THE INTERACTION OF INTEREST RATES, CREDIT, INFLATION AND MONETARY POLICY IN VIETNAM

A Dissertation
Submitted to the National Graduate Institute for Policy Studies (GRIPS)
in Partial Fulfilment of the Requirements for the Degree of

Ph.D. in Public Economics

by

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August 2020

Abstract

This thesis aims to study the interaction of interest rates, banking credit, inflation and monetary policy for the case of Vietnam. Apart from the chapters of introduction, brief description of Vietnam economy relevant to the research, and conclusions, this thesis consists of three main chapters.

Chapter 3, the first of the three main chapters, examines the predictive powers of monetary policy variable and financial variables including banking credit and interest rates for the future inflation and economic growth rates of Vietnam. This chapter applies dynamic model averaging (DMA), which can deal with structural changes in macroeconomic relationships and difficulties arisen from the data of developing countries like Vietnam. The forecasting model includes, among other variables, the growth rate of money supply M2, interest rate and banking credit. DMA found high predictive power of money supply and banking credit, suggesting that monetary policy transmission through credit channel is more effective than through the interest rate channel.

Chapter 4, the second main chapter, tests the Expectation Hypothesis on the term structure of interest rates using Vietnam interbank market data. It is shown that the Expectation Hypothesis is rejected on the very short-term interbank interest rates of Vietnam, which is similar to the results of previous studies on very short-term repo rates of US. This result can be explained by the fact that the testing procedure applied in these studies is very powerful, and this test already rejected Expectation Hypothesis on US repo rates which contain very small differences between term rates, then it is expected to reject Expectation Hypothesis on Vietnam interbank rates which contain much greater differences between term rates.

Chapter 5, the third main chapter, estimates the effectiveness of the credit channel in Vietnam using a novel Bayesian Vector Autoregression Model with stochastic volatility. It is shown that introducing stochastic volatility substantially improves the empirical model, and permits the estimation of time-varying volatilities and impulse responses. It is found that monetary policy transmission

through the credit channel in Vietnam is effective for influencing the inflation rate, but not the economic growth rate.

Acknowledgements

First and foremost, I would like to express my sincere gratitude to Professor Roberto Leon-Gonzalez, my main PhD academic advisor, who have never been hesitate to share his knowledge, experience and practical skills in doing research with his supervisees. I would like to thank him for his academic guidance and kind support throughout my PhD study. I have learnt from him not only important lessons on economics and econometrics but also valuable skills in doing research.

My sincere appreciation also goes to Professor Fujimoto and Professor Porapakkarm, my sub advisors, who have provided insightful and constructive advices and comments for my research. My special gratitude extends to Professor Morohoshi and Professor Kakamu who kindly serve as members of the committee for my dissertation defense at GRIPS and gave me useful comments. All of their constructive advices and comments have not only facilitated me in completing my PhD dissertation but also helped me to gain valuable experience and skills in doing further research in the future.

I am indebted to my organization in Vietnam, Banking Academy of Vietnam, and the Japan - IMF Scholarship Program for Asia (JISPA) for providing me the consent and also financial support so that I can have an opportunity to pursue my study in such a wonderful country like Japan. I also would like to express my deep appreciation to the faculty members at GRIPS who always kindly and supportively share their valuable knowledge and research experiences with students. In addition, I would like to thank all the GRIPS staffs and program co-ordinators for all of the supports and assistances, both directly and indirectly, from them throughout my study and living in Japan.

Lastly and importantly, I am forever grateful to my family and friends who always love and warmly support me without any condition. Along the journey to achieve the PhD degree, I have had chances to meet many friends from all over the world, particularly I am lucky to be in the same batch with my PA classmates. I would like to thank them for all of the experiences and memories we have had together throughout my 3-year PhD study. All of the family and friends' love and encouragement is the strength for me to go toward the end of my PhD journey.

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1 Introduction

In every economy, the financial system plays a central role in the circulation of funds for economic activities. Through the financial system, funds are transferred from those who have excess funds (usually referred as investors or lenders) to those who need additional funds (usually referred to as borrowers). Investors are those who have some amount of money which they are willing to invest for a period of time. On the other hand, borrowers are those who have investment opportunities but do not have sufficient funds to invest and require additional money. When the following conditions are all agreed by both lender and borrower, including the amount of money (i.e. the volume of funds), the period of time during which the funds are lent to the borrower by the lender, and the price (i.e. the interest that the borrower has to pay the investor for the use of the funds in that period of time), the funds will be transferred from investor to borrower; and financial market is the marketplace for this type of transaction. Therefore, the financial market plays an important role in smoothing investment activities in particular and the economic activity of the whole economy in general.

Given the important role that financial market plays in promoting the economic activities, it should be recognized that financial market and macroeconomic conditions have a strong correlation. Indeed, the relationship between financial market and macroeconomic conditions has been an important matter in every economy. Especially since the global financial crisis in 2008, the relationship between financial market and the macro economy has been more acknowledged and has received much attention from both researchers and policy makers. A movement in the financial market can have an influence on the macro economy and vice versa, macroeconomic conditions can also be reflected in the movement of indices in the financial market.

As the movement of financial market can reflect macroeconomic conditions, it should be acknowledged that the financial market reflects changes in public policies which directly or indirectly affect the economy. In other words, the financial market can be impacted by the changes in policies. One of the most influential policies that can have an impact on the movement of the financial market is monetary policy from central bank. The close relationship between monetary policy status and financial market status has been widely recognized in every economy. An announcement from the central bank, for example stating that the discount rate would be cut or that there would be quantitative easing at some point in time in the future, can have significant influence on the financial market at the current time. Therefore, the interaction among monetary policy, financial system and macro economy is undeniable and has become an important matter to policy makers, especially central bankers.

For the case of Vietnam, among components of the financial system, direct financing is still playing a less important role than indirect financing in facilitating investment and stimulating economic growth. In other words, banking credit is relatively more active than the stock market in circulating funds for business and investment activities in Vietnam. Therefore, in order to gain an insight into the relationship among the monetary policy, financial system and macro economy of Vietnam, this dissertation aims to study the interaction of interest rates, banking credit, inflation and monetary policy for the case of Vietnam.

This dissertation consists of studies regarding to the interaction of monetary policy, banking credit, interest rates and macroeconomic condition of Vietnam. The first study aims to assess the predictive power of monetary policy and financial variables for the future macroeconomic movements of Vietnam. The study forecasts inflation and economic growth rates of Vietnam using dynamic model averaging (DMA), which is designed to deal with structural changes in macroeconomic relationship and difficulties arisen from the data of developing countries like Vietnam. The forecasting model includes the growth rate of money supply M2 as monetary policy changes and interest rate and banking credit as two important channels in monetary transmission mechanism. The high predictive power of money supply and banking credit was found by DMA, which suggests that monetary policy transmission through credit channel seems to be effective.

The second study in dissertation takes an investigation into the term structure of interest rates of Vietnam. The Expectation Hypothesis is widely acknowledged as important for explaining the term structure of interest rates. Therefore, this study tests the Expectation Hypothesis on term structure of very short-term interest rates in the Vietnam interbank market. The testing results show that the Expectation Hypothesis is rejected for the Vietnam interbank data. Finally, the third study aims to measure the effectiveness of monetary policy transmission through credit channel in Vietnam, given the finding in the first study that banking credit together with money supply growth rate have high predictive power for the future inflation rate of Vietnam. The result shows that while the transmission through credit channel is effective for influencing inflation rate, it is not for economic growth rate of Vietnam.

Therefore, the structure of this dissertation, aside from the first chapter of introduction, includes other five chapters. Before the presentation of the three empirical studies in this dissertation, chapter 2 will give a brief description of the macroeconomic conditions, interest rates, banking credit, and monetary policy framework of Vietnam. Chapter 3 presents the first study which will forecast Vietnam's inflation and economic growth rates using Dynamic Model Averaging (DMA). The second study is presented in chapter 4 which will test Expectation Hypothesis on term structure of Vietnam interbank interest rates. The third study is described in chapter 5 which will estimate the effectiveness of monetary policy transmission through credit channel in Vietnam. Chapter 6 ends the dissertation with the conclusions and policy implications.

2 Brief Description of Interest Rates, Banking Credit, Inflation and Monetary Policy in Vietnam

Before going into the empirical studies of the thesis, the second chapter of the dissertation is designed to give brief description of interest rates, banking credit, inflation and monetary policy of Vietnam. This chapter, more than showing the status of interest rates, banking credit, inflation and monetary policy, desires to present the relationship among the macroeconomic condition, the indirect financing market and the monetary policy framework of Vietnam. Therefore, the structure of this chapter includes three sections. Section 2.1 will give some insights into the macroeconomic condition of Vietnamese economy. Section 2.2 will show the development of indirect financing market of Vietnam through two key indicators representing the price and quantity of this market, which are the interest rates and banking credit. Finally, section 2.3 will shed some lights on the monetary policy framework conducted by SBV.

2.1 Macroeconomic Condition of Vietnam

The macroeconomic condition of Vietnamese economy will be shown through two key indicators which are inflation rate and economic growth rate.

[Figure 2.1 about here.]

Figure 2.1 shows monthly inflation rate (h = 1), averaged six-months inflation rate (h = 6) and averaged twelve-months inflation rate (h = 12) of Vietnam, which are corresponding to the various forecasting horizons of inflation rate applied for the next chapter. The data was collected and calculated for the period from 1995 January to 2019 June. Some facts are realized through this figure. First of all, all three lines move together, or the moving directions of three inflation rates are consistent with each other, although their volatilities are different. Specifically, the averaged six-month inflation rate is less volatile than the monthly inflation rate. This is reasonable because the average has less variance than any of the components. For the same logic, the monthly averaged 12-month inflation rate is even less volatile than the other two rates.

Secondly, from 1995 January to 2019 June, there are two periods when inflation rate was noticeably higher than the rest of sample, in 2008 and 2011, when the inflation rate were reported to be 19.89% and 18%, respectively. In the basket of goods and services used to calculate the Vietnam consumer price index (CPI), the group of food and restaurant service frequently takes high proportion, and this group was also in charge of high inflation rate in Vietnam in 2008 and 2011. Specifically, the price index of food and restaurant service increased by 31.86% and 24.8% in 2008 and 2011, respectively. However, since 2012, the inflation rate of Vietnam is much lower and less volatile than the previous period, thanks to strongly tightened monetary policy of SBV in 2011. This fact shows the close relationship between the monetary policy and inflation rate movement in Vietnam.

[Figure 2.2 about here.]

Figure 2.2 shows the economic growth rate of Vietnam, which is measured by the growth rate of industrial production index (IPI). Similarly to figure 2.1 about the inflation rate, figure 2.2 presents monthly economic growth rate (h = 1), averaged six-months economic growth rate (h = 6) and averaged twelve-months economic growth rate (h = 12) of Vietnam, which are corresponding to the various forecasting horizons of economic growth rate applied for the next chapter. The data was collected and calculated for the period from 2008 February to 2019 June. Some facts are realized through this figure. First of all, it is easily seen that all three lines move closely together with different volatilities; monthly economic growth rate is the most volatile, followed by averaged six-month economic growth rate and averaged 12-month economic growth rate, respectively.

Secondly, in spite of normally being positive, monthly economic growth rate, in every year, seasonally goes down below zero in February before going up again above zero in

March. The reason is that February is usually the time when Vietnam has the longest holiday of lunar new year, therefore the industrial production value in February is less than in other months. After February, the industrial production value is normally fully recovered in March; therefore, the negative economic growth rate in February and the positive economic growth rate in March are normally have the same absolute value. This is another fact about the seasonality of Vietnam economic growth rate. Thirdly, it should be realized that the movement of economic growth rate in times of contractionary monetary policy from SBV, for example in 2011, is not significantly different from other periods. Therefore, it can be concluded that Vietnam's economic growth rate seems to be less sensitive to the change of monetary policy than the inflation rate.

For the conclusion about the macroeconomic condition of Vietnam, it can be seen that Vietnamese economy has been experiencing stable economic growth rate, around 5% and 6% per year, from 2008 to now. However, before 2012, the macroeconomic environment seemed to be unstable with high and volatile inflation. After 2012, thanks to the efficient monetary policy conduction by SBV, the inflation rate is much lower and less volatile. It also should be recognized that while inflation rate has close relationship with the changes of monetary policy, the economic growth rate seems to be less sensitive to the monetary policy movement. Instead of that, economic growth rate of Vietnam is more affected by seasonality factors.

2.2 Overview of Interest Rates and Banking Credit

In every financial system, there exist two components, direct finance which is operated in financial markets like stock market, and indirect finance which is operated through financial intermediaries, which are mainly commercial banks. For the case of Vietnam, like other developing countries whose stock markets are still underdeveloped, indirect finance has been seen to be more active than direct finance in circulating fund for business and investment activities. Therefore, in order to have an insight into the development of indirect financing component of Vietnam financial system, this section will present two key indicators representing for the price and quantity of indirect financing operation. First of all, the price of the indirect financing operation will be reflected by the deposit and lending interest rates that Vietnam's commercial banks offers to households and corporations in the economy. This data was collected from International Financial Statistics database of International Monetary Fund (IMF). Secondly, the quantity of indirect financing operation will be presented by the volume of banking credit in the economy. This data was collected from the State Bank of Vietnam (SBV).

[Figure 2.3 about here.]

From Figure 2.3, both the deposit and lending interest rates are seen to be noticeably high in 2008 and 2011. Specifically, in 2008, while deposit rate reached a peak of 17.16% per year in 2008 August, the lending rate reached a peak of 20.25% per year in 2008 July. The second period witnessed high interest rates in Vietnam is 2011. During that year, the lending rate reached a peak of 18.09% per year in 2011 July, whereas the deposit rate was found to remain at 14% per year from 2011 February until the end of the year. As seen before, 2008 and 2011 are also two years when Vietnamese economy experienced high inflation rates of 19.89% and 18.13%, respectively. These facts show that there is a correlation between the inflation rate and the banks? interest rates of Vietnam. Indeed, when the economy experiences high inflation rate, the nominal deposit interest rates that commercial banks offer to the depositors should also be high to ensure the positive real interest rate for the depositors. Similarly, the nominal lending interest rates should also be high to ensure the positive real interest rate for the banks and also their profits.

Since 2012, the deposit and lending interest rates have been seen to be gradually decreased and recently stable at approximately 5% per year and 7.7% per year, respectively. This is related to the fact that Vietnam economy has experienced the low and stable inflation rate in the past few years, since 2012. The fact that both the inflation rate and the banking interest rates experience the low levels with small variances in recent years should have some relation with the soundness in monetary policy conduction of SBV, which will be shown in the next section.

[Figure 2.4 about here.]

Figure 2.4 will give an insight into the quantity of indirect financing activity in Vietnam. Specifically, Figure 2.4 presents the quarterly growth rate of banking credit in Vietnam. It can be seen that the growth rate of banking credit is noticeably high in 2007. The high banking credit growth in this period can be explained by the high demand from the borrowers since they were expecting good investing opportunities in the near future. This phenomenon should be related to the fact that in the early of 2007, Vietnam has officially become a member of the World Trade Organization (WTO). This historical milestone undeniably has opened many opportunities for Vietnamese economy to grow, which undoubtedly was recognized by investors and market participants. Therefore, they expected about the economic growth prosperity of Vietnamese economy in the near future and their demand of banking loan was increasing, pushing the credit growth highly increased in this period.

In 2011, because the lending interest rate from the banking system increased highly, as seen before, the demand on lending from commercial banks of households and corporations was relatively decreased compared to previous period. This fact made the growth rate of banking credit decreased sharply in this period, however this growth rate was still reported to be positive. The period from 2012 to the current time has witnessed the credit growth rate fluctuating around 3% and 4% most of the time. Moreover, the banking credit growth have also been seen to hardly come over 6%. This pattern can be explained by the fact that during this time, the lending interest rate has been quite stable and the SBV has tried to stabilize the growth rate of money supply in order to promoting economic growth without generating any inflation pressure.

For the conclusion regarding the status of interest rates and banking credit in Vietnam, it can be seen that there is a correlation between banking credit condition and the macroeconomic movement of Vietnam, especially the inflation rate. In terms of financing activity, which is closely related to the value of money, inflation rate should have a considerable impact on the interest rates of banking system and therefore the volume of banking credit. On the other hand, the movements in the indirect financial market, for example the changes of lending and deposit interest rates, can also affect inflation expectation of publicity, and therefore affect the inflation rate in the economy. Moreover, this section also showed that the status of banking interest rates and credit has some correlation with the monetary policy of SBV.

2.3 Monetary Policy Framework

This section will introduce the monetary policy framework which is implemented by the SBV through presenting the instruments and targets of the monetary policy. The monetary policy instruments which are frequently adjusted by SBV are the pair of discount rate and re-financing rate. Through discounting and re-financing operations which apply discount and re-financing rates respectively, SBV can inject liquidity into the market or withdraw it from the market. By that, SBV can implement expansionary or contractionary monetary policy. Regarding to the targets of SBV monetary policy, the final targets, or sometimes referred as goals of monetary policy, include promoting economic growth and stabilizing the price. However, SBV monetary policy has a priority in stabilizing price. Besides the final targets, SBV also sets an intermediate target of monetary aggregate M2, which supports the monetary policy implementation of SBV to achieve the monetary policy goals.

This pair of discount and re-financing rates are applied when SBV finances fund for commercial banks, most of the time because commercial banks have the liquidity shortage for a short period of time. However, there is a difference in the way that SBV finances fund for commercial banks. Specifically, discount rate is applied when a commercial bank wants its holding financial security to be discounted by SBV. By discounting the financial security, the commercial bank can have an amount of money from SBV. The discounted security has to be in a list of qualified financial securities for discounting operation of SBV that SBV announces to all commercial banks. Because this is discounting operation, and it does not have any default risk, therefore the discount rate is lower than re-financing rate which is applied when commercial bank wants to borrow an amount of money from SBV. When a commercial bank does not hold a qualified security for discounting window of SBV, but demand an amount of liquidity from the central bank, that commercial bank can borrow money through re-financing operation of SBV, which costs higher than discounting operation.

[Figure 2.5 about here.]

As stated before, it is reasonable for re-financing rate to be higher than discount rate, which can also be seen in Figure 2.5, and this pair of policy rates are directly adjusted by SBV. Therefore, an increase in these policy rates can be a signal of contractionary monetary policy from SBV. Whereas, if SBV adjusts this pair of policy rates to be a low level, this can be a signal of expansionary monetary policy. From Figure 2.5, it can be clearly seen that, during two periods of 2008 and 2011, SBV conducted contractionary monetary policy in an attempt to dampen the inflation rate. Comparing between these contraction periods, the monetary contraction during 2011 was stronger than the one during 2008 with higher policy rates and longer duration in which the policy rates were kept at a high level. That makes the Vietnam inflation rate since 2012 to be much lower and more stable than the previous time. Therefore, since 2012, the pair of discount rate and re-financing rates of SBV has also been gradually decreased and recently remained stable at 4% and 6%, respectively.

Regarding to the targets of monetary policy of SBV, as stated before, SBV has not only monetary policy goals, which are promoting economic growth and stabilizing price, but also an intermediate target of money aggregate M2. Specifically, through achieving the target of M2, or the growth rate of M2, this will support SBV in controlling the inflation rate. Figure 2.6 will show a relationship between these two targets, M2 growth rate and inflation rate, of monetary policy of Vietnam.

