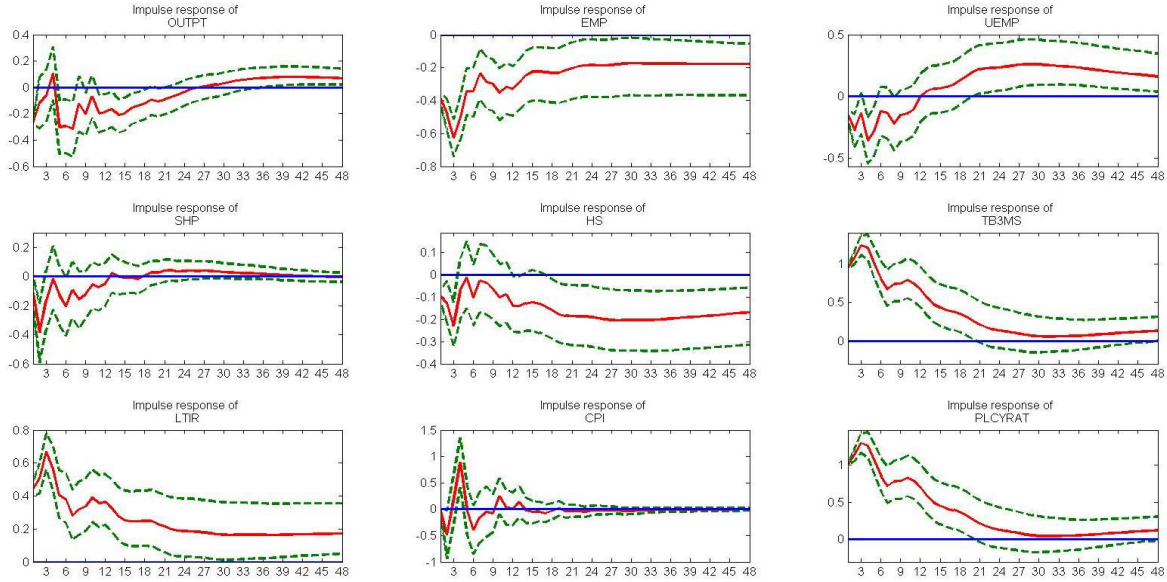

Figure 4. The Canada impulse response functions to Policy Rate, (POLICYRAT), from FAVAR (Y = POLICYRAT, 5 factors), the dashed lines are the 10th and the 90th percentiles and the posterior median is given by the solid line.