[Figure 2.6 about here.]

Figure 2.6 shows annual growth rate of money aggregate M2 and inflation rate of Vietnam from 2001 to 2019. It can be seen that from 2003 to 2007, the annual M2 growth rate was kept at a high level, more than 30% per year. The M2 growth rate even reached nearly 50% in 2007. This had caused a considerable pressure on the inflation rate of Vietnam. As a result, during the period 2003-2008, the inflation rate had increased highly, and this rate reached 12.63% and 19.89% in 2007 and 2008, respectively. Because of the tightened monetary policy in 2008, the inflation rate decreased quite sharply to 6.52% in 2009. However, since the M2 growth rate increased back to the level of 30% per year in 2010, the inflation rate of Vietnam once again increased highly in 2011. The inflation rate in this year was reported to be 18.13%. After that, thanks to the strongly tightened monetary policy in 2011 and the soundness in monetary policy conduction of SBV with low money growth rate in the following years, the inflation rate since 2012 has been much lower, at 6.81% in 2012 and even lower in the following years.

From the above analysis, it is recognized that there is a strong relationship between the money supply and inflation of Vietnam, particularly the correlation between the growth rate of M2 and inflation rate. However, it should also be noticed that there is some lag in the impact of changes in M2 growth rate on the inflation rate of Vietnam. This is reasonable because there needs time for the changes in money supply to transmit to the economy. For example, an increase in money aggregate M2 can promote both the consumption and investment, those are two important components in the aggregate demand of the economy. When consumption and investment increase, this will have some impact on the macroeconomic condition of Vietnam, including inflation and economic growth rates. From that perspective, it is expected to have time lag in the impact of M2 growth rate changes on the inflation rate in Vietnam.

From the overviews of macroeconomic condition, banking credit and interest rates, and monetary policy framework of Vietnam, some of the insights into the interaction of interest rates, banking credit, inflation and monetary policy in Vietnam has been revealed. First of all, there is a correlation between the macroeconomic and financial conditions of Vietnam, which suggests the vital role of banking credit in the movement of macroeconomic environment in Vietnam. Moreover, the changes in monetary policy and the movements of banking credit, interest rates express a considerable impact on the Vietnam inflation rate. Those are the important features in the interaction of interest rates, banking credit, inflation and monetary policy in Vietnam. Secondly, this also shows the importance of banking system in transmitting the monetary policy implementation of SBV to the macro economy in order to meet the goals of monetary policy, especially the goal of controlling inflation rate and stabilizing price. More specifically, banking credit can be considered to play an important role in monetary policy transmission in Vietnam.

3 Forecasting Vietnam's Inflation and Economic Growth Rates Using Dynamic Model Averaging

3.1 Introduction

Forecasting macroeconomic variables has always been paid attention by not only policy makers but also market participants. Among of all, inflation is one of the most desirable variables to be predicted, however predicting this variable faces many difficulties. The forecasting methods which have been applied throughout the existing literature are usually found not to be robust across the countries, periods and different measurements of inflation. For example, for US inflation forecasting, Stock and Watson (1999) used the variables included in Phillips curve's equation and other variables which they considered to be good predictors. This model of Stock and Watson (1999) can be considered as a generalized version of Phillips curve. The result was quite positive as the authors concluded that their model outperforms the model based only on the original Phillips curve. However, Atkeson and Ohanian (2001) also generalized Phillips curve and found that this kind of model could not beat naive forecast in which the forecasted value is the same as the last observation's value.

The ambiguous results produced by those papers shows the structural breaks in data of inflation and its explanatory variables. This can be caused due to the change in policy regime, macroeconomic structure, etc. Therefore, as the next stage in forecasting inflation, time-varying parameter (TVP) model has been applied and was generally found to outperform other traditional methods (Cogley, Morozov and Sargent, 2005; Groen, Paap and Ravazzolo, 2013). However, TVP model has also been challenged. People find that allowing for only the parameters to change (which means using only one model with same predictors) is not enough, the selection of predictors also need to change, which is equivalent to changing the forecasting model also. The method allowing forecasting model to change overtime together with changing coefficients can be the most desirable method in forecasting inflation.

Recently, dynamic model averaging, the method which was developed by Raftery et al. (2010) and allows to do forecast with both changing models and changing parameters, has been applied in forecasting inflation (Koop and Korobilis, 2012; Filippo, 2015). The result was very bright as all of the papers have so far confirmed the goodness of DMA in forecasting inflation. In those papers, DMA was also compared with other forecasting methods including autoregression and TVP models and proved to be very competent and prominent in dealing with structure breaks of inflation.

Besides inflation forecast, forecasting economic growth also receives much attention from both academia and practitioners. Forecasting growth means forecasting prospects of the economy as economic growth comes along with investment and employment opportunities. That is why economic growth is also one of the most desirable macroeconomic variables to be predicted. Recently, Nicoletti and Passaro (2012) applied DMA in forecasting Italian GDP growth. The method was proved to be a good tool in identifying good predictors of the Italia's economic growth in different periods.

Unquestionably, dynamic model averaging has some desirable properties in forecasting macroeconomic variables, especially the variables of developing economies. As stated before, one of the main difficulties in forecasting macroeconomic variables is structural break and the variables of developing countries are expected to have more structural breaks than those of developed countries. The reasons include that, compared with developed economies, developing economies are expected to experience more dynamic economic growth path and also more frequent changes in policy and legal framework. Moreover, most of the developing countries including Vietnam are small open economies, which are sensitive to the external shocks from the global economy or influential economies, such as the global financial crisis in 2008, the European sovereign debt crisis in 2010, or the structural changes in China's economy in recent years. With all the shocks which can come from both inside and outside of the economy, the relationship among macro variables of a developing economy is supposed to change overtime and DMA can deal with this situation by allowing both the forecasting model and the parameters to change overtime.

Another visible problem related to the macroeconomic data of developing countries is that those time series data are usually short, which means that less information will be used in forecasting these variables. Moreover, the period for different data to be available is normally not the same. It makes the data utilization even harder. However, by allowing forecasting model to dynamically change overtime, DMA helps to solve that problem. For example, for a variable whose data is only available at some points in time of the whole sample, DMA can consider the models containing other variables than this variable when its data is not available and then dynamically switch to the models containing this variable when its data becomes available. Therefore, all possible predictors can be used, and for each predictor, the longest data which can be collected will be utilized without worrying about the mismatch of the data.

With all the difficulties in forecasting macroeconomic variables in developing countries and the desirable properties that DMA offers to deal with those difficulties, there is a strong motivation to apply DMA in forecasting inflation and economic growth, two important macroeconomic variables, in a typical developing economy like Vietnam. In fact, this study is one of the first works applying DMA in forecasting macroeconomic variables for the case of a developing economy. For the purpose of forecasting inflation and economic growth in Vietnam, this study will apply DMA in two separate exercises of forecasting inflation rate, and economic growth rate. The rest of this chapter is divided into five subsections: 3.2 - Literature Review, 3.3 - Methodology, 3.4 - Data, 3.5 - Forecasting Results and 3.6 - Concluding Remarks. The chapter found that dynamic model averaging (DMA) is a potential tool in forecasting macroeconomic variables of Vietnam which produce accurate forecasts of both inflation and economic growth rates, compared to other forecasting methods.

3.2 Literature Review

The literature regarding forecast inflation and economic growth has continued increasing because of the importance of forecasting these variables to not only policy makers but also market participants. The more recent work is produced, the more advanced econometric technique is applied in the attempt to find the suitable forecasting model. First of all, the literature of forecasting inflation seems to start with the papers which applied Phillips curve's equation. Among all, Stock and Watson (1999) was seen to be a representative paper. Stock and Watson (1999) generalized Phillips curve's equation to forecast US inflation rate at 12-month horizon. Using monthly data from 1959 January to 1997 September, the authors found that their forecasting model with a new activity index composited by 168 economic indicators outperforms the other Phillips curve-based models. However, Atkeson and Ohanian (2001) checked the accuracies of several fashionable Phillips curve-based inflation forecasts at that time, including the one in Stock and Watson (1999), a non-accelerating inflation rate of unemployment (NAIRU) model and the Federal Reserve's model, and found that no one did better than naive forecast for the data from 1984 onward. This empirical result relates to the monetary policy change in the US in the early 1980s which leaded the changing relationship among macroeconomic variables, therefore fixed regression model could not produce accurate forecast anymore. Under the Volcker-Greenspan period, the Federal fund rate was seen to be more sensitive to inflation expectation (Clarida, Gali and Gertler, 2000).

Since the fixed model has no longer been good in forecasting inflation in the context of changing monetary policy or other changes in economic environment, time-varying parameter (TVP) model has been involved in the attempt to build a better forecast model. Among all, Cogley, Morozov and Sargent (2005) was seen to be one of the earliest work applying TVP model in forecasting inflation. This study applied Bayesian vector-autoregression (BVAR) with TVP on UK inflation rate. The model was found to be comparable with the forecasting method being used by Bank of England (BOE). Not only that, Green, Paap and Ravazzolo (2013) applied Bayesian model averaging (BMA) with TVP on US inflation rate from 1960 to 2011. The model was proved to produce accurate forecast, especially after 1984, the time from when previous papers found the change in Federal fund rate reaction rule and that the Phillips curve-based forecast is not better than naive forecast (Clarida, Gali and Gertler, 2000; Atkeson and Ohanian, 2001).

TVP model has so far proved its goodness in forecasting inflation. It is also seen that the applied TVP model in the literature become more and more complicated as the authors want to build a forecast model which is flexible enough to capture changing relationship among inflation and its predictors. Although applying a complicated TVP model can produce a better forecast model, its computational cost also increases. In this context, Koop and Korobilis (2012) applied dynamic model averaging (DMA), the method was first introduced in Raftery, Karny and Ettler (2010). DMA firstly allows for both changing model and changing parameters, which are the desirable properties in designing a forecast model for inflation. Secondly, by using two forgetting factors, DMA does not cost much computational power, and it makes building flexible forecast model for inflation become more feasible. Using quarterly data of US inflation rate from 1960 to 2008, DMA was found to produce accurate forecasts for US inflation rate at one-quarter, one-year and two-year horizons. Later, Filippo (2015) also applied DMA to forecast inflation rates of the US and Euro area. On the sample from 1980 to 2012, DMA was proved to give good forecast of inflation in both economies. These papers also compared DMA with other forecasting methods including autoregression and TVP models and its forecasting performance was usually found to be better than the others.

It can be easily seen that DMA has been proved to be a competent choice in forecasting inflation rate, among other complicated models. More broadly, its properties is not only fit for inflation forecast but also desired in forecasting other macroeconomic variables, including economic growth. Although there are not many applications of DMA in economic growth forecast as in inflation forecast, for the papers which applied DMA, this method was found to produce good forecast of economic growth. Among all, Nicoletti and Passaro (2012) applied DMA in forecasting Italian GDP growth from

1990 to 2009. The method was proved to be a good tool in identifying good predictors of the Italian economic growth in different periods. Specifically, bank credit spread was found to be a good predictor in the recession period, while government bond's yield spread was found to be a good predictor in the period of sound economic condition.

Despite its increasing popularity in forecasting macroeconomic variables of developed countries, the application of DMA for the case of developing countries has not been seen much. Especially for Vietnam, this is the first work applying DMA in forecasting inflation and economic growth. Before, several works have been done using different methods. Among all, Nguyen and Tran (2015) investigated the accuracies in forecasting inflation by ARIMA, Grey model (GM), discrete Grey model (DGM), together with other models. The investigation was on several inflation measurements including consumer price index (CPI), raw materials price and gold price, and using the monthly data from 2005 January to 2013 November, the paper found that while ARIMA produces good forecast for raw materials price and gold price, both GM(1,1) and DGM(1,1) produce good forecast for CPI. Later, Tran (2017) used a series of both univariate and VAR models in forecasting Vietnamese inflation rate and found that while AR(6) is the best model in forecasting quarterly inflation rate, VAR containing inflation rate, interest rate, exchange rate and real retail sales is the best model in forecasting monthly inflation rate. Generally from these papers, univariate models including AR, ARIMA and GM seem to be reliable in forecasting Vietnamese inflation. These empirical results suggests past value of inflation rate as a good predictor of future inflation rate of Vietnam.

Contribution of this study to the literature can be view in several perspectives. Firstly, this study contributes to the literature of DMA application in developing countries. Based on the properties that DMA offers to deal with structural breaks in the relationship among macroeconomic variables, the application of DMA in developing countries is expected to be very promising, yet as mentioned above there have not been many studies applying DMA in developing countries. Secondly, the work is the first work applying DMA in forecasting inflation and economic growth in Vietnam, which makes this study contribute to not only the literature but also the monetary policy conduction of State Bank of Vietnam (SBV) and also other public policies of Vietnamese government.

3.3 Methodology

3.3.1 Dynamic Model Averaging and Dynamic Model Selection

Dynamic model averaging (DMA), as its terminology, considers K models which have different subsets of predictors $z_t^{(k)}$[1], where $z_t^{(k)}$ is a vector of predictors and $\theta_t^{(k)}$ are time-varying coefficients in model k for $k = 1, 2, ..., K$. Therefore, the standard set-up can be, following Raftery et al. (2010):

$$y_t = z_t^{(k)}\theta_t^{(k)} + \epsilon_t^{(k)}. \quad (1)$$

$$\theta_{t+1}^{(k)} = \theta_t^{(k)} + \eta_t^{(k)}.^2 \quad (2)$$

With $\epsilon_t^{(k)} \sim N(0, H_t^{(k)})$ and $\eta_t^{(k)} \sim N(0, Q_t^{(k)})$. Let $L_t \in \{1, 2, ..., K\}$ denote the true model at time t, $\pi_{t|t-1,k} = Pr(L_t = k|Y_{t-1})$ is the probability that model k is true model at time t, given the information up to time $t-1$ ($Y_{t-1} = \{y_1, y_2, ..., y_{t-1}\}$). DMA then do model averaging and specify fitted value of dependent variable as:

$$\hat{y}_t^{DMA} = \sum_{k=1}^{K} \pi_{t|t-1,k} z_t^{(k)} \hat{\theta}_{t-1}^{(k)}. \quad (3)$$

On the other hand, Dynamic Model Selection (DMS) selects the predicting result of the best model k^*, which has the highest $\pi_{t|t-1,k^*}$, for each point in time.

$$\hat{y}_t^{DMS} = z_t^{(k^*)}\hat{\theta}_{t-1}^{(k^*)}. \quad (4)$$

[1] $z_t^{(k)}$ includes predictors available at time t. This means that $z_t^{(k)}$ contains lag of all regressors up to period $t-1$. y_t will be defined as in section 3.4 as either the inflation in period t, or the average inflation between period t and period $t+h$

[2] It should be noted here that theoretically it is possible to not assume a random walk for $\theta_t^{(k)}$, for example it can be a stationary process. However, as the changes in $\theta_t^{(k)}$ reflect structural changes in parameters, these do not need to revert to a historical mean like a stationary process. Therefore, in this literature, it is common to use a random walk transition equation for the parameters. Besides, making $\theta_t^{(k)}$ a stationary process means that we have to estimate one more parameter and it is not clear that the forecast is going to be improved for this reason. Indeed, this method tries to simplify the computation so it is reasonable to use a random walk for $\theta_t^{(k)}$.

It is easily seen that with m predictors, the number of models which are considered at each point in time is $K = 2^m$, as all the possible combinations of m predictors are counted. With a large m, the procedure will cost very much computational power. Therefore, following Raftery et al. (2010), the procedure is simplified by applying two forgeting factors α and λ $(0 < \alpha, \lambda \leq 1)$. First of all, λ plays a role in calculating $\theta_{t-1}^{(k)}$. For a specific model k with time-varying parameters, Kalman filtering can be applied to carry out the recursive forecasting as follows:

$$\theta_{t-1|t-1}^{(k)} \sim N(\hat{\theta}_{t-1}^{(k)}, \textstyle\sum_{t-1|t-1}^{(k)}). \qquad (5)$$

$$\theta_{t|t-1}^{(k)} \sim N(\hat{\theta}_{t-1}^{(k)}, \textstyle\sum_{t|t-1}^{(k)}). \qquad (6)$$

Where

$$\textstyle\sum_{t|t-1}^{(k)} = \textstyle\sum_{t-1|t-1}^{(k)} + Q_t^{(k)}. \qquad (7)$$

However, when λ is applied, the last equation becomes simplified as:

$$\textstyle\sum_{t|t-1}^{(k)} = \frac{1}{\lambda} \textstyle\sum_{t-1|t-1}^{(k)}. \qquad (8)$$

The estimation of model k's parameters is then achieved by the updating equations as follows:

$$\theta_{t|t}^{(k)} \sim N(\hat{\theta}_t^{(k)}, \textstyle\sum_{t|t}^{(k)})$$

$$\hat{\theta}_t^{(k)} = \hat{\theta}_{t-1}^{(k)} + \textstyle\sum_{t|t-1}^{(k)} z_t^{(k)} (H_t^{(k)} + z_t^{(k)} \textstyle\sum_{t|t-1}^{(k)} z_t^{(k)\prime})^{-1} (y_t - z_t^{(k)} \hat{\theta}_{t-1}^{(k)})$$

$$\textstyle\sum_{t|t}^{(k)} = \textstyle\sum_{t|t-1}^{(k)} - \textstyle\sum_{t|t-1}^{(k)} z_t^{(k)} (H_t^{(k)} + z_t^{(k)} \textstyle\sum_{t|t-1}^{(k)} z_t^{(k)\prime})^{-1} z_t^{(k)} \textstyle\sum_{t|t-1}^{(k)}$$

The forgetting factor λ can be interpreted in the way that observations j periods in the past have weight λ^j in calculating the prediction. For example, when $\lambda = 0.99$, monthly data suggests that observations three years ago receive approximately 70% as much weight as last month's observations. While with $\lambda = 0.95$, observations three years ago only receive approximately 16% as much weight as last month's observations. Therefore, lower λ suggests the parameters changing more quickly.

For the case of multiple models, α is applied and simplifies the probability, given the information up to time $t-1$, of model k as:

$$\pi_{t|t-1,k} = \frac{\pi^{\alpha}_{t-1|t-1,k}}{\sum_{l=1}^{K} \pi^{\alpha}_{t-1|t-1,l}}. \qquad (9)$$

The updating equation is:

$$\pi_{t|t,k} = \frac{\pi_{t|t-1,k} P_k(y_t|Y_{t-1})}{\sum_{l=1}^{K} \pi_{t|t-1,l} P_l(y_t|Y_{t-1})}$$

With $P_l(y_t|Y_{t-1})$ is the predictive density (it can be Normal density) for model l evaluated at y_t. The forgetting factor α can be interpreted in the way that if model k forecasted well in the recent past, it will receive more weight in forecasting at the present time. For example with monthly data, $\alpha = 0.99$ suggests that forecast performance three years ago receives 70% as much weight as forecast performance last month. While with $\alpha = 0.95$, forecast performance three years ago only receives 16% as much weight as forecast performance last month. Therefore, lower α suggests the predicting models changing more quickly. It is also worth to note that when setting $\alpha = \lambda = 1$, DMA becomes Bayesian model averaging (BMA) in which both the weight and coefficients of each model do not change overtime.

Regarding error variance $H_t^{(k)}$, Raftery et al. (2010) applied homoskedastic error variance $H_t^{(k)} = H^{(k)}$, while Koop and Korobilis (2012) applied Exponentially Weighted Moving Average (EWMA) estimate of $H_t^{(k)}$:

$$\hat{H}_t^{(k)} = \sqrt{(1-\kappa)\sum_{j=1}^{t} \kappa^{j-1}(y_j - z_j^{(k)}\hat{\theta}_j^{(k)})^2}\ , \text{ with } \kappa \text{ is decay factor}$$

The application of EWMA can be seen more in finance field than in economic field, as researchers in finance field usually deal with long time-series data with more frequent fluctuation than economic data. Moreover, the data used in this study can not be seen as long data with less than 300 observations. Therefore, adding this complication unnecessarily brings a better result than simply applying homoskedastic error variance. In fact, this study run the regression in both cases of applying EWMA and homoskedastic error variance and found no significant difference between these two regressions, at least in root mean square error (RMSE). Therefore, this study will introduce the regression assuming $H_t^{(k)} = H^{(k)}$ as the main result, and the result of regression assuming that $H_t^{(k)}$ follows EWMA is presented in the Appendix A. For the case of EWMA, κ is decay factor and proposed to be 0.97 for monthly data and 0.94 for daily data by Riskmetrics (1996). However, in this study, despite of using monthly data, κ will be set less than 0.97. The reason is that from running DMA with a range of values (0.8, 1) for both λ and α, in order to find the best forecasting model, the values outside (0.95, 0.99), which is the usual range applied in other DMA applications, are usually selected. This suggests a substantial instability in both parameters and forecasting models. Therefore, it is reasonable to expect that error variance $H_t^{(k)}$, if follows EWMA, changes more quickly than usual. However, setting $\kappa \leq 0.94$, the value applied for daily data, also seems to be inappropriate. Therefore in case of applying EWMA, κ is set to be 0.95.

3.3.2 Other forecasting methods

Beside DMA and DMS, other forecasting methods will also be introduced to compare with forecasting performance of DMA and DMS. First of all, naive forecast in which the forecasted value is same as the last observation's value. Naive forecast has usually been introduced in many previous papers to compare with more advanced technical methods. Despite of its simplicity, it was shown to forecast better than several forecasting models (Atkeson and Ohanian, 2001). All in all, comparing with naive forecast can be a basic comparison to prove the predictive power of applied method. The other common comparable forecasting methods include out-of-sample OLS, rolling OLS, AR(1) and AR(2) which are all estimated by least squares method. Besides, more advanced methods are also applied:

- Time-Varying Parameter (TVP) Model

The standard set-up for TVP model can be written as:

$$y_t = z_t\theta_t + \epsilon_t. \quad (10)$$

$$\theta_t = \theta_{t-1} + \eta_t. \quad (11)$$

With $\epsilon_t \sim N(0, H_t)$ and $\eta_t \sim N(0, Q_t)$. This can be considered as a simple version of DMA when only one model, which contains all predictors, will be estimated. Since a range of values for α and λ is used in DMA to find the best forecasting model, it is fair that a same range of values for λ should be used in TVP model to find the best forecasting model. There is a notice that the applied package in this study, fDMA package, only produces in-sample forecast for TVP model. Therefore, differently from other forecast methods which are conducted in out-of-sample manner, the forecast by TVP model is conducted in in-sample manner.

- Bayesian Vector Autoregression

Firstly, the reduced form of VAR process is introduced:

$$\overrightarrow{Y}_t = \delta + \theta_1 \overrightarrow{Y}_{t-1} + ... + \theta_p \overrightarrow{Y}_{t-p} + \overrightarrow{\epsilon}_t, \quad (12)$$
$$\overrightarrow{\epsilon}_t \sim N(0, \textstyle\sum).$$

Bayesian analysis puts a prior on (δ, θ_1,..., θ_p, $\sum$). This study applies non-informative prior on δ (normal distribution, $\delta \sim N(\underline{\delta}, Var(\delta))$), non-informative prior on $\sum$ (inverted Wishart), and informative priors on θ_1,..., θ_p (normal distribution). It is common to set priors as follows:

$$\begin{aligned} E(\theta_1) = I,\ Var(\theta_1) &\propto \pi_1^2 \quad (13) \\ E(\theta_2) = 0,\ Var(\theta_2) &\propto \tfrac{\pi_1^2}{(2^{\pi_3})^2} \\ E(\theta_3) = 0,\ Var(\theta_3) &\propto \tfrac{\pi_1^2}{(3^{\pi_3})^2} \\ &... \\ E(\theta_p) = 0,\ Var(\theta_p) &\propto \tfrac{\pi_1^2}{(p^{\pi_3})^2} \\ E(\delta) = \underline{\delta},\ Var(\delta) &\propto (\pi_1 \pi_4)^2 \end{aligned}$$

Where π_1 is called overall variance, π_3 is lag decay, π_4 is variance of constant and deterministic components, and $\underline{\delta}$ is prior mean of deterministic components, which is usually set to be 0. Therefore, with π_1, π_3 and π_4 decided, Bayesian Vectorautoregression (BVAR) can make forecasts on all variables contained in $\overrightarrow{Y}_t$. For this study, $\pi_1 = 0.1$, $\pi_3 = 0.5$ and $\pi_4 = 1$, the optimal lag will be chosen based on Bayesian information criterion (BIC). This study also runs BVAR in two cases, firstly using all the predictors (Large BVAR) and secondly using some predictors which are chosen from the good predictors of DMA's forecasting (Small BVAR).

3.4 Data

This section describes the data which is employed to produce the forecasts for inflation and economic growth rates of Vietnam for different forecasting horizons. Therefore, inflation rate for different forecasting horizons can be calculated using this formula:

$$\pi_{t,t+h} = \frac{1}{h} log(\frac{CPI_{t+h}}{CPI_t}), \qquad (14)$$

with CPI_t is consumer price index at time t.

And economic growth rate for different forecasting horizons can be calculated using the following formula:

$$g_{t,t+h} = \frac{1}{h} log(\frac{IPI_{t+h}}{IPI_t}), \qquad (15)$$

with IPI_t is industrial production index at time t.

[Table 3.1 about here.]

Table 3.1 show the details on the data. This data was collected from 1995 to 2019 June. Although most of the series are monthly, for some variables in some periods or whole sample, only quarterly data is available. They are FDI in the whole sample, M2 in the year of 2000 and CRE in the period 2004 - 2011. For those variables, the most recent information at the time that the forecast is made will be used. (More detail will be explained later in this section)

Among the variables, apart from two dependent variables, which are INF and GROW, M2 and CRE are variables representing the impact of monetary policy on the forecasted variables, the group of VNI, OVN, SPREAD6 and SPREAD9 variables is included to estimate the impact of financial variables on forecasted variables. And last but not least, as mentioned above about the possible impact of external variables on Vietnamese macroeconomy, FDI, OIL, USIPI and USCPI[3] are also included. The statistical summary, including unit root test's result, of three dependent variables for different forecasting horizons (one-month, six-month and one-year) and predictors are presented in Table 3.2 and Table 3.3, respectively.

[Table 3.2 about here.]

[Table 3.3 about here.]

From tables 3.2 and 3.3 showing the statistical summary and ADF test results of dependent and independent variables employed in the forecasting model. All the time-series for dependent variables an predictor variables are proved to be stationary by ADF test, which means that all of the time-series can enter the model at their level without taking any transformation.

Dealing with missing data and different frequencies

As DMA allows for the forecasting model to change over time, this property helps to deal with missing data. Specifically, I put 0 for missing data, and the methodology will realize that those 0 values are useless for forecasting, therefore the models with missing data will not be used. However, when the data becomes available, the model containing that variable will be used, as DMA dynamically rotates among the models.

For data with different frequencies, I use the information that is available at time t for both quarterly and monthly variables. It would be ideal to have monthly information for all variables, but it is better to use the quarterly data in some way, rather than not to use it at all. Given the main purpose of the analysis is to get a good forecast, so using all the available information could be important, even if the information is at a different frequency. Specifically, for quarterly data, in period t I define value of

[3] For the future work, I will try to use the Chinese macroeconomic data, instead of US data. Because compared to US, China is the bigger trading partner of Vietnam.

predictor z_t as the most recent value of quarterly data that is available at period t. For example, FDI is quarterly, and would enter z_t as follows[4]:

t	z_t
January 1999	FDI in 1998 Q4
February 1999	FDI in 1998 Q4
March 1999	FDI in 1999 Q1
April 1999	FDI in 1999 Q1
May 1999	FDI in 1999 Q1
June 1999	FDI in 1999 Q2
...	...

Given that the main purpose of this chapter is to produce a good forecast and utilize as much available information as possible, the same treatment is also applied to quarterly data of M2 and CRE.

3.5 Forecasting Results

In this section, there are three sub-sections. The first two sub-sections present the forecasting results of inflation rate, and economic growth rate, respectively. The last sub-section compares the forecasting performances of DMA, DMS and other forecasting methods. For each forecasting exercise, averaged number of predictors and posterior inclusion probabilities of good predictors will be introduced. About the computation of these numbers, averaged number of predictors (or averaged size of forecasting model) at each point in time is calculated as:

$$E(Size_t) = \sum_{k=1}^{K} \pi_{t|t-1,k} Size_{k,t}$$

Where $E(Size_t)$ is averaged size of forecasting model (or averaged number of predictors) at time t, $Size_{k,t}$ is the number of predictors in model k at time t and $\pi_{t|t-1,k}$ is the probability that model k is the true model at time t given the information up to time $t-1$ (or the weight of model k at time t). The posterior inclusion probability of predictor is the total weights of models which contain that particular predictor. As the

[4]It should be noted that the variable FDI is the growth rate of disbursed foreign direct investment inflows (please variable description in Table 3.1). With the quarterly growth rate, FDI would enter z_t as quarterly growth rate divided by three, such that to be comparable to other monthly growth rates. The same treatment is applied for other quarterly growth rates of M2 and CRE.

models change overtime, the posterior inclusion probability of a predictor also changes overtime. Here, only the inclusion probabilities of good predictors are introduced; and a good predictor is defined as the one whose inclusion probability is greater than 50% at least one point in time.

3.5.1 Inflation Rate Forecast

[Figure 3.1 about here.]

From Figure 3.1 showing averaged number of predictors for forecasting inflation rate at different horizons, all three lines for one month (h = 1), six months (h = 6) and one year (h = 12) horizons move differently from each other. It shows not only that the forecasting model for each horizon changes overtime, but also that the ways in which the models of different horizons change are different. Specifically, for h = 1, the averaged number of predictors frequently fluctuates from five to seven. For h = 6, the averaged number of predictors fluctuates around seven and eight; this number have been seen to be stable at eight in recent years, from 2014. For h = 12, the averaged number of predictors fluctuates between six and nine before being stable at eight, similarly to the case of h = 6, in the recent years.

[Figure 3.2 about here.]

Figure 3.2 shows the posterior inclusion probabilities of good predictors in forecasting next month's inflation rate (h = 1). The good predictors are divided into three groups. The first group (Figure 3.2's top graph) contains monetary policy transmission related variables, M2 and CRE, and the current inflation rate (INFL1). The second group (Figure 3.2's centered graph) contains financial variables, SPREAD6, OVN and VNI. The third group (Figure 3.2's bottom graph) contains variables measuring the potential impact of external shocks on Vietnam's inflation rate, which are FDI, OIL, USIPI and USCPI. From the top graph, M2 and CRE display high inclusion probabilities of M2 and CRE, showing the predictive power of monetary policy over next month's inflation rate. Specifically, inflation rate, as one of the prioritized goals of the State Bank of Vietnam (SBV) in conducting monetary policy, should be correlated to the changes in monetary policy of SBV, even though it is short horizon, one month. Because the changes of monetary policy may instantly lead to the changes in expectations and behaviors of market participants which may result in the changes in the market. This finding is also consistent with the fact that in recent years, SBV is efficiently controlling the inflation rate in Vietnam (refers to chapter 2, section 2.1 and section 2.3 which show the close relationship between the changes of SBV monetary policy and the movements of inflation rate of Vietnam). The high inclusion probability of CRE in forecasting INF, which is found in this chapter, is consistent with the theory that an increase in banking credit should cause a pressure on inflation rate by increasing the consumption and investment. This finding is also practically consistent with the status of Vietnamese economy where the inflation rate and banking credit frequently move together (refers to chapter 2, section 2.1 and section 2.2).

Moving to the centered graph about the financial variables, the inclusion probabilities of these variables fluctuate substantially. In the recent years when the inflation rate of Vietnam has not been as largely volatile as before, VNI and OVN display higher probabilities than SPREAD6. This empirical result is reasonable, as in forecasting for such a short horizon like next month's inflation rate (h = 1), it is reasonable to expect VNI and OVN to be more useful than SPREAD6 which is expected to be more useful in forecasting for longer horizon like 6-month. The bottom graph shows the high predictive power of external variables, especially the world's oil price (OIL) over Vietnam's inflation rate in next month.

[Figure 3.3 about here.]

Figure 3.3 shows the good predictors in forecasting inflation rate of the next six months (h = 6). Compared with the forecasting exercise of h = 1 (figure 3.2), the variables shown in Figure 3.3 are not much different. The monetary policy transmission related variables, M2 and CRE, still show predictive power over the future inflation rate of the next six months (see Figure 3.3's top graph). From the centered graph, the inclusion probability of SPREAD6 for h = 6 is substantially higher than for h = 1. This result is consistent with the previous analysis that SPREAD6 is expected to have high predictive power for 6-month horizon, rather than for 1-month horizon. From the bottom graph, among external variables, FDI have substantially high predictive power over the future inflation rate in the next 6-month of Vietnam.

[Figure 3.4 about here.]

Figure 3.4 shows good predictors in forecasting inflation rate of the next year (12-month horizon). The identification of good predictors has not changed from 6-month horizon to 12-month horizon, although the inclusion probabilities of these good predictors have changed to some extent. From the top graph, monetary policy-related variables, M2 and CRE, together with current inflation rate still have some predictive power over the next year's inflation rate. From the centered graph, among financial variables, money market variables including SPREAD6 and OVN are having higher predictive power for the future inflation rate of next year than stock market variable which is VNI. From the bottom graph, all external variables have some predictive power for the next year's inflation rate of Vietnam to some extent. Moreover, the inclusion probabilities of these variables tend to increase, showing that the external variables are displaying increasing predictive power for the future inflation rate of Vietnam. In other words, the inflation rate seems to be more sensitive to the external shocks.

[Table 3.4 about here.]

Table 3.4 presents the coefficient means, estimated by DMA, of good predictors for inflation rate forecast. Among all, the coefficient mean of current inflation rate (INFL1) is the greatest in magnitude, throughout different horizons. According to Table 3.4, while the current month's inflation rate has positive impact on the next month's inflation rate, the current six-month inflation rate has negative impact on inflation rate of the next six months. This empirical result can be interpreted in the way that a high inflation rate in the last six months tends to result in a lower inflation rate in the next six months. The same logic could be applied to explain for the negative coefficient mean of INFL1 in h = 12, which means that if the economy has experienced a high inflation rate in the last 12 months, in the next 12 month, the inflation rate is likely to be lower than the previous period.

[Figure 3.5 about here.]

Figure 3.5 shows the predicted values of inflation rate beyond the sample span and their 95% credible intervals. While the top graph of Figure 3.5 predicts monthly inflation rate in 2019 July, the centered graph predicts the averaged six-month inflation rate from 2019 June to 2019 December, and the bottom graph predicts the averaged twelve-month inflation rate from 2019 June to 2020 June. In fact, the monthly inflation rate of 2019 July is 0.18%, which is inside the 95% credible interval; this is an evidence of the suitability of DMA applied to forecast inflation rate of Vietnam.

3.5.2 Economic Growth Rate Forecast

[Figure 3.6 about here.]

Figure 3.6 shows averaged numbers of predictors for economic growth forecasts of different horizons. It can be seen that the averaged numbers of predictors for forecasting the future economic growth rate at different horizons fluctuate through time and the way these numbers fluctuate is also different from each other. Similarly to the exercise of forecasting inflation rate, this evidence suggest that the forecasting model for economic growth rate of Vietnam is also change over time. The averaged numbers of predictors for 1-month and 12-month horizons fluctuate in a large band and recently stable at nearly five, while the averaged number of predictors for 6-month horizon is less fluctuating, only around seven.

[Figure 3.7 about here.]

From Figure 3.7, there are six explanatory variables considered to be good predictors in forecasting next month's economic growth. They are the current month's economic growth (GROWL1), M2, VNI, OIL, FDI and USIPI. It can be seen that for the impact of the monetary policy transmission related variables, only M2 is found to be a good predictor, which suggests that CRE has a weak impact on future economic growth rate of Vietnam. In addition, there are three external variables defined as good predictors in forecasting next month economic growth rate. Among these, the inclusion probabilities OIL is the highest, which suggests high predictive power of OIL for next month economic growth rate of Vietnam.

This empirical evidence shows that the predictive power of monetary policy's variables over future economic growth is declined while the external variables are playing more important roles in predicting Vietnam's future economic growth rate. One of the main causes for the declining predictive power of monetary policy-related variables, M2 and CRE, for the future economic growth rate comes from the fact that banking credit, one of the important channels in monetary policy transmission, has a weak impact on Vietnam?s economic growth. In other words, the poor economic performance of borrowers has made an increase in banking credit not to have significant impact on the growth of the economy. This result is also linked to the empirical evidence on the ineffectiveness of credit channel for influencing economic growth rate of Vietnam, which will be shown in chapter 5.

[Figure 3.8 about here.]

There are more good predictors shown in forecasting economic growth rate at h = 6 (see Figure 3.8). From the top graph, M2 and current economic status including current inflation rate (INFL1) and current economic growth rate (GROWL1) have high predictive power for economic growth rate in the next six months. From the centered graph showing inclusion probabilities of financial variables, money market variables including SPREAD6 and SPREAD9 seems to have greater predictive power over the future economic growth rate for long horizon like 6-month than the growth of stock price index VNI. From the bottom graph, four external variables display some predictive power for the future economic growth rate of Vietnam at 6-month horizon to some extent.

[Figure 3.9 about here.]

Moving to forecasting economic growth at h = 12 (see Figure 3.9), there are less variables considered to be good predictors than in case of h = 6, which is consistent with the previous result of averaged numbers of predictors for different horizons. From the top graph, the current economic status, INFL1 and GROWL1, have some impact on the future economic growth rate, especially GROWL1. This shows that there is strong correlation between economic growth rates of different years in Vietnam, which is consistent with the fact that the Vietnam economic growth rate tends to be stable around 5% to 6% through years. From the centered graph, similarly to 6-month horizon, SPREAD6 and SPREAD9 display higher inclusion probability than VNI, which confirm the predictive power of money market variable for future economic growth rate of Vietnam at long horizon. From the bottom graph, among all external variables, FDI and USCPI show some predictive power for the next year economic growth rate.

[Table 3.5 about here.]

Table 3.5 presents the coefficient means, estimated by DMA, of good predictors for forecasting economic growth at different horizons. First of all, the good predictors for different horizons are different from each other[5]. Differently from the forecasting of inflation rate, for the exercise of forecasting economic growth rate, one independent variable which is identified as a good predictor for this forecasting horizon may not be a good predictor for another forecasting horizon. This shows that compared to inflation rate forecast, in economic growth forecast, the good predictor identification display more changes over the forecasting horizons.