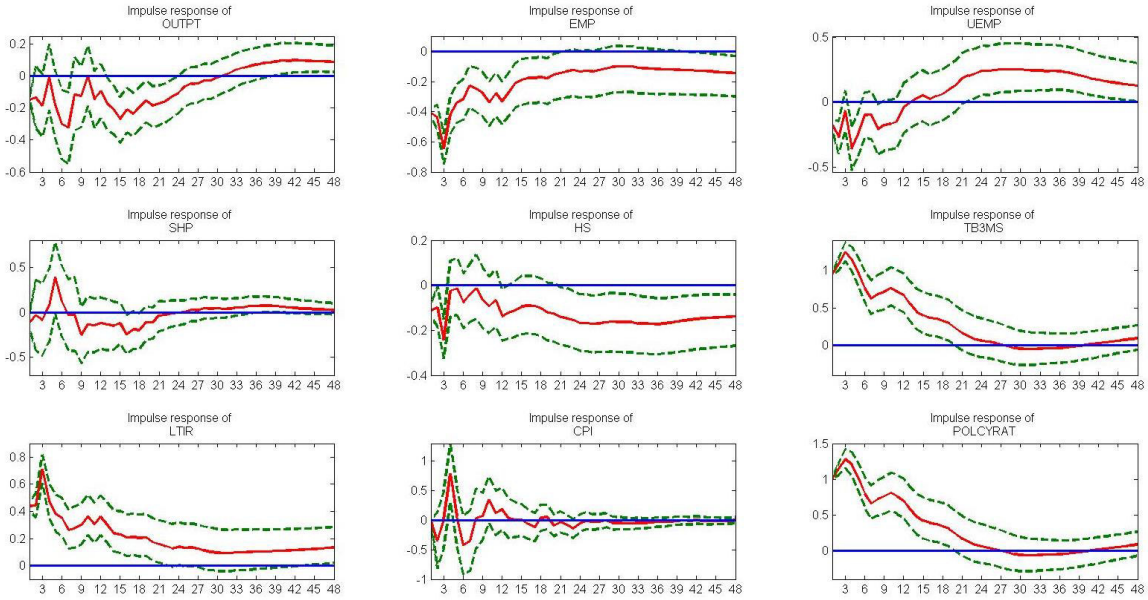

Figure 5. The U.K, impulse response functions to Official Bank Rate, (EOBR), from FAVAR (Y = EOBR, 3 factors), the dashed lines are the 10th and the 90th percentiles and the posterior median is given by the solid line.

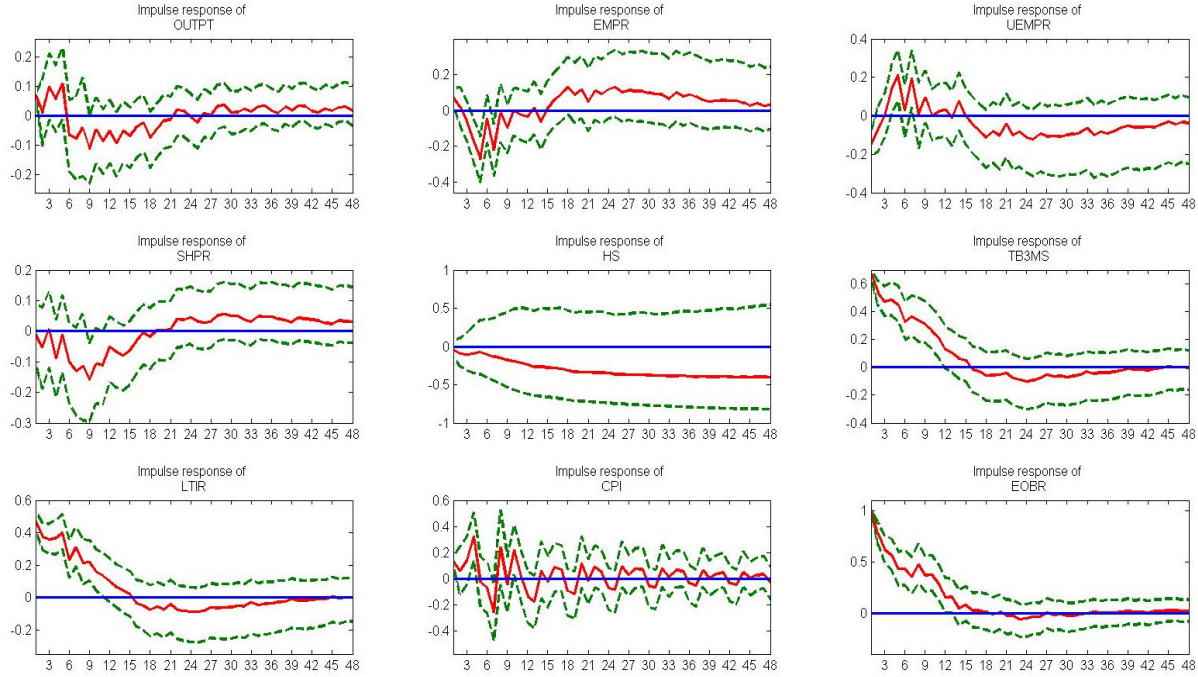

Figure 6. The U.K, impulse response functions to Official Bank Rate, (EOBR), from FAVAR (Y =EOBR, 5 factors), the dashed lines are the 10th and the 90th percentiles and the posterior median is given by the solid line.