[5] Only coefficient means of good predictors appear in the table, therefore for some horizon, some variable's coefficient mean does not show up

Among all variables, GROWL1 displays the strongest impact on future economic growth rate as its coefficient means are the greatest in absolute value throughout horizons. The negative signs of these coefficient means are consistent with the practical evidence shown before in chapter 2 about the movement of Vietnam economic growth rate. Specifically, economic growth rate which is measured by industrial production index (IPI) growth rate display high variance, especially during a year. That is why for h = 1 and h = 6, the coefficient means of GROWL1 are more negative than for h = 12. Moreover, current inflation rate (INFL1) was found to have positive impact on future economic growth rate at 6-month and 12-month horizons; the increasing price can be considered as a sign of increasing aggregate demand which pushes up the economic growth.

[Figure 3.10 about here.]

Figure 3.10 shows the predicted values of economic growth rate beyond the sample span and their 95% credible intervals. Specifically, the top graph of Figure 3.10 predicts the monthly economic growth rate in 2019 July and the centered graph predicts the averaged six-month economic growth from 2019 June to 2019 December, while the bottom graph predicts the averaged twelve-month economic growth from 2019 June to 2020 June. In fact, the economic growth rate in 2019 July is 0.054 (or 5.4%) and the averaged six-month economic growth rate in 2019 December is 0.016 (or 1.6%), both of them are inside the corresponding credible intervals provided by DMA. These are the evidences showing the suitability of DMA in forecasting future economic growth rate of Vietnam.

3.5.3 Compare DMA with other forecasting methods

In this sub-section, the comparison among DMA, DMS with other forecasting methods will be introduced, based on two criteria including Root Mean Square Error (RMSE) and Mean Absolute Error (MAE).

[Table 3.6 about here.]

[Table 3.7 about here.]

Tables 3.6 and 3.7 compare the forecasting performances of DMA, DMS and other forecasting methods through forecasting exercises of different dependent variables at different horizons. It can be seen that the performances of DMA and DMS in every forecasting exercises are approximate to each other and better than other forecasting methods in most of the exercises. Especially, DMA and DMS were found to perform better than time-varying parameter (TVP) model, as the RMSEs of DMA and DMS are smaller than TVP's RMSE, eventhough it is in-sample RMSE, as noted before in Methodology.

Since DMA was proved to be the best method in forecasting Vietnam's inflation and economic growth, next we should look at how DMA perform in forecasting different macroeconomic variables. Between inflation rate forecast and economic growth forecast, the RMSE of economic growth forecast is significantly bigger, showing that forecasting economic growth rate in Vietnam is more difficult than forecasting inflation rate.

3.5.4 Robustness Check for Data Seasonality

It can be seen that the time-series data of inflation rate and economic growth rate of Vietnam display the seasonality. Therefore, there is a motivation to run the regression on the data file which includes the lagged values of inflation rate and economic growth rate of the same month in the previous year to take into account the data seasonality. Table 3.8 shows the forecasting performances of DMA estimation with the lagged values of same month included and the DMA estimation without these values.

[Table 3.8 about here.]

From table 3.8, it can be seen that for all the forecasting exercises, the RMSEs and MAEs of the two estimations with and without lagged values are not very different from each other. In fact, these numbers are approximate to each other in most of the exercises. It can also be seen that for most of the inflation rate forecasting exercises, including lagged value slightly improve the forecasting performance of the model. However, for economic growth forecasting exercises, including lagged value of the same month can improve the forecast but the improvement is not consistent through different forecasting horizon. For instance, in the exercise of forecasting economic growth rate, including lagged value of same month improve the forecast for one-month horizon, however for six-month horizon, the RMSE of the regression with lagged value included (0.0198) is actually greater than the RMSE of the regression not including lagged value (0.0186). This is the same for the other forecasting performance criteria which is MAE.

3.6 Concluding Remarks

It is unquestionably that the macroeconomic variables of developing countries, compared with those of advanced countries, experience more structural breaks. Therefore, one of the desirable method in forecasting macroeconomic variable of developing countries is dynamic model averaging (DMA). This study applied DMA in forecasting inflation and economic growth of Vietnam and provides some conclusions:

Regarding the goodness of DMA in forecasting macroeconomic variables of Vietnam and developing countries in general, some evidences of the DMA's suitability are found in the study. Firstly, from the DMA estimations, both averaged number of predictors and the identification of good predictors change overtime. It shows that the method allowing for model changing, like DMA, should be applied. Secondly, in comparison with other forecasting methods, DMA was also proved to be the best model which produces the smallest RMSE among all. Finally, the forecasted values beyond the sample span of DMA were proven to be not far from the real values (for 2019 July and December). All in all, DMA is expected to produce accurate forecast for macroeconomic variables of developing countries.

Regarding the forecast of inflation and economic growth of Vietnam, some good predictors are noticed, depending on forecasted variable and horizon, including monetary policy transmission related variables (M2 and CRE), financial variables (SPREAD6 and OVN) and external variables like OIL. Besides, other conclusions are also made. Among all, the SBV's monetary policy was shown to have more predictive power over inflation than economic growth, it somehow showed the effectiveness of monetary policy in controlling inflation in Vietnam. Moreover, the predictive power of external variables including OIL and FDI are increasing. This brings both benefit and challenge for policy implementation. The benefit is that there are information to be refer in forecasting future inflation and economic growth rates. However, the bigger predictive power also means the bigger impact of those external variables on domestic variables, which makes Vietnam's economy is more sensitive to external shocks.

For the future work, among the predictors which have been employed in this study, it would be more appreciated if, instead of using US data, Chinese macroeconomic variables including inflation and economic growth rates are included. There are some important reasons for this replacement. First of all, China is the bigger trading partner of Vietnam than the US. Secondly, the study already found the rising predictive power of external variables over the domestic macroeconomic condition. Therefore, the careful selection of external variables in the forecasting model may provide important results for researchers and policy makers.

4 Testing Expectation Hypothesis on Term Structure of Vietnam Interbank Interest Rates

4.1 Introduction

Since expectation hypothesis was first introduced in Fisher (1896), the hypothesis has received much attention as this is an intuitive way to describe the term structure of interest rate. In other words, the expectation hypothesis provides the link between long- and short-term interest rates which have the same level of riskiness. In the context that an investor has an amount of money which he can invest in a period of time (called n). The investor has two choices, either investing in a n-term loan or rolling over the investment in a shorter-term loan (called m-term loan, with $m = n/k$ and k is an integer). The market equilibrium will make the profits from these two investing strategies equal to each other. If there is any factor making these not equal to each other, it can steam from the preference of liquidity from the investor (shorter-term loan is more liquid than longer-term loan). Therefore long-term interest rate may contain a so-called term premium. All in all, expectation hypothesis can be expressed by this equation:

$$i_t^{(n)} = \frac{1}{k} \sum_{i=0}^{k-1} E_t[i_{t+mi}^{(m)}] + c^{(n,m)}. \qquad (16)$$

Where $i_t^{(n)}$ is a long-term interest rate and $i_t^{(m)}$ is a short-term interest rate with $m = n/k$ and k is an integer. $E_t[i_{t+mi}^{(m)}]$ is conditional expectation of future short-term rate $i_{t+mi}^{(m)}$ based on the information available at time t, $c^{(n,m)}$ is a term premium between long- and short-term interest rates and $c^{(n,m)}$ is constant over time.

However, expectation hypothesis (EH) is mostly rejected in empirical works (Fama, 1984; Froot, 1989; Bekaert and Hodrick, 2001; Dittmar and Thornton, 2004; Sarno et al., 2007). These studies test EH using T-bill rates which range from 1-month to 30-years. An exception in the literature which can not reject EH is Longstaff (2000). This study, instead of using T-bill rates like many previous studies, tests EH using US repo rates ranging from overnight to 3-months. As seen before, EH shows the relationship between long- and short-term interest rates which have the same level of riskiness.

Therefore, most of the studies in the literature used T-bill rates, as T-bill rates are widely accepted as risk-free rates. Longstaff (2000) is the first study testing EH on repo rates. The argument for the validity of repo rates as risk-free rates is that first of all, repo rate reflects pure cost of a default-free loan because of the nature of a repurchase contract (or repo contract). Besides, T-bill rate may be affected by other factors; some investors hold T-bill for other purpose than looking for a default-free investment, like paying tax or meeting the requirement from central bank for commercial banks. These regulatory and liquidity characteristics of T-bill could make its rate lower than riskless rate. Therefore, according to the study, repo rate could even be a better proxy of risk-free rate than T-bill rate.

Moreover, the other motivation to test EH on very short-term interest rates is that if EH can not even explain the term structure of very short-term interest rates, it seems to be no use for the interest rates whose longer maturities. Therefore, later studies in the literature have shown more interest in testing EH using very short-term rates, for example Della Corte et al. (2008). For Vietnam's financial market, knowing the term structure of interest rates is very important as it may give information on the future economic conditions. Therefore, based on available data from Vietnam's interbank market, it gives a strong motivation to test EH on very short-term interest rates, like interbank rates of Vietnam.

The chapter will provide a test on the validity of expectation hypothesis for the data of Vietnam interbank market. After the literature review, the test framework will be explained on subsection 4.3 - Methodology, the data investigation will be presented in 4.4 - Data, followed by 4.5 - Empirical Results and 4.6 - Concluding Remarks. The chapter applied VAR test (Della Corte et al. (2008)) to the data of Vietnam interbank interest rate and concluded that expectation hypothesis is rejected for this data.

4.2 Literature Review

The earliest studies testing EH on US T-bill rates are Fama (1984) and Froot (1989). Froot (1989) test EH on term structure of short- and long-term interest rates and also whether the long-term interest rate over-react or under-react to the changes of short-term interest rate. Due to the limitation of data in those days, the author collected the interest rates of various kinds of financial instruments, including Treasury bill, Eurodollar deposit, mortgage loan. All of these financial instruments were considered to be riskless instruments, so that they can be used to test EH. The maturities are also limited as 3-months, 12-months, 10-years, 20-years, and 30-years. For the term structure of short-term rates, whose maturities are shorter or equal to 1-year, EH was rejected, as the term premium was found to be varied over time. However, for the term structure of long-term intest rates, whose maturities are longer than 1-year, EH was not rejected. Although longer-term rate was found to under-react to the changes of shorter-term rate, these rates move in one-to-one relation, which implies that term premium is constant over time and EH holds. Similarly to Froot (1989), Fama (1984) also tested EH by detecting whether the term premium is constant or varied over time. To ensure the tested interest rates to have same level of riskiness, Fama (1984) only collected T-bill rates. However, due to data limitation, the collected T-bill rates only range from 1-month to 6-month, for the period 1959-1982. Similarly to Froot (1989), Fama (1984) also detected the variation in term premium for Treasury bill rates, which implies that EH does not holds for this data.

Bekaert and Hodrick (2001) tested EH on term structure of interest rates for different currencies, including US dollar (USD), Deutsche mark (DEM), Great Britain pound (GBP). Unlike previous studies testing whether the term premium is constant or varied over time to draw the conclusion on whether EH holds or not, respectively, Bekaert and Hodrick (2001) directly tested the validity of EH for the employed data by generating VAR process for a pair of long- and short-term interest rates and treating EH as restriction. Whether the EH restrictions affect VAR estimation or not is equivalent to the invalidity and validity of EH for this data, respectively. By that, this testing framework, or called VAR test, is considered to be more accurate than previously applied testing strategies. The VAR test was applied to testing EH on pairs of 1-month and 12-months T-bill rates of three currencies USD, DEM, and GBP for the period 1975 January-1997 July with the total of 270 monthly observations. The result shows that EH is rejected for USD and DEM, but not for GBP.

After Bekaert and Hodrick (2001), many studies applied the VAR test to testing EH on term structure of interest rates with various maturities. For example, Dittmar and Thornton (2004) used monthly data from 1952 January to 1991 February of T-bill rates whose maturities ranging 1-month to 10-years. EH was found to be rejected for all pairs of interest rates whose maturities are less than 4-years. Sarno et al. (2007) revised VAR process of Bekaert and Hodrick (2001) by adding macroeconomic variables like unemployment and inflation rates. For the monthly data from 1952 to 2003 of T-bill rates whose maturities ranging from 1-month to 10-years, the rejection of EH is mixed. Specifically, for the pairs where long-term rate is 10-years, EH is not rejected. However, for the pairs of shorter-term rates, EH is rejected at most of the pairs.

Most of the studies in the literature tested EH using T-bill rates; and those studies frequently reject EH. Longstaff (2000) is an exception when this study found that EH can not be rejected for the term structure of very short-term interest rates. Instead of using T-bill rates whose maturities ranging from 1-month to several years, Longstaff (2000) employed US repo rates whose maturities ranging from overnight to 3-months. This study argued that repo rate reflects the pure cost of a default-free loan because of the nature of a repo contract (or repurchase contract), while T-bill rate may be affected by other factors like liquidity preference or regulation. Some investors hold T-bill for other purpose than looking for a default-free investment, like paying tax or meeting the requirement from central bank for commercial banks. Therefore, T-bill rate may be even lower than riskless rate. The study tested EH equation at both unconditional and conditional levels and concluded that EH can not be rejected at both levels.

The study of Longstaff (2000) have opened a new dimension in the literature of testing EH. Not only that the testing result for very short-term interest rates from overnight to several months is strikingly different from the testing results for T-bill rates, which is already widely accepted as a conventional way to test EH in the literature; but also there is another reason for the importance of testing EH on very short-term interest rate. If EH can not even explain the term structure of very short-term interest rates, it should not be used to explain the term structure of longer-term interest rates. Therefore, later studies in the literature have shown more interest in testing EH on very short-term rates. Della Corte et al. (2008) revisited the test of EH on very short-term interest rate using the VAR test framework from Bekaert and Hodrick (2001), which was expected to provide more accurate statistical testing on EH. Differently from Longstaff (2000), the VAR test in Della Corte et al. (2008) rejected EH for all pairs of long- and short-term repo rates ranging from overnight to 3-months.

For Vietnam's financial market, having an insight into the term structure of interest rate is very important, as it may give information on the future economic conditions. Therefore, testing EH on Vietnam's interest rates is important to not only market participants but also policy makers. Particularly for the case of Vietnam, while the market for government bond in Vietnam is still underdeveloped, the very short-term interbank interest rates are already available. All of these reasons show strong motivation to test EH on the interbank rates of Vietnam.

4.3 Methodology

As stated before, most of the studies in the literature tested EH based on a single equation, which is normally an implication of EH, and therefore only prodived indirect test on EH. However, the VAR test, which was used in Bekaert and Hodrick (2001) and Della Corte et al. (2008), is seen to be a more appropriate tool as it builds a VAR process for the relationship between long-term and short-term rates and treats EH as a non-linear restriction. Therefore, EH can be directly tested by testing this restriction. One important assumption in our analysis is that the term premium is constant over time. All the empirical literature that tests the rational expectation hypothesis makes this assumption. Although in theory the rational expectation hypothesis can be formulated with a time-varying term premium, empirically this substantially complicates the analysis. This is because it would be difficult to separate changes in the term premium from departures from the expectation hypothesis using empirical data (using for example a time-varying intercept). Moreover, in the empirical analysis of this chapter, the interest rates are of a high frequency, and so the term premium is less likely to change over a short period of time, especially given the fact that the Vietnam inter-bank market is highly liquid.

For VAR test framework, first of all, the belowed VAR process expresses relationship between a pair of long-term interest rate i_t^n and short-term interest rate i_t^m, where $n = km$ and k is an integer:

$$i_t^m = a_1 i_{t-1}^m + b_1 i_{t-1}^n + a_2 i_{t-2}^m + b_2 i_{t-2}^n + \cdots + a_p i_{t-p}^m + b_p i_{t-p}^n + u_{1,t}. \quad (17)$$
$$i_t^n = c_1 i_{t-1}^m + d_1 i_{t-1}^n + c_2 i_{t-2}^m + d_2 i_{t-2}^n + \cdots + c_p i_{t-p}^m + d_p i_{t-p}^n + u_{2,t}.$$

p here is the lag of VAR process and is set to be equal to five, taking into account the fact that there are five working days in a week. The data used for i_t^m and i_t^n is demeaned data. This will allow us to ignore the term premium $c^{n,m}$. In the above VAR process, both the long-term and short-term rates are explained by their past values, which is consistent with the rationality of market participants implying that the participants should make decision based on the available information at that time.

To facilitate the generating of EH restriction, the VAR process is transformed into:

$$Y_t = \mathit{\Gamma} Y_{t-1} + V_t. \quad (18)$$

Where $\underset{(2p\times 1)}{Y_t} = \begin{pmatrix} i_t^m & i_t^n & i_{t-1}^m & i_{t-1}^n & \ldots & i_{t-p+1}^m & i_{t-p+1}^n \end{pmatrix}'$,

then $\underset{(2p\times 1)}{Y_{t-1}} = \begin{pmatrix} i_{t-1}^m & i_{t-1}^n & i_{t-2}^m & i_{t-2}^n & \ldots & i_{t-p}^m & i_{t-p}^n \end{pmatrix}'$.

And $\underset{(2p\times 2p)}{\Gamma} = \begin{bmatrix} a_1 & b_1 & a_2 & b_2 & \dots & a_{p-1} & b_{p-1} & a_p & b_p \\ c_1 & d_1 & c_2 & d_2 & \dots & c_{p-1} & d_{p-1} & c_p & d_p \\ 1 & 0 & 0 & 0 & \dots & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & \dots & 0 & 0 & 0 & 0 \\ \vdots & & & & & & & & \\ 0 & 0 & 0 & 0 & \dots & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \dots & 0 & 1 & 0 & 0 \end{bmatrix}$, $\underset{(2p\times 1)}{V_t} = \begin{bmatrix} u_{1,t} \\ u_{2,t} \\ 0 \\ \vdots \\ 0 \end{bmatrix}$

The next step is generating EH restriction. Let $\underset{(2p\times 1)}{e_1} = \begin{pmatrix} 1 & 0 & 0 & \dots & 0 \end{pmatrix}'$ and $\underset{(2p\times 1)}{e_2} = \begin{pmatrix} 0 & 1 & 0 & \dots & 0 \end{pmatrix}'$. Then, $i_t^n = e_2' Y_t$ and $E_t(i_{t+i}^m) = e_1' \Gamma^i Y_t$. Therefore, the EH equation[6]:

$$i_t^{(n)} = \tfrac{1}{k} \textstyle\sum_{i=0}^{k-1} E_t[i_{t+mi}^{(m)}].$$

Equivalent to:

$$e_2' Y_t = k^{-1} \textstyle\sum_{i=0}^{k-1} e_1' \Gamma^{mi} Y_t. \qquad (19)$$

Some transformations are involved to make EH restriction equivalent to:

$$e_2' = e_1' k^{-1} (I - \Gamma^m)^{-1} (I - \Gamma^n). \qquad (20)$$

Let $a(\theta) = e_2' - e_1' k^{-1} (I - \Gamma^m)^{-1} (I - \Gamma^n)$, where $a(\cdot)$ is a known non-linear function and θ includes all the parameters. Then testing EH is equivalent to testing the null hypothesis $H_0 : a(\theta) = 0$.

The above VAR process can be estimated by GMM, using the orthogonality condition of error terms $u_t \equiv [u_{1,t}, u_{2,t}]$. Since the current disturbance has no relevance with the lagged values of either dependent or independent variables, let $y_t \equiv [i_t^m, i_t^n]$ and we have instrument x_{t-1}, which contains lagged values of y_t and a constant term possibly. Define $g(z_t, \theta) \equiv u_t \otimes x_{t-1}$, where $z_t \equiv (y_t', x_{t-1}')'$ and θ is a vector of parameters. Then the orthogonality condition is $E[g(z_t, \theta)] \equiv 0$. GMM will estimate θ through minimizing the moment:

[6] Since this study uses demeaned data, therefore it allows us to ignore the constant term premium $c^{(n,m)}$. Here, in the EH equation $c^{(n,m)} = 0$

$$Q_T(\theta) \equiv g_T(\theta)' \Omega_T^{-1} g_T(\theta).$$

Where $g_T(\theta) \equiv \frac{1}{T}\sum_{t=1}^{T} g(z_t, \theta)$, and Ω_T^{-1} is a positive semidefinite matrix. So that is the estimating procedure of so-called unconstrained VAR. Next, we move to estimating procedure of constrained VAR in which the EH restriction ($a(\theta) = 0$) is imposed. Similarly to solving an optimization problem with restrictions, Lagrangian is applied:

$$\mathcal{L} = -\tfrac{1}{2} g_T(\theta)' \Omega_T^{-1} g_T(\theta) - a_T(\theta)'\gamma. \qquad (21)$$

Where γ is a vector of Lagrangian multipliers and $a_T(\theta)$ is the sample counterpart of $a(\theta)$ for a sample of size T. Then, testing the EH restrictions is equivalent to testing whether Lagrange multipliers are jointly equal to zero. Specifically, when EH restrictions are not binding, which implies that EH restrictions are valid for the data, Lagrange multipliers will be jointly equal to zero. In other case, if the Lagrange multipliers are not jointly equal to zero, which means that at least one of the EH restrictions is binding, this will imply that EH restrictions have some impact on the estimation of the VAR process of the data, therefore EH is not valid for this data. This testing strategy, diffrent from other applied tests in the literature, will allow us to directly test the validity of EH for the data. The null hypothesis that EH holds ($H_0 : a(\theta) = 0$) is equivalent to the null hypothesis that Lagrange multipliers are jointly equal to zero ($H_0 : \gamma = 0$), which can be tested using either Lagrange multiplier (LM) or distance metric (DM) statistics:

$$LM = T\bar{\gamma}(A_T B_T^{-1} A_T')\bar{\gamma} \rightarrow \chi^2_{(2p)}. \qquad (22)$$
$$DM = T g_T(\bar{\theta})' \Omega_T^{-1} g_T(\bar{\theta}) \rightarrow \chi^2_{(2p)}. \qquad (23)$$

Where $\bar{\gamma}$ and $\bar{\theta}$ are constrained VAR estimates, $A_T \equiv \nabla_\theta a_T(\theta)$ (first derivative of $a_T(\theta)$ with respect to θ), $G_T \equiv \nabla_\theta g_T(\theta)$ (first derivative of $g_T(\theta)$ with respect to θ), and $B_T \equiv G_T' \Omega_T^{-1} G_T$ (details will be explained in the Appendix B).

4.4 Data

This chapter tests EH on very short-term interest rates of Vietnam. In the previous studies in the literature (Longstaff, 2000; Della Corte et al., 2008), the repo rates are employed. However, as a matter of fact that Vietnam's financial market is far behind the financial markets of developed countries in terms of development, the financial instruments in Vietnam's financial market are not as various as those in the advanced economies' financial markets. The general collateral repurchase contract is not available to be transacted in the financial market of Vietnam. Therefore, testing EH using repo rates becomes infeasible. An alternative measurement of riskless interest rates is needed; and it seems that there is no better choice than the interbank interest rates.

Vietnam's interbank market is where all insured commercial banks in Vietnam, including both domestic and foreign ones, borrow and lend short-term loans with each other. The State Bank of Vietnam (SBV) also participates in this market but only with the role of supervisor. As under the supervision of the SBV and the reputations of participating commercial banks, the interbank market is considered to be the most liquid market in financial system in Vietnam, and interbank rates are virtually riskless rates. Thus, interbank rate is the most appropriate choice for testing EH on very short-term interest rates of Vietnam. The data of Vietnam interbank rates from overnight to 6-months were collected for the period from January 2, 2007 to April 17, 2020 with the total of 3285 daily observations.

[Table 4.1 about here.]

Table 4.1 presents some basic descriptive statistics of Vietnam interbank rates. The means and standard deviations are calculated for the whole sample and for different weekdays, which will present some day-of-the-week regularities of Vietnam interbank rates. First of all, comparing means of interest rates of different maturities, from overnight to 6-months, a longer-term rate is always higher than a shorter-term rate. Specifically, the mean increases from 5.3740 for overnight rate to 7.7696 for 6-months rate. The term premiums here are significant. For example, the average term premium between overnight and 6-months rates is nearly 2.4 percentage points. Whereas, the average term premium calculated for the pair of overnight and 3-month rates is a bit lower, nearly 2 percentage points, however this number is extremely higher than the average term premium between overnight and 3-months of U.S repo rates reported in Longstaff (2000) and Della Corte et al. (2008), which is only around 0.04 or 0.03 percentage points, respectively. This difference presents a high preference on shorter-term lending and borrowing in the interbank market of Vietnam.

From the means for different weekdays reported in Table 4.1, it can be seen that the calendar regularities of interest rates of different maturities are different from each other. Specifically, for the interest rates whose maturities are less or equal to 1-month, the rates tend to slightly decrease from Monday to Tuesday, but increase back on Wednesday, and then decrease for the rest of the week. During a week, the Wednesday rate is the highest, and the Monday rate is higher than the Friday rate. For the interest rates whose maturities are more than 1-month, the weekly movement of the rate is less fluctuating than the shorter-term interest rates. For example, the mean of 3-months and 6-months rate increase from Monday to Wednesday and Tuesday, respectively, then decrease for the rest of the week. For all maturities, the Monday mean is frequently reported to be higher than the Friday mean. For example, for the overnight rate, the Monday mean is 0.08 percentage points higher than the Friday mean. For other maturities within 1-month, the differences are around 0.1 percentage points, which is as twice as the difference reported in Della Corte et al. (2008) for the US repo rates. This suggests that the weekly movement of very short-term rates in Vietnam is more fluctuating than that in US.

The standard deviations of interbank interest rates of Vietnam are very high. For interest rates whose maturities within 1-month, all the standard deviations are reported higher than 4 percentage points. The standard deviations of 3-months and 6-months interest rates are slightly lower, 3.63 and 3.44 percentage points, respectively. These standard deviations are extremely higher than those reported in Della Corte et al. (2008) for US repo rates, which are only around 1.6 and 1.7 percentage points. This difference may suggest that the interest rates in developing economies experience much higher fluctuation then those in advanced economies, even if they are very short-term rates. For Vietnam's case, one of the undeniable reasons is that Vietnamese economy has experienced a higher and more fluctuating inflation than the U.S. economy, which has driven the fluctuation of Vietnam's interbank rates. Especially, in 2008, Vietnam experienced very high inflation of more than 20%, which caused a high interbank overnight rate of 21.48% in 2008 February and the other interbank rates were also at high levels of approximately 20%.

Table 4.1 also presents serial correlation coefficients of Vietnam interbank rates of different maturities. Those calculated coefficients show high persistence of the interbank rates. For all the rates, the first order serial correlation coefficient (ρ_1) is the highest, around 0.98 and 0.99, then higher order correlation coefficicent is getting slightly lower, ρ_5 is around 0.95 and 0.97, showing that the further apart the observations are, the less correlated they are, regardless the day-of-the-week regularities. Moreover, comparing among maturities, overnight rate is less persist than other rates. The similar properties were also found in US repo rates reported in Della Corte et al. (2008).

[Table 4.2 about here.]

Table 4.2 presents some descriptive statistics for daily changes in interbank rates. As same as the interbank rates, the daily changes also display high variance. Especially compared with the statistics for US repo rates reported in Della Corte et al. (2008), the standard deviations of daily changes of Vietnam interbank rates are much higher than those of US repo rates. Specifically, for the maturity of overnight, while the standard deviation of daily changes of Vietnam interbank rate is 0.5868 percentage points, this number for US repo rates is only 0.1738 percentage points. The standard deviation of daily change in overnight rate is also the highest among all the maturities of US repo rates; and this number is much higher than those of other maturities, which are all only around 0.05 and 0.06 percentage points. Differently from that property of US repo rates, the daily changes in Vietnam interbank rates all display high standard deviation, more than 0.5 percentage points. Through the descriptive statistics of both the daily changes in interbank rates and the rates themselve, it can be seen that very short-term interest rates of Vietnam present much higher variance than those of US in particular and advanced economies in general.

[Table 4.3 about here.]

Table 4.3 gives some information about the term premiums between overnight interest rate and other interest rates whose longer maturities in the interbank market of Vietnam. First of all, the term premium increases sharply when the maturity increase. Specifically, while the term premium between 1-week interest rate and overnight interest rate is calculated as 0.4602 percentage point, the term premium between 6-months interest rate and overnight interest rate is calculated as 2.3377 percentage points, which is extremely higher the term premium of shorter-term interest rate.

Secondly, it should be noticed that the term premium is significant to compare with the interest rates. Specifically, average 1-week rate of 5.8350 has term premium of 0.4602, while average 3-months rate of 7.3264 has even more significant term premium of 1.9317. Whereas, Longstaff (2000) also calculated the term premiums for the short-term interest rates that applied in the study, the term premiums were reported to range from 0.0056 percentage points to 0.0319 percentage points, corresponding to the maturities from 1-week to 3-months. These term premiums are insignificant to compare with the US repo rates, which was an evidence so that Longstaff (2000) concluded the validity of pure EH in which term premium is zero. However, for the case of Vietnam interbank market, the term premiums are much higher and significant. This is an evidence showing that the term structures of Vietnam interest rates are very unusual, especially compared to the interest rates of advanced economies. Therefore, this may suggest that EH could fail to explain the term structure of Vietnam interest rates or, in other words, the rejection of EH for the data of Vietnam interbank interest rates.

4.5 Empirical Results

This chapter applies the so-called VAR test using Lagrange multiplier (LM) and distance metric (DM) statistics, following Della Corte et al. (2008), to the data of Vietnam interbank interest rates to test the validity of expectation hypothesis for this data. Before showing the testing results of LM and DM statistics, the unconstrained VAR and constrained VAR estimations will be presented.

[Table 4.4 about here.]

According to the result shown in Table 4.4, it seems that the lagged short-term rates have more impact on the current short-term rate than on the current long-term rate; and similarly, the current long-term rate is more influenced by the lagged long-term rates than the lagged short-term ones. For example, in panel A, while the coefficient of i_{t-1}^m on i_t^m is 0.4211, the one on i_t^n is only -0.0225, which is insignificant to compare with the earlier value. The similar thing happens to the long-term interest rate, while the coefficient of i_{t-1}^n on i_t^m is as small as -0.0027, the one on i_t^n is much greater, 0.6759. Moreover, more lagged interest rate has smaller impact on current interest rate, this happens to both short- and long-term interest rates. For instance, in panel A, while the coefficient of i^m_{t-1} on i^m_t is 0.4122, the one of i^m_{t-2} is lower, only 0.2337. This pattern appears in all other panels.

[Table 4.5 about here.]

Comparing the unconstrained VAR and constrained VAR estimations in Table 4.4 and 4.5, the standard errors of constrained VAR estimation were found to be significantly greater than the ones of unconstrained VAR estimation, which is similar to the finding in Della Corte et al. (2008). For example, while most of the standard errors of coefficients in unconstrained VAR are around 0.005, the standard errors of coefficients in constrained VAR are significantly greater. Besides, the coefficients in constrained VAR are frequently greater than the ones in unconstrained VAR in terms of absolute value. More importantly, the sign of coefficient in constrained VAR sometimes is opposite to the corresponding one in unconstrained VAR. These are visible evidences to show that the expectation hypothesis's restrictions have some influence on the estimation of data. In other words, the data does not naturally follow the expectation hypothesis. However, the validity of expectation hypothesis for the data of Vietnam interbank rates should be examined in a more precise way. Therefore, as mentioned before in Methodology section, the impact of expectation hypothesis restrictions in the VAR regime should be statistically tested by using two statistics LM and DM.

[Table 4.6 about here.]

According to Table 4.6, all p-values of the tests using either LM or DM statistics are less than 5%, it means that the expectation hypothesis is rejected on every pair of short- and long-term interest rates of Vietnam interbank market. This finding is consistent with the previous finding in Della Corte et al. (2008), which used the same methodology.

This empirical result of the rejection of EH for the data of Vietnam interbank interest rate should be expected, because of the following reasons. First of all, the VAR test applied in this study is very powerful and tends to reject the null hypothesis. In other words, even if the departure which leads to the unholding of EH is very small, the EH could be rejected. That is why, in the study of Della Corte et al. (2008,) eventhough the US repo rates of different maturities are very similar, which seems to fit the pure EH, the test still reject EH for this data.

Secondly, the characteristics of Vietnam interbank rates are very different from those of US repo rates, despite having same maturities. More specifically, the variances of Vietnam interbank rates are much higher than the variances of US repo rates. One of the main driving forces of high variances of Vietnam interbank rates is high and volatile inflation rate of Vietnam. It is widely acknowledged that inflation expectation is a component in nominal interest rate. When the inflation rate is high, the inflation expectation from the market participants is not only high but also unstable, making high interest rates with great variances. This is also consistent with the fact that has already been shown in chapter 2 that inflation rate and the interest rates tend to move together (please see figures 2.1 and 2.3). Additionally, the average term premiums (referred to Table 4.3) of Vietnam interbank rates are not only much greater than those of US repo rates but also very significant to compare with the rates. Therefore, with the powerful testing procedure like VAR test, the rejection of EH for the data of Vietnam interbank rates seems to be already suggested from the data investigation.

4.6 Concluding Remarks

Similarly to most of the studies in the literature of testing expectation hypothesis on term structure of interest rate, this study also rejects expectation hypothesis for the very short-term interest rates in the interbank market of Vietnam. The rejection is not very surprising because of two main reasons. The first reason comes from the properties of testing procedure. The VAR test applied in this study, though provides the direct test on the validity of EH for the data, is very powerful and tends to reject the null hypothesis. The second reason comes from the characteristics of Vietnam interbank rates. Although the interbank rates are very short-term interest rates whose maturities range from overnight to six months, those rates are quite different from each other, leading to great term premiums. These characteristics of Vietnam interbank rates are very different from the ones of US repo rates.

Additionally, it is noteworthy that there are some significant differences between very short-term interest rates of Vietnam and advanced economies, particularly US. Besides containin great term premium as stated above, the very short-term rates of Vietnam display much higher variance than those rates of US; one of the main driving factors here is inflation which is higher and more volatile in developing economies like Vietnam than in advanced economies like US.

5 Estimating The Effectiveness of Monetary Policy Transmission Through Credit Channel in Vietnam

5.1 Introduction

Monetary policy transmission has always received lots of attention from not only researchers but also policy makers, because of its importance in monetary policy implementation of central bank in every economy. There are several channels through which the changes in monetary policy can transmit to the economy and have impact on the macroeconomic condition. Among all, credit channel has been frequently found to be an important channel in the monetary policy transmission by the empirical research on many countries, including both developing and advanced economies.

This study applies Bayesian Vector Autoregression (BVAR) model with stochastic volatility (SV) which had been introduced in the paper of Chan et al. (2018) to estimate the effectiveness of credit channel in the monetary policy transmission in Vietnam. Comparing with homoskedastic BVAR model, BVAR with SV model is an appropriate tool to address the changing variance of macroeconomic variables. Therefore, BVAR-SV is expected to produce more robust results in measuring the effectiveness of credit channel in monetary policy transmission in Vietnam.

Additionally, the stochastic volatility model of Chan et al. (2018) presents more appropriate features in estimating VAR process than other previous stochastic volatility models. First of all, the result which is produced by this stochastic volatility model is invariant to the ordering of variables. This feature is especially important in computing the impulse response functions. Secondly, this stochastic volatility model allows for fat tails in the volatility distributions which implies that the volatilities of macroeconomic variables can jump to large value.

5.2 Literature Review

One of the earliest papers showing the importance of credit channel of monetary policy transmission is Bernanke and Gertler (1995). By examining the macroeconomic time-series data from 1965 January to 1993 December of the US, the paper showed the important link from the monetary policy stance to the economy is the accessibility to banking credit of households and businesses, which is measured by their external finance premium. According to the paper, when monetary policy is tightened, the accessibility to banking credit of households and businesses is restricted, or their external finance premium is increased, therefore their consumption and investment is reduced, making the aggregate demand of the economy shrunk. As a result, the economic activity should be slowed down and the price also goes down. By using external finance premium to indicate the accessibility to banking credit of households and businesses, this paper gave more insight into the transmission of monetary policy, which had not been addressed by the neoclassical channel. By that, this paper also showed how banking credit can drive the economic activity and how important the credit channel is in monetary policy transmission.

The research on credit channel of monetary policy transmission continues to be diversified into variety of aspects. Specifically, the heterogeneity in the effect of credit channel is paid more attention. Kashyap and Stein (2000) looked at the micro data of all insured commercial banks in the US from 1976 to 1993 and concluded that the effect of credit channel on banks depends on the bank's size and liquidity. In other word, the lending of smaller bank with less liquid balance sheet is more sensitive to the change of monetary policy. This result leads to the idea that the effect of credit channel should be heterogenous on different types of financial system. Iturriaga (2000) showed that the credit channel is more effective in the bank-based financial system than in the market-based financial system.

Moreover, Den Haan et al. (2007) found the heterogenous effect of credit channel on different types of lending, including business loan, consumer loan and mortgage loan.

The paper showed that when there is a monetary shock, consumer loan and mortgage loan react more sharply than business loan. Another factor affecting the credit channel is bank's ownership. Bhaumik et al. (2011) collected the bank-based micro data in India and found an evidence on the impact of ownership on the reaction of bank to changes of monetary policy. In other words, the transmission of monetary policy through credit channel is different on different types of bank's ownership. Specifically, when monetary policy is tightened, foreign banks react more strongly than state-owned banks and old private bank. Whereas, new private banks, which tend to seek opportunity to expand market share, try to maintain the stream of credit to the economy. Even in the case they contract their credit, the credit contraction was found not to be significant.

After the global financial crisis in 2008, the credit channel was more investigated in the context of crisis and the conduction of unconventional monetary policy by central bank. Most of the papers showed the effectiveness of credit channel, especially in the period of crisis (Ciccarelli et al., 2010, Diamond and Rajan, 2006, Gertler and Kiyotaki, 2010, Boivin et al., 2010, Adrian and Shin, 2010). Gertler and Karadi (2009) assessed the impact of unconventional monetary policy during crisis and found that regardless of whether the zero-lower bound of nominal interest rate has been reached, the unconventional monetary policy is effective in supporting economic activity by injecting the banking system with liquidity.

Regarding to literature on the credit channel in Vietnam, Nguyen et al. (2019) applied VAR model to monthly data from 1998 January to 2017 November and found the effectiveness of monetary policy in stablizing price and inducing economic growth. For monetary transmisison mechanism, credit growth was found to play an important role in controlling inflation rate, while there is no significant evidence on the role of credit growth in stimulating economic growth. Moreover, Vo and Nguyen (2017), by examining the monthly data from 2003 January to 2012 December, concluded that inflation rate react to the changes of monetary policy while there is no evidence on the reaction of economic growth to the monetary policy's movement. Another paper is Anwar and

Nguyen (2018) which used quarterly data from 1995 to 2004 and concluded that the Vietnamese economy reacts more strongly to external shocks than the movements of monetary policy. It can be seen that different results have been produced by previous studies regarding to effectiveness and transmission of monetary policy in Vietnam. Most of the studies showed evidence on the broad impact of monetary policy on the economy, rather than monetary policy transmission.

Moreover, VAR has been seen to be a popular tool in empirical works on monetary policy in Vietnam (see Vo and Nguyen (2017), Anwar and Nguyen (2018) and Nguyen et al. (2019)). However, all of VAR models which have been applied are featured with constant var-cov matrix of error term, which does not seem to suits macroeconomic variables. Stochastic volatility (SV) model can bring some benefits in estimating multivariate model containing macroeconomic variables, as SV model allows the var-cov matrix of error term to change over time, which is corresponding to the fact that the variance of macroeconomic variables tend to change over time. All in all, this study applies the SV model which is introduced in the paper of Chan et al. (2018) to estimate the effectiveness of credit channel in the monetary policy transmission in Vietnam. The SV model of Chan et al. (2018) presents more appropriate features in estimating VAR than other SV models. Firstly, its result is invariant to the ordering of variables. Secondly, it allows for fat tails in the volatility distribution which implies that macroeconomic variable's volatility can jump to large values.

5.3 Methodology and Data

5.3.1 Bayesian Vector Autoregression

The reduced form of VAR process can be presented as:

$$Y_t = \delta + \theta_1 Y_{t-1} + ... + \theta_p Y_{t-p} + \epsilon_t, \qquad (24)$$
$$\epsilon_t \sim N(0, \sum).$$

Where Y_t is a $r \times 1$ vector of variables, p is the lag, and ϵ_t is a $r \times 1$ vector of error term, which follows a normal distribution $N(0, \sum)$. Bayesian analysis puts a prior on

(δ, θ_1,..., θ_p, $\sum$). This study applies non-informative prior on δ (normal distribution, $\delta \sim N(\underline{\delta}, Var(\delta))$), non-informative prior on $\sum$ (inverted Wishart), and informative priors on θ_1,..., θ_p (normal distribution). It is common to set priors as follows:

$$
\begin{aligned}
E(\theta_1) = I,\ Var(\theta_1) \propto \pi_1^2 \qquad (25)\\
E(\theta_2) = 0,\ Var(\theta_2) \propto \tfrac{\pi_1^2}{(2^{\pi_3})^2}\\
E(\theta_3) = 0,\ Var(\theta_3) \propto \tfrac{\pi_1^2}{(3^{\pi_3})^2}\\
...\\
E(\theta_p) = 0,\ Var(\theta_p) \propto \tfrac{\pi_1^2}{(p^{\pi_3})^2}\\
E(\delta) = \underline{\delta},\ Var(\delta) \propto (\pi_1\pi_4)^2
\end{aligned}
$$

Where π_1 is overall variance, π_3 is lag decay, π_4 is variance of constant and deterministic components, and $\underline{\delta}$ is prior mean of deterministic components, which is usually set to be 0. Specifically for this study, $\pi_1 = 0.05$, $\pi_3 = 0.5$ and $\pi_4 = 1$. Several combinations of values for π_1, π_3, π_4 have been tried, and these numbers are chosen because they produces the smallest root mean square error (RMSE) when the BVAR model is used in forecasting, which also implies that the model with these values is the most appropriate for the employed data. The lag is set to two, based on Bayesian information criterion (BIC)[7].

5.3.2 Bayesian Vector Autoregression - Stochastic Volatility

Another approach to estimate VAR is stochastic volatility (SV) model. This study follows the framework of stochastic volatility model which was introduced in the paper of Chan, Doucet, Leon-Gonzalez and Strachan (2018). This stochastic volatility model, compared with other stochastic volatility models, provides some benefits. First of all, it is invariant to the ordering of the variables. Secondly, it allows for fat tails in the volatility distribution through the degree of freedom parameter n. This implies that the volatility can suddenly jump to large values, a feature which is empirically relevant

[7] $BIC = log(Likelihood) - \frac{k}{2}log(T)$, where the Likelihood is evaluated at the posterior mean of the parameters, k is the number of parameters, and T is the sample size. The BIC is a criterion for model selection, which approximates the marginal likelihood, consistent as the sample size increases and was proposed by Schwarz (1978).

for macroeconomic time-series.

This SV model is, instead of having constant var-cov matrix of error term ϵ_t, allowing var-cov matrix of error term ϵ_t to change over time:

$$\sum_t = AK_t^{-1}A'. \qquad (26)$$

Where A determines the long-run var-cov matrix, and K_t is a Wishart Autoregressive process of order 1 (WAR(1))

It should be noted that the framework of the SV model in Chan et al. (2018) allows for co-heteroskedasticity. Co-heteroskedasticity means that there are linear combinations of the vector Y_t that are conditionally homoskedastic. This concept was first defined in the paper of Engle and Kozicki (1993), as one of the so-called "common features" that could appear in the data, such as common cycles, cointegration or co-heteroscedasticity. In case of co-heteroskedasticity, only the var-cov matrix of the heteroskedastic component depends on K_t^{-1}. However, in this study, we did not find evidence of co-heteroskedasticity (which will be shown later in section 5.4. Empirical Results of this chapter), and therefore the whole var-cov matrix of ϵ_t changes with time, such that $\sum_t = AK_t^{-1}A'$.

Let $K_t = Z_t'Z_t$, where Z_t is a $n \times r$ matrix (while r is the number of variables, n is called as degree of freedom parameter of volatility distribution). Z_t is distributed as a Gaussian AR(1) process:

$$Z_t = Z_{t-1}\rho + e_t. \qquad (27)$$

$$e_t \sim N(0, I_r \otimes I_n).$$

With ρ is a diagonal matrix with diagonal elements smaller than one in absolute value.

As stated before, K_t is a Wishart Autoregressive process of order 1 (WAR(1)) whose properties were introduced in previous literature (Gourieroux et al. (2009), Koop et al. (2011)). Among all the properties, the stationary distribution of K_t is a Wishart distribution with n degree of freedom. Moreover, unconditional expectation $E(K_t)$ and conditional expectation of K_t on K_{t-1} are expressed as:

$$E(K_t) = n(I - \rho^2)^{-1}. \quad (28)$$

$$E(K_t|K_{t-1}) = \rho K_{t-1}\rho + (I - \rho^2)^{1/2}E(K_t)(I - \rho^2)^{1/2}. \quad (29)$$

The degree of freedom parameter n being adjusted will allow the volatility to jump over time. Because a smaller n will allow the distribution of volatility to have fat tails, which implies that the volatility can jump higher. On the other hand, when n is a bigger number, the distribution of volatility has thinner tails. In this case, the volatility is less likely to jump high over time. For the macroeconomic time-series, it is likely to expect that the volatility of macroeconomic variable to jump high over time. Therefore in this study, n is expected to be a small number. Indeed, the estimation of n for the data applied in this study is approximately 8.35[8].

ρ is the auto-correlation of the precision matrix (the inverse of volatility). As the parameter presenting the correlation between volatility over time, when ρ is closer to one in absolute value, it implies that volatility moves more smoothly over time. On the other hand, when ρ is closer to zero in absolute value, it implies that the volatility changes very quickly over time. For macroeconomic data, it is reasonable to expect ρ to be closer to 1, implying that volatilities move smoothly over time. Specifically in this study, ρ is estimated to be[9]:

$$\begin{pmatrix} 0.8601 & 0 & 0 & 0 \\ 0 & 0.9874 & 0 & 0 \\ 0 & 0 & 0.9715 & 0 \\ 0 & 0 & 0 & 0.9504 \end{pmatrix}$$

It should be noted that the likelihood cannot be evaluated analytically, therefore a particle filter is used to calculate it numerically. Specifically, this study uses the

[8]The prior for n is a log-normal distribution, with log(n) being normal with a prior of mean of 2.44 and variance 1.5

[9]The prior for each diagonal element of ρ is a beta distribution with mean 0.95, and parameters 95, 5

particle filter following section 4 - Likelihood and Particle Filter in Chan et al. (2018). Moreover, one of the important results that can be produced by both homoskedastic BVAR and BVAR with SV models is impulse response function which shows the impact of a structural shock to one variable on another variable in the model. Specifically, impulse response function is a function showing impulse responses at different horizons, in which an impulse response at a specific horizon s ($IR_t(s; i, j)$) can be computed as the difference of two conditional expectations (e.g. Koop et al. (1996)):

$$IR_t(s; i, j) = E(y_{i,t+s}|\xi_{jt} = 1, y_{1:(t-1)}) - E(y_{i,t+s}|\xi_{jt} = 0, y_{1:(t-1)}). \quad (30)$$

Where $IR_t(s; i, j)$ is an impulse response of variable i to a structural shock ξ_{jt} to variable j at time t. $E(y_{i,t+s}|\xi_{jt} = 1, y_{1:(t-1)})$ is conditional expectation of the value of variable i at s horizon in the future given a structural shock ξ_{jt} and the information up to time $t-1$ ($y_{1:(t-1)}$), while $E(y_{i,t+s}|\xi_{jt} = 0, y_{1:(t-1)})$ is conditional expectation of the value of variable i at s horizon in the future given only the information up to time $t-1$ ($y_{1:(t-1)}$) without a shock. Therefore, an impulse response is calculated as the difference between two conditional expectations. All in all, $IR_t(s; i, j)$ shows the impact of ξ_{jt} on variable i at horizon s.

5.3.3 Data

To examine the transmission mechanism of monetary policy through credit channel in Vietnam, the following variables are included: (1) GDP is economic growth rate, which is the growth rate of real GDP from 2004 October to 2007 December and the growth rate of industrial production index (IPI) from 2008 January to 2019 December; (2) INF is inflation rate, which is the growth rate of consumer price index (CPI); (3) CRE is growth rate of banking credit; (4) M2 is the growth rate of money aggregate M2. The monthly data of these variables is collected from 2004 October to 2019 December, which makes the total number of observations is 183. All time-series data are presented as percentage point and the statistical summary of those employed variables are presented in Table 5.1.

[Table 5.1 about here.]

For more details about the data of GDP, from 2004 October to 2007 December, quarterly data of real GDP growth rate is interpolated into monthly data by linear interpolation method of Eviews. From 2008 January to 2019 December, monthly growth rate of industrial production index (IPI) is used. For the purpose of utilizing as long time-series data as possible, the data of GDP employed in this study is combined by two time-series of real GDP growth rate and IPI growth rate.

[Table 5.2 about here.]

From Table 5.2, the means and variances of real GDP growth rate and IPI growth rate are not very different from each other, which implies that both of these time-series data behave in the same manner. For the min and max values of real GDP growth rate and IPI growth rate, which can be seen to be extreme for the monthly data. However, for the case of Vietnam, monthly economic growth rate, either measured by real GDP or IPI, is affected by seasonality factor in February every year. Because February is usually the time for long holiday of lunar new year in Vietnam, therefore the production value is reduced during this month, making the growth rate to be negative. However, the production value will be fully recovered in March, making the growth rate in March to be positive with the absolute value which is approximate to the absolute value of growth rate in February. That is why min and max values of both two data are approximate to each other and they arise from the same year. This fact can be referred to chapter 2 - section 2.1 about the macroeconomic condition of Vietnam. Moreover, because the volatility of GDP is suspected to be higher in the latter period, therefore the IPI growth rate from 2008 to 2019 may have more extreme min and max values than real GDP growth rate from 2004 to 2007.

5.4 Empirical Results

5.4.1 Bayesian Vector Autoregression (BVAR)

To see the impact of monetary policy on the economy through credit channel, two estimations of BVAR with M2 and CRE as impulse variable will be presented. To examine whether the transmission of monetary policy through credit channel is effective, it is expected that: firstly, M2 should have some significant impact on CRE in the estimation of BVAR with M2 as impulse variable; secondly, CRE is expected to have significant impact on GDP and INF in the estimation of BVAR with CRE as impulse variable.

First of all, to see the overall impact of monetary policy on the economy, the Figure 5.1 shows the response of GDP, INF and CRE to the shock to M2. It is seen that while a positive one-standard-deviation shock to M2 has no significant impact on GDP, this shock has positive and statistically significant impact on the inflation rate. At 90% credible interval, this positive impact of M2 on INF lasts for more than a year. Moreover, through the impulse response function, the impact is seen to increase from the first period to the second period after the shock, as the increases of inflation rate in those periods are 0.05 and 0.055 percentage point, respectively. The second period after the shock is also the period in which the impact of M2 on INF is the strongest. After that, this impact is gradually decreased. Specifically, the increase of inflation rate is estimated as 0.035 percentage point in the third period, 0.03 percentage point in the fourth period and even lower in the latter periods.

[Figure 5.1 about here.]

As expected by the theory, the shock to the growth rate of money supply (variable M2) also has positive and statistically significant impact on the growth rate of banking credit (variable CRE). At 90% credible interval, this positive impact lasts for more than a year after the shock was taken place. Specifically, this shock makes the credit growth to increase by 0.085 percentage point in the first period and 0.11 percentage point in the second period after the shock. From the third period, the increase of credit growth is gradually decreased. The increase of credit growth is estimated as 0.075 percentage point in the third period, 0.06 percentage point in the fourth period and even lower in the latter periods. It is easily seen that the highest increase of credit growth is in the second period, which is coincident with the time when inflation rate increases by the highest amount due to the shock to M2. This means that the shock to M2 has the strongest impact on both credit growth and inflation rate in the second period after the shock.

[Figure 5.2 about here.]

Next, considering the impact of CRE on GDP and INF, from Figure 5.2, it is reported that while the shock to CRE has no significant impact on GDP, this shock has positive and statistically significant impact on INF. This result is consistent with the previously reported results on the impact of M2 to other variables. Specifically, M2 was proved to have positive and statistically significant impact on both CRE and INF. Therefore, CRE, as a channel in monetary policy transmission, is also expected to have positive impact on INF. This result can be interpreted in the way that when the State Bank of Vietnam (SBV) decides to increase the growth rate of money supply, this also increases the ability of banking system in giving loan to the economy. And the increase in banking credit normally will increase the price by increasing consumption and investment. Therefore, this empirical result is consistent with the theory and also shows the effectiveness of credit channel in monetary policy transmission for influencing inflation rate in Vietnam, which is consistent with the finding in chapter 3 about the high predictive power of M2 and CRE for the future inflation rate.

The impact of monetary policy through credit channel is also consistent in term of its impact on the economic growth of Vietnam. Both M2 and CRE were found to have no significant impact on GDP. This result can be interpreted in the way that although increase in money supply can expand the volume of banking credit, it is not necessary to promote the economic activity. Because the impact of banking credit on economic activity also depends on the efficiency of borrower's economic activity. This issue also related to high non-performing loan of Vietnamese banking system during 2013-2014. Non-performing loan implies the situation that the borrower can not pay back a portion or total of the loan, which is mainly caused by the low efficiency of the borrower's investing or business activity. Therefore, inefficient economic activity of borrower, which can be reflected by non-performing loan, can be considered as a cause of ineffectiveness in monetary policy transmission through credit channel to the economic growth of Vietnam. This finding is also consistent with the previous finding in chapter 3 about the low predictive power of monetary policy-related variables, M2 and CRE, for the future economic growth rate.

5.4.2 Bayesian Vector Autoregression - Stochastic Volatility (BVAR-SV)

As stated before, the applied framework of SV model allows the number of heteroskedastic component in the error term ϵ_t to be from one up to the number of variables in VAR. And based on the value of log-likelihood, it allows us to find the optimal number of heteroskedastic error. It also should be noticed that if the number of heteroskedastic error is smaller than the number of variables, it means there is some homoskedastic component, or homoskedastic linear combination, in the error term ϵ_t. This case is referred as co-heteroskedasticity, which can be appeared in the multivariate model, especially when the number of variables is large. However, since this VAR contains only four variables, it is reasonable to not find any co-heteroskedasticity. In fact, the models with different numbers of heteroskedastic errors (from one to four) were run and the model with all four heteroskedastic errors had the highest value of the log-likelihood and Bayesian Information Criterion (BIC) among all choices (Table 5.3).

[Table 5.3 about here.]

From Table 5.3, $r_1 = 0$ refers to homoskedastic BVAR. It can be easily seen that the log-likelihood value of homoskedastic BVAR is the lowest among all options. By comparing these values, it is showed that BVAR with all heteroskedastic errors ($r_1 = 4$) has the highest log-likelihood and BIC values, being the most appropriate model in this case.

- ***The estimated volatilities of variables***

[Figure 5.3 about here.]

Figure 5.3 shows the estimated volatility of economic growth of Vietnam from 2004 to 2019. From the beginning to around 2008, the volatility of economic growth was seen to be quite stable at a low level. Specifically, the estimated volatility in this period usually fluctuates around 60 and 80, which implies the standard deviation fluctuates around 7.75 and 8.94. This period is also the time when the global financial crisis in 2008 had not affected significantly the Vietnamese economy. That enhances to the conclusion that in the pre-crisis period, the Vietnamese economic growth is less volatile.

From 2009, the global financial crisis started to have more significant impact on the Vietnamese economy, therefore the volatility of economic growth started to increase. There are some explanations for the late impact of the 2008 global financial crisis on Vietnamese economy. First of all, Vietnam had started to join the World Trade Organization (WTO) in 2007. Since then, the trading relationship between Vietnam and other countries has gradually expanded, and 2008 is only the beginning time of Vietnam's trading activities with the rest of the world. Therefore, eventhough the global financial crisis started in 2008, it did not have significant impact on Vietnam's economy.

Besides, as widely mentioned, the crisis had stronger effect on markets of high-valued goods like automobile, real estate, and other durable goods, while non-durable goods were less impacted. On the other hand, the main exported goods of Vietnam are rice, fishery products, clothing, footwear,..., which are non-durable goods. Therefore, Vietnam's exporting activities was less impacted by the crisis. That is why the level of volatility in 2009 and in the latter periods are not very different from each other. In other words, the volatility of economic growth after 2009 is still kept at high level, as the economy is integrating into the global economy. And along with the integration into the global economy, the economy of Vietnam is now more exposed to the external risk than the pre-crisis period. Therefore, it is reasonable to expect that the economic growth of Vietnam may experience higher volatility in the future.

[Figure 5.4 about here.]

From the figure 5.4 showing volatility of inflation rate (INF), there are two periods of time that the inflation rate of Vietnam had experienced the much higher volatility than the rest of the sample. Firstly, from 2007 August to 2008 December, the estimated volatility of inflation rate rapidly increased and reached a peak of about 2.22 at 2008 March. Secondly, from 2010 August to 2011 September, the volatility of inflation rate was once again soared up and reached a peak of about 1.3 at 2011 April. These two periods are also the time when Vietnamese economy experienced considerably high level of inflation rate. Specifically, the inflation rate of 2008 and 2011 were reported to be 19.89% and 18.13%, respectively. During these two periods, food and restaurant service was recorded to be the group whose price strongly increased, by 31.86% and 24.8% in 2008 and 2011 respectively, and this group was also the main factor driving high inflation in 2008 and 2011.

From figure 5.4, it is also easily seen that for the period before 2012, the volatility is not only higher but also much more fluctuating than the period after that. The reason is that before 2012, together with the strong economic growth, the economy of Vietnam had also been endured with inflation pressure. Moreover, the monetary policy before the most recent monetary policy contraction from the end of 2010 thoughout 2011 is not tightened strongly enough to deal with the rise of inflation. The rise of interest rate which is not as high as the rise of inflation rate makes the real interest rate decresed and furthermore pushes up the demand. Evidently, from 2008 January to 2010 October, the discount rate of SBV rises from 6.5% to 8%, while the inflation rate during this time is more than 30%. Whereas, from 2010 November to 2011 December, the discount rate was adjusted to rise from 8% to 15% by SBV, which is much stronger than the previous tightened monetary policy and also the most tightened monetary policy that SBV has ever conducted. This makes the inflation rate since 2012 much stablized than the previous time. The volatility of inflation rate in the recent time is estimated as low as around 0.25.

[Figure 5.5 about here.]

From figure 5.5, the volatility of credit growth rate is seen to generally increase over time, from around 1 in 2004 December to roughly 1.5 in 2019 December. Together with the fact that the Vietnamese economy is more opened to the rest of the world, the Vietnam's financial market is also integrating into the global financial market. This means that the Vietnam's financial market is getting more sensitive to the movement of the global financial market. Therefore, financial variables in general and the growth rate of banking credit in particular are supposed to be more volatile than the previous period.

From 2004 December to 2019 December, the volatility of banking credit growth rate reached a peak of 2.4 at 2014 January. This estimated result is consistent with the fact that during the time 2013 - 2014, the Vietnamese banking system had experienced a relatively high ratio of non-performing loan, compared with other periods. Therefore, the domestic banking system in this period was more vulnerable than in other periods. Plus, the banks tends to be more reluctant to give out loan to the economy, which causes a huge shrinkage in baning credit volume in this time. Therefore, the high volatility of banking credit growth rate is witnessed during this time.

[Figure 5.6 about here.]

From the figure 5.6, it can be easily seen that the growth rate of money supply had experienced a high volatility from the beginning to 2012. Especially, the volatility of M2 reached a peak of 18 in 2012 August, which implies the standard deviation of 4.24. However, since 2013, the volatility has been much much lower and also stabilized. Specifically, the estimated volatility of M2 has been around 2 since 2013. This result is consistent with the previous result on the estimated volatility of inflation rate, which was also shown to be much lower from 2013. Because theoretically, while inflation rate is one of the targets of monetary policy, money aggregate is one of the monetary policy instruments that the SBV can adjust to affect the inflation rate. Therefore, there should be a close relationship between two variables M2 and INF in this case. Thanks to the resilience of SBV's monetary policy in the recent time, both INF and M2 are experiencing low volatility. These estimated volatilities of INF and M2 not only confirm the theory but also show the effectiveness of monetary policy of SBV in the recent time.

- Impulse response function

BVAR-SV allows for the variance-covariance matrix to change over time, therefore it is possible to show how the impulse response functions change over time. This part will show both the impulse response functions calculated using the estimated stationary var-cov matrix and the impulse response functions calculated using the var-cov matrix in 2008 March, when estimated volatility of inflation rate become maximum.

[Figure 5.7 about here.]

[Figure 5.8 about here.]

[Figure 5.9 about here.]

[Figure 5.10 about here.]

First of all, comparing between the impulse response functions calculated using estimated stationary var-cov matrix (Figures 5.7 and 5.8) and the impulse response functions calculated using estimated var-cov matrix in 2008 March (Figures 5.9 and 5.10), they are similar to each other, although some slight difference can be detected. For example, the response function of INF to M2 using the stationary var-cov matrix shows the strongest increase of INF in the second period after the shock, which is nearly 0.06 percentage points. However, this number in the response function using the estimated var-cov matrix for 2008 March is slightly smaller, around 0.05 percentage points. Moreover, the shape of the impulse response of GDP changes, but in both cases it is not significant.

Figure 5.7 and 5.8 present the impulse response functions of different variables to the shocks to M2 and CRE in BVAR-SV model. These estimated functions are not significantly different from the impulse response functions which were collected from BVAR model. Therefore, it can be concluded that both BVAR and BVAR-SV's estimations suggest the significant impact of monetary policy through credit channel to inflation rate of Vietnam, while there is no significant evidence on the impact of monetary policy through credit channel on the economic growth of Vietnam.

Apart from the similarity between the impulse response functions of BVAR and BVAR-SV, there are some slightly differences being detected. For example, the estimated impact of M2 on CRE in BVAR-SV is slightly smaller than the estimated impact in BVAR. While the strongest increase of CRE to a positive one-standard-deviation shock to M2 in BVAR is 0.11 percentage point, the strongest increase of CRE in BVAR-SV is less than 0.1 percentage point. Regarding to response of INF to CRE, according to BVAR-SV's estimation, a positive one-standard-deviation shock to CRE makes inflation rate to increase by approximately 0.09 percentage point in the second period after the shock. However, in BVAR's estimation, this increase is slightly higher, about 0.138 percentage point.

5.4.3 Robustness Check

In this sub-section, the BVAR-SV with all heteroskedastic errors will be estimated again using only the data of industrial production index (IPI) growth rate for economic growth rate, which is variable GROW in the model. The number of total observations is 144, including monthly data from 2008 January to 2019 December[10].

[10]The estimated parameters for this model are: (1) the degree of freedom parameter $n = 8.44$; (2) the auto-correlation of the precision matrix ρ is diagonal matrix with diagonal elements equal (0.8720 0.9771 0.9699 0.9549)

[Figure 5.11 about here.]

The impulse response functions produced by the model using only data of IPI are not significantly different from the corresponding ones produced from using longer data of both real GDP and IPI. Specifically, the results from both models are consistent with each other to show while a positive one-standard-deviation shock to M2 has no significant impact on GDP, this shock has a positive and statistically significant impact on INF. The greatest increase of INF due to the shock is nearly 0.03 percentage point, slightly smaller than the number from the baseline estimation. Moreover, both models also conclude the significant impact of M2 on CRE. From the impulse response function of CRE to M2 produce by robustness-check estimation, the greatest increase of CRE due to a positive one-standard-deviation shock to M2 is approximately 0.07 percentage points, which is slightly smaller than the number from the baseline estimation.

[Figure 5.12 about here.]

Similarly to the impulse response functions of different variables to the shock to M2, the impulse response functions of variables to the shock to CRE also display similarities with the corresponding ones produced by baseline estimation. The results from both estimations are consistent with each other and show that while a positive one-standard-deviation shock to CRE has no significant impact on GDP, this shock has a positive and statistically significant impact on INF. This confirms the effectiveness of credit channel in monetary policy transmission for influencing inflation rate of Vietnam.

5.5 Concluding Remarks

Based on the estimations of BVAR and BVAR-SV, this study showed the effectiveness of monetary policy transmission through credit channel in stabilizing price. However, there is no significant evidence on the impact of monetary policy through credit channel on the economic growth of Vietnam.

Besides the impulse response functions, BVAR-SV also estimates the volatilities of macroeconomic variables regarding to the credit channel of monetary policy transmission in Vietnam. Among all, it is noteworthy that the volatilities of both money growth and inflation rate are much lower in the past few years than before. This result supports the fact that monetary policy of SBV is doing a good job in stabilizing price, in order to generate sound macroeconomic environment for economic development.

6 Conclusions

This thesis studies the interaction of interest rates, banking credit, inflation and monetary policy in Vietnam. The three main chapters of the thesis (1) forecast inflation and economic growth rates of Vietnam using, among other variables, monetary policy variable and financial variables including interest rate and banking credit; (2) test the Expectation Hypothesis on the term structure of Vietnam interbank interest rates; and (3) measure the effectiveness of monetary policy transmission through credit channel in Vietnam.

Chapter 3, the first of the three main chapters, by forecasting inflation and economic growth rates of Vietnam using dynamic model averaging (DMA), detects relatively high predictive power of several predictors, including monetary policy transmission related variables (M2 and CRE), financial variables (SPREAD6 and OVN) and external variables such as OIL and FDI. Among these predictors, the high predictive power of money supply (M2) and banking credit (CRE) for future inflation rate suggests the effective transmission of monetary policy through credit channel. Furthermore, DMA has been shown to produce accurate forecasts of inflation and economic growth rates of Vietnam; therefore, it is recommended for application of the forecasting of macroeconomic variables in developing countries in general.

Chapter 4, the second main chapter, applies the VAR test, which, unlike other testing procedures, provides direct testing of the validity of EH and has been frequently applied in the literature. The study rejects EH on the term structure of Vietnam interbank rates, which is in line with the findings of previous studies on US repo rates. This result can be explained by the fact that the applied VAR test in these studies is very powerful and tends to reject the null hypothesis that EH holds. As the test already rejected EH on US repo rates, which contain very small differences between term rates, it is reasonable that EH is rejected on Vietnam interbank rates, which contain much greater differences between term rates. Apart from that difference between Vietnam interbank rates and US repo rates, the statistical investigation in this chapter also reveals that the variances of Vietnam interbank rates are much greater than those of US repo rates, which is the result of the fact that Vietnam inflation rate is higher and more volatile than US inflation rate.

Chapter 5, the third main chapter, as suggested by the result in chapter 3, measured the effectiveness of monetary policy transmission through credit channel in Vietnam by using both homoskedastic BVAR and heteroskedastic BVAR which is allowed by introducing stochastic volatility into the model. First of all, introducing stochastic volatility is proven to substantially improve the empirical model and permits the estimation of time-varying impulse response functions and volatilities of variables, which can give some explanation on the produced result. Secondly, the results from both models are consistent with each other, showing the effective monetary policy transmission through credit channel for influencing inflation rate, but not economic growth rate. The ineffective transmission through credit channel for economic growth rate may be explained by the inefficient economic activity of borrowers which leads to the weak impact of banking credit on economic growth.

Regarding policy implications, the conclusions drawn in the three main chapters suggest two key policy implications. First of all, Vietnam's macroeconomic condition is shown in chapter 3 to be growing more sensitive to external shocks, particularly oil price and foreign investment inflows. Therefore, improving the accuracy of macroeconomic variables forecasting is very important and would contribute to the stability of the Vietnamese macroeconomic environment. Secondly, the banking system has been playing an important role in the SBV monetary policy transmission mechanism, as credit channel is shown in chapter 5 to be an effective channel in the monetary policy transmission. Therefore, in order to facilitate efficient banking system operation and thus improve the effectiveness of monetary policy transmission, banking supervision is necessary and should be paid more attention by both bankers and central bankers, particularly the supervision on banking credit activity, as poor performance of borrowers is detected as one of the main causes of ineffective monetary policy transmission through credit channel for economic growth rate.

Regarding the plan for future work, given the high predictive power of external variables for the future macroeconomic condition of Vietnam, as found in chapter 3, a forecasting model including more informative external variables would enable researchers and policy makers to forecast the future macroeconomic condition of Vietnam more accurately. Particularly for variables representing the macroeconomic condition of influential economies of Vietnamese economy, instead of using US macroeconomic variables as before, a forecasting model including Chinese macroeconomic variables would be more appropriate, given that China is a bigger trading partner for Vietnam than the US.

A Appendix A - DMA estimation assuming that error variance $H_t^{(k)}$ follows Exponentially Weighted Moving Average (EWMA)

1. Averaged Number of Predictors

From Figure A.1 presenting averaged number of predictors for different forecasting exercises, most of the lines shrink overtime, showing that DMA give priority to parsimonious models which include few predictors, same as concluded in Koop and Korobilis (2012). For inflation rate forecast (refer to Figure A.1 - Inflation Rate Forecast graph), the averaged number of predictors contained in forecasting exercises of all three horizons reduce overtime and finally reach around six for all three horizons. Referring to Figure A.1 - Economic Growth Forecast graph, forecasting economic growth rate for 6-month horizon utilizes more predictors than for other horizons. Specifically, while the averaged number of predictor for 12-month horizon reduce to around two, the averaged numbers of predictors for 1-month and 6-month horizons reduce to around five.

[Figure A.1 about here.]

2. Good Predictors for Each Forecasting Exercise

- *Inflation Rate Forecast*

[Figure A.2 about here.]

Among different forecast horizons, forecasting inflation rate at h = 1 is the only exercise showing some good predictors in 12 potential explanatory variables. For forecasting inflation rate at h = 6 and h = 12, there is no variable whose inclusion probability is greater than 50% at any point in time. From Figure A.2, M2, CRE and OVN are the good predictors for next month inflation rate. Especially, the predictive power of these predictors are increasing recently. From around 2013 till now, the inclusion probabilities of these predictors are increasing, compared to previous period. In fact, the period from 2013 till now is also the period when there had been not much change in monetary policy from SBV (policy interest rate remains stable) and the inflation rate also remains stable at around 5% and 6% per year. Therefore, it can be concluded that in the stable monetary policy condition, the inflation rate remains stable and predictive power of predictors are increasing.

In addition, as mentioned above about the coincidence of the stable monetary policy and stable inflation rate in the period from 2012 to now, it is suspected that monetary policy should also have some predictive power over Vietnam's future inflation rate. In fact, the growth rate of money supply (M2) is shown to be one of three good predictors in forecasting inflation rate in Vietnam (Figure A.2).

- *Economic Growth Forecast*

[Figure A.3 about here.]

For economic growth forecast, forecasting next month's economic growth (h = 1) is the only exercise showing some good predictors. Refer to Figure A.3, there are three variables considered to be good predictors in forecasting next month's economic growth rate: GROWL1, M2, and SPREAD9. Among all, the current month's economic growth rate (GROWL1) plays the most important role in forecasting future economic growth rate of Vietnam. Besides, the inclusion probabilities of M2 and SPREAD9 are lower, showing a relative low predictive power of monetary policy and money market related variables for the future economic growth rate of Vietnam. This shows that compared to inflation rate, economic growth rate of Vietnam seems to be less sensitive to the changes of SBV monetary policy.

B Appendix B - LM Statistics of VAR test

To maximize $\mathcal{L} = \frac{-1}{2} g_T(\theta)' \Omega_T^{-1} g_T(\theta) - a_T(\theta)'\gamma$, the first-order conditions are:

$$\begin{bmatrix} 0 \\ 0 \end{bmatrix} = \begin{bmatrix} -G_T' \Omega_T^{-1} g_T(\bar{\theta}) - A_T' \bar{\gamma} \\ -a_T(\bar{\theta}) \end{bmatrix}$$

Where $A_T \equiv \nabla_\theta a_T(\theta)$ (first derivative of $a_T(\theta)$ with respect to θ), $G_T \equiv \nabla_\theta g_T(\theta)$ (first derivative of $g_T(\theta)$ with respect to θ), $\bar{\theta}$ and $\bar{\gamma}$ are estimated θ and γ by constrained VAR, respectively. Applying the Taylor's expansion for $g_T(\theta)$ and $a_T(\theta)$ around the true value θ_0 on the FOCs:

$$\begin{bmatrix} 0 \\ 0 \end{bmatrix} = \begin{bmatrix} -G_T' \Omega_T^{-1} g_T(\theta_0) - A_T' \bar{\gamma} - B_T(\bar{\theta} - \theta_0) \\ -a_T(\theta_0) - A_T(\bar{\theta} - \theta_0) \end{bmatrix} \quad \text{where } B_T \equiv G_T' \Omega_T^{-1} G_T$$

$$\Leftrightarrow \begin{bmatrix} 0 \\ 0 \end{bmatrix} = \begin{bmatrix} -G_T' \Omega_T^{-1} g_T(\theta_0) - A_T' \bar{\gamma} - B_T(\bar{\theta} - \theta_0) \\ -A_T(\bar{\theta} - \theta_0) \end{bmatrix} \quad (a_T(\theta_0) = 0 \text{ under } H_0 : a(\theta) = 0)$$

$$\Leftrightarrow \begin{bmatrix} 0 \\ 0 \end{bmatrix} = \begin{bmatrix} -G_T' \Omega_T^{-1} g_T(\theta_0) \\ 0 \end{bmatrix} - \begin{bmatrix} B_T & A_T' \\ A_T & 0 \end{bmatrix} \begin{bmatrix} (\bar{\theta} - \theta_0) \\ \bar{\gamma} \end{bmatrix}$$

By the formula for the inverse of a partioned matrix,

$$\begin{bmatrix} B_T & A_T' \\ A_T & 0 \end{bmatrix}^{-1} = \begin{bmatrix} B_T^{-1/2} M_T B_T^{-1/2} & B_T^{-1} A_T' (A_T B_T^{-1} A_T')^{-1} \\ (A_T B_T^{-1} A_T')^{-1} A_T B_T^{-1} & -(A_T B_T^{-1} A_T')^{-1} \end{bmatrix}$$

Where $M_T = I - B_T^{-1/2} A_T' (A_T B_T^{-1} A_T')^{-1} A_T B_T^{-1/2}$, then:

$$\begin{bmatrix} (\bar{\theta} - \theta_0) \\ \bar{\gamma} \end{bmatrix} = \begin{bmatrix} B_T & A_T' \\ A_T & 0 \end{bmatrix}^{-1} \begin{bmatrix} -G_T' \Omega_T^{-1} g_T(\theta_0) \\ 0 \end{bmatrix}$$

$$= \begin{bmatrix} B_T^{-1/2} M_T B_T^{-1/2} & B_T^{-1} A_T' (A_T B_T^{-1} A_T')^{-1} \\ (A_T B_T^{-1} A_T')^{-1} A_T B_T^{-1} & -(A_T B_T^{-1} A_T')^{-1} \end{bmatrix} \begin{bmatrix} -G_T' \Omega_T^{-1} g_T(\theta_0) \\ 0 \end{bmatrix}$$

$$= \begin{bmatrix} -B_T^{-1/2} M_T B_T^{-1/2} G_T' \Omega_T^{-1} g_T(\theta_0) \\ -(A_T B_T^{-1} A_T')^{-1} A_T B_T^{-1} G_T' \Omega_T^{-1} g_T(\theta_0) \end{bmatrix}$$

The equation above equivalent to:

$$\begin{bmatrix} \sqrt{T}(\bar{\theta} - \theta_0) \\ \sqrt{T}\bar{\gamma} \end{bmatrix} = \begin{bmatrix} -B_T^{-1/2} M_T B_T^{-1/2} G_T' \Omega_T^{-1} \sqrt{T} g_T(\theta_0) \\ -(A_T B_T^{-1} A_T')^{-1} A_T B_T^{-1} G_T' \Omega_T^{-1} \sqrt{T} g_T(\theta_0) \end{bmatrix}$$

Then $\sqrt{T}\bar{\gamma} = -(A_T B_T^{-1} A_T')^{-1} A_T B_T^{-1} G_T' \Omega_T^{-1} \sqrt{T} g_T(\theta_0)$. Since $\sqrt{T} g_T(\theta_0) \underset{d}{\rightarrow} N(0, S)$ where $S = E[g(z_t, \theta) g(z_t, \theta)']$, and for the optimal two-step GMM, $S = \Omega_T$ then:

$$\sqrt{T}\bar{\gamma} \underset{d}{\rightarrow} N(0, (A_T B_T^{-1} A_T')^{-1} A_T B_T^{-1} G_T' \Omega_T^{-1} \Omega_T (\Omega_T^{-1})' G_T (B_T^{-1})' A_T' [(A_T B_T^{-1} A_T')^{-1}]')$$

Since Ω_T is symmetric, so is Ω_T^{-1}, then $(\Omega_T^{-1})' = \Omega_T^{-1}$. The similar explanation can also be used for $B_T \equiv G_T' \Omega_T^{-1} G_T$ and $A_T B_T^{-1} A_T'$, therefore $(B_T^{-1})' = B_T^{-1}$ and $[(A_T B_T^{-1} A_T')^{-1}]' = (A_T B_T^{-1} A_T')^{-1}$. Using those equations above, $\sqrt{T}\bar{\gamma} \underset{d}{\rightarrow} N(0, (A_T B_T^{-1} A_T')^{-1})$. As the purpose of testing whether the Lagrange multipliers are jointly zero, the LM statistic is set:

$$LM = T\bar{\gamma}'(A_T B_T^{-1} A_T')\bar{\gamma} \underset{d}{\rightarrow} \chi^2_{(2p)}$$

With $2p$ is the number of non-linear restrictions which are represented by $a(\theta) = 0$ and also the number of elements in γ.

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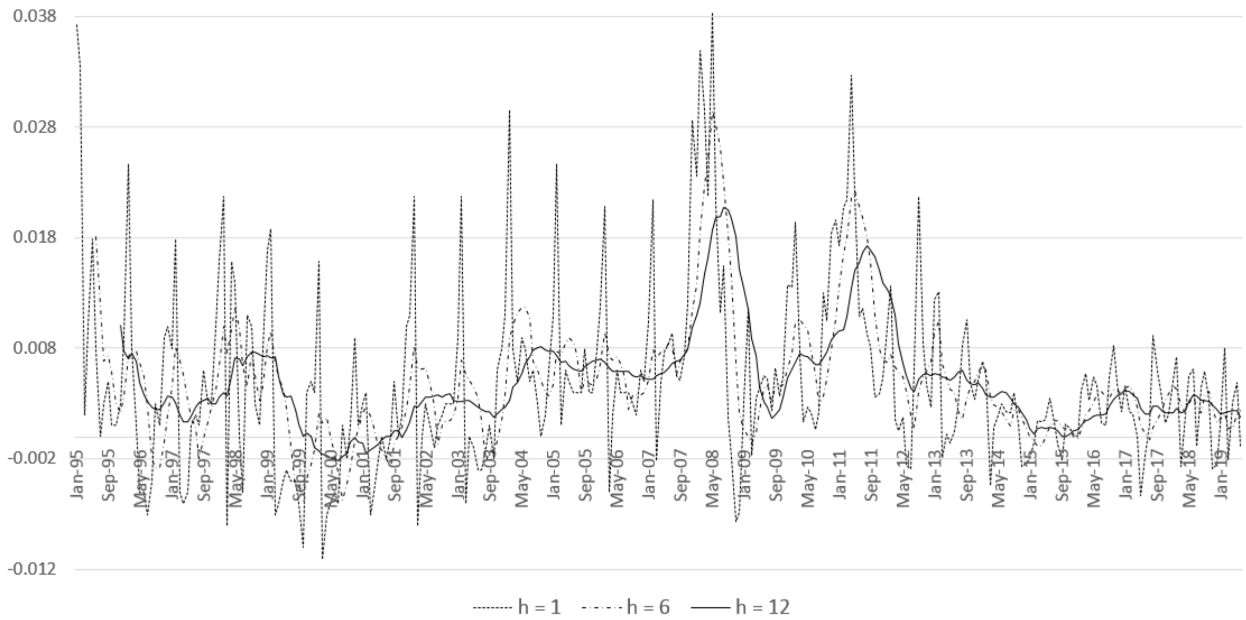

Figure 2.1: Inflation Rate

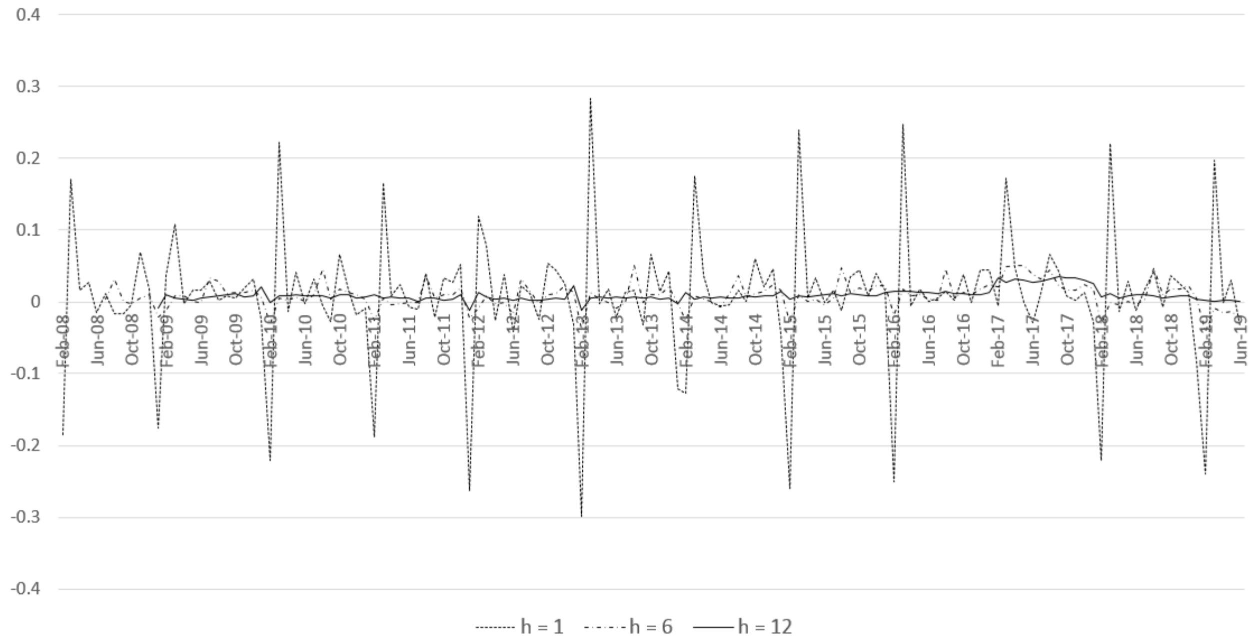

Figure 2.2: Economic Growth

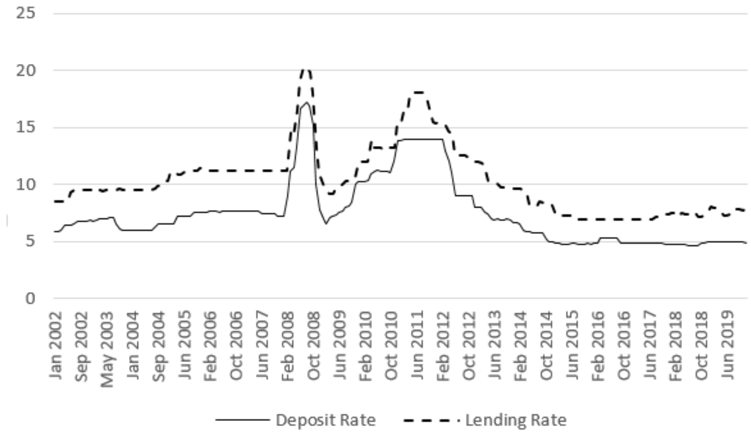

Figure 2.3: Deposit and Lending Interest Rates

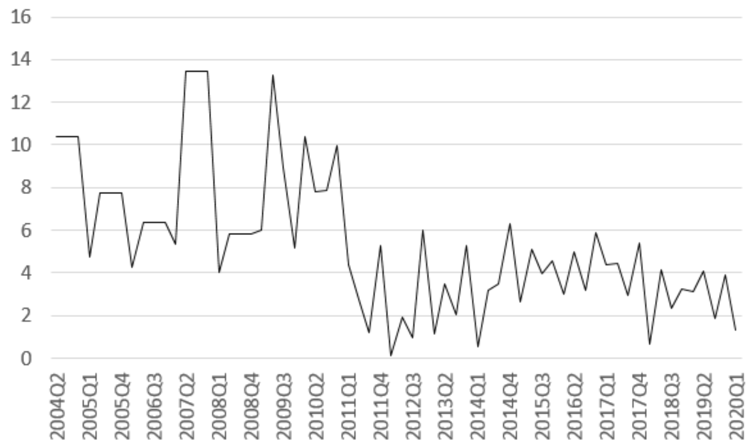

Figure 2.4: Banking Credit Growth Rate

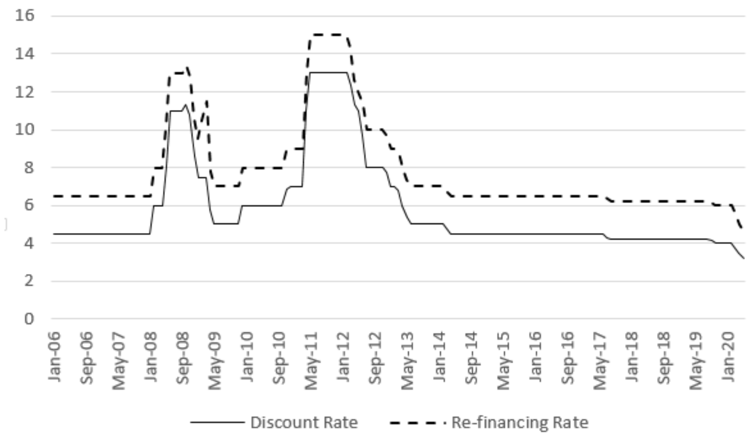

Figure 2.5: Policy Interest Rates of SBV

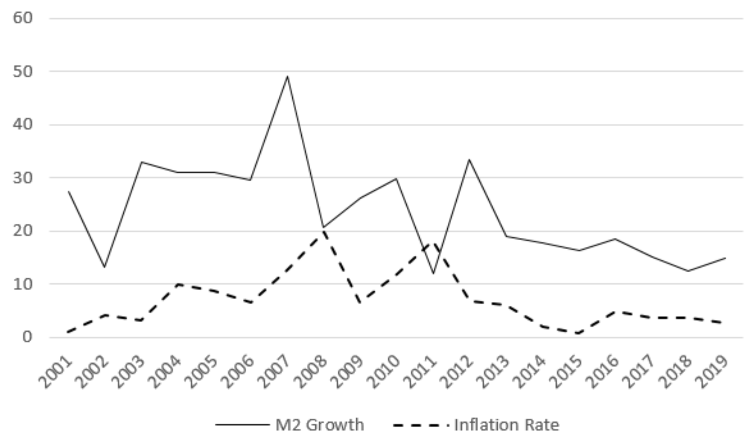

Figure 2.6: Growth Rate of Money Aggregate M2 and Inflation Rate

Table 3.1: All Variables in Forecasting Model

Name	Definition	Period	Frequency	Source
INF	Inflation rate	1995-2019	Monthly	GSO
GROW	Growth rate of industrial production index	2008-2019	Monthly	GSO
M2	Growth rate of money aggregate M2	2000-2019	Quarterly in 2000, Monthly in 2001-2019	SBV
CRE	Growth rate of banking credit	2004-2019	Quarterly in 2004-2011, Monthly in 2012-2019	SBV
VNI	Growth rate of VN Index of Ho Chi Minh Stock Exchange market	2002-2019	Monthly	investing.com
OVN	Averaged overnight interest rate in Vietnam's interbank market	2004-2019	Monthly	SBV
SPREAD6	Spread between averaged overnight and 6-month rates in interbank market	2007-2019	Monthly	SBV
SPREAD9	Spread between averaged overnight and 9-month rates in interbank market	2012-2019	Monthly	SBV
FDI	Growth rate of disbursed foreign direct investment	1996-2019	Quarterly	SBV
OIL	Growth rate of oil price in global market	1995-2019	Monthly	WB
USIPI	Growth rate of IPI of the United States	1995-2019	Monthly	IFS
USCPI	Growth rate of CPI of the United States	1995-2019	Monthly	IFS

Table 3.2: Statistical Summary of Dependent Variables

Variable	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**	**ADF**
INF1	294	0.0051	0.0083	-0.0111	0.0384	-3.4904***
INF6	290	0.0050	0.0055	-0.0057	0.0295	-3.3985**
INF12	284	0.0050	0.0044	-0.0022	0.0208	-2.6873*
GROW1	137	0.0083	0.0918	-0.2980	0.2837	-2.5826*
GROW6	132	0.0087	0.0182	-0.0420	0.0512	-2.6211*
GROW12	127	0.0093	0.0085	-0.0122	0.0359	-2.6101*

Note: ADF means the statistics from the augmented Dickey-Fuller unit root tests. *, ** and *** denote rejections of non-stationarity at the 10%, 5% and 1% significance levels, respectively.

Table 3.3: Statistical Summary of Predictors

Variable	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**	**ADF**
M2	229	0.0180	0.0167	-0.0176	0.1153	-6.0665***
CRE	181	0.0186	0.0121	-0.0187	0.0449	-3.4038*
VNI	201	0.0122	0.0908	-0.2401	0.3852	-10.1355***
OVN	177	-0.0001	0.0137	-0.0757	0.0609	-2.8643*
SPREAD6	150	0.0105	0.0143	-0.0448	0.0507	-4.0246***
SPREAD9	80	0.0216	0.0139	-0.0006	0.0639	-3.4226**
FDI	277	0.0581	0.2112	-0.2605	0.8333	-6.3586***
OIL	294	0.0080	0.0821	-0.2706	0.2244	-13.2726***
USIPI	294	0.0016	0.0192	-0.0498	0.0563	-3.9308***
USCPI	294	0.0018	0.0035	-0.0192	0.0122	-11.2485***

Note: ADF means the statistics from the augmented Dickey-Fuller unit root tests. *, ** and *** denote rejections of non-stationarity at the 10%, 5% and 1% significance levels, respectively.

Table 3.4: Coefficient Means for Inflation Rate Forecast

	INFL1	M2	CRE	SPREAD6	OVN
h = 1	0.0612	0.0490	0.0187	0.0352	0.0179
h = 6	-0.0879	0.0162	0.0443	0.0191	0.0023
h = 12	-0.1180	0.0042	0.0218	0.0269	0.0044

	VNI	FDI	OIL	USIPI	USCPI
h = 1	0.0017	-0.0002	0.0101	-0.0148	0.0885
h = 6	-0.0008	-0.0023	0.0021	-0.0003	-0.0177
h = 12	-0.0002	0.0001	0.0007	0.0000	0.009

Table 3.5: Coefficient Means for Economic Growth Forecast

	GROWL1	INFL1	M2	SPREAD6	SPREAD9
h = 1	-0.2264	-	-0.5822	-	-
h = 6	-0.4747	0.0749	-0.0664	-0.0402	0.0253
h = 12	-0.1993	0.1592	-	0.0273	-0.0139

	VNI	FDI	OIL	USIPI	USCPI
h = 1	-0.0478	-0.0116	0.0715	-0.1685	-
h = 6	0.0013	0.0107	-0.0057	-0.0283	-0.0447
h = 12	0.0011	0.0004	-	-	-0.0149

Table 3.6: Comparing Different Methods in Inflation Rate Forecast

	h=1		h=6		h=12	
	RMSE	MAE	RMSE	MAE	RMSE	MAE
DMA	0.0033	0.0027	0.0014	0.0012	0.0010	0.0008
DMS	0.0033	0.0026	0.0016	0.0013	0.0011	0.0008
Naive	0.0041	0.0034	0.0023	0.0019	0.0016	0.0013
AR(1)	0.0036	0.0028	0.0024	0.0019	0.0020	0.0017
AR(2)	0.0036	0.0028	0.0021	0.0016	0.0019	0.0017
OLS	0.0036	0.0028	0.0029	0.0023	0.0027	0.0022
Rolling OLS	0.0034	0.0027	0.0016	0.0012	0.0014	0.0012
TVP	0.0072	0.0049	0.0047	0.0035	0.0036	0.0028
Small BVAR	0.0044	-	0.0029	-	0.0019	-
Large BVAR	0.0046	-	0.0033	-	0.0029	-

Table 3.7: Comparing Different Methods in Economic Growth Forecast

	h=1		h=6		h=12	
	RMSE	MAE	RMSE	MAE	RMSE	MAE
DMA	0.0866	0.0554	0.0186	0.0123	0.0081	0.0053
DMS	0.0862	0.0573	0.0179	0.0129	0.0091	0.0059
Naive	0.1536	0.0929	0.0336	0.0267	0.0161	0.0133
AR(1)	0.0869	0.0537	0.0229	0.0184	0.0133	0.0109
AR(2)	0.0857	0.0557	0.0213	0.0171	0.0138	0.0120
OLS	0.0848	0.0545	0.0220	0.0176	0.0128	0.0100
Rolling OLS	0.0866	0.0632	0.0217	0.0175	0.0129	0.0104
TVP	0.1012	0.0623	0.0171	0.0127	0.0088	0.0067
Small BVAR	0.0862	-	0.0225	-	0.0177	-
Large BVAR	0.0972	-	0.0205	-	0.0096	-

Table 3.8: Robustness Check for Data Seasonality

	RMSE		MAE	
	Including Lagged Value of Same Month	Not Including	Including Lagged Value of Same Month	Not Including
Panel A: Inflation Rate Forecast				
h = 1	0.0033	0.0033	0.0026	0.0027
h = 6	0.0013	0.0014	0.0011	0.0012
h = 12	0.0010	0.0010	0.0008	0.0010
Panel B: Economic Growth Forecast				
h = 1	0.0610	0.0866	0.0420	0.0554
h = 6	0.0198	0.0186	0.0150	0.0123
h = 12	0.0081	0.0081	0.0053	0.0053

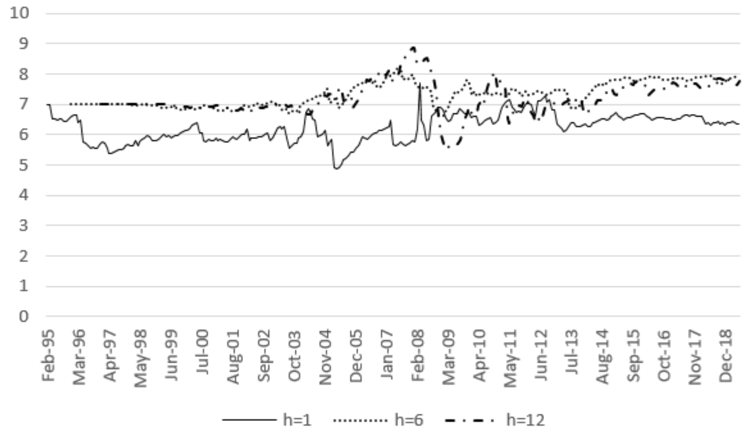

Figure 3.1: Averaged Number of Predictors for Inflation Rate Forecast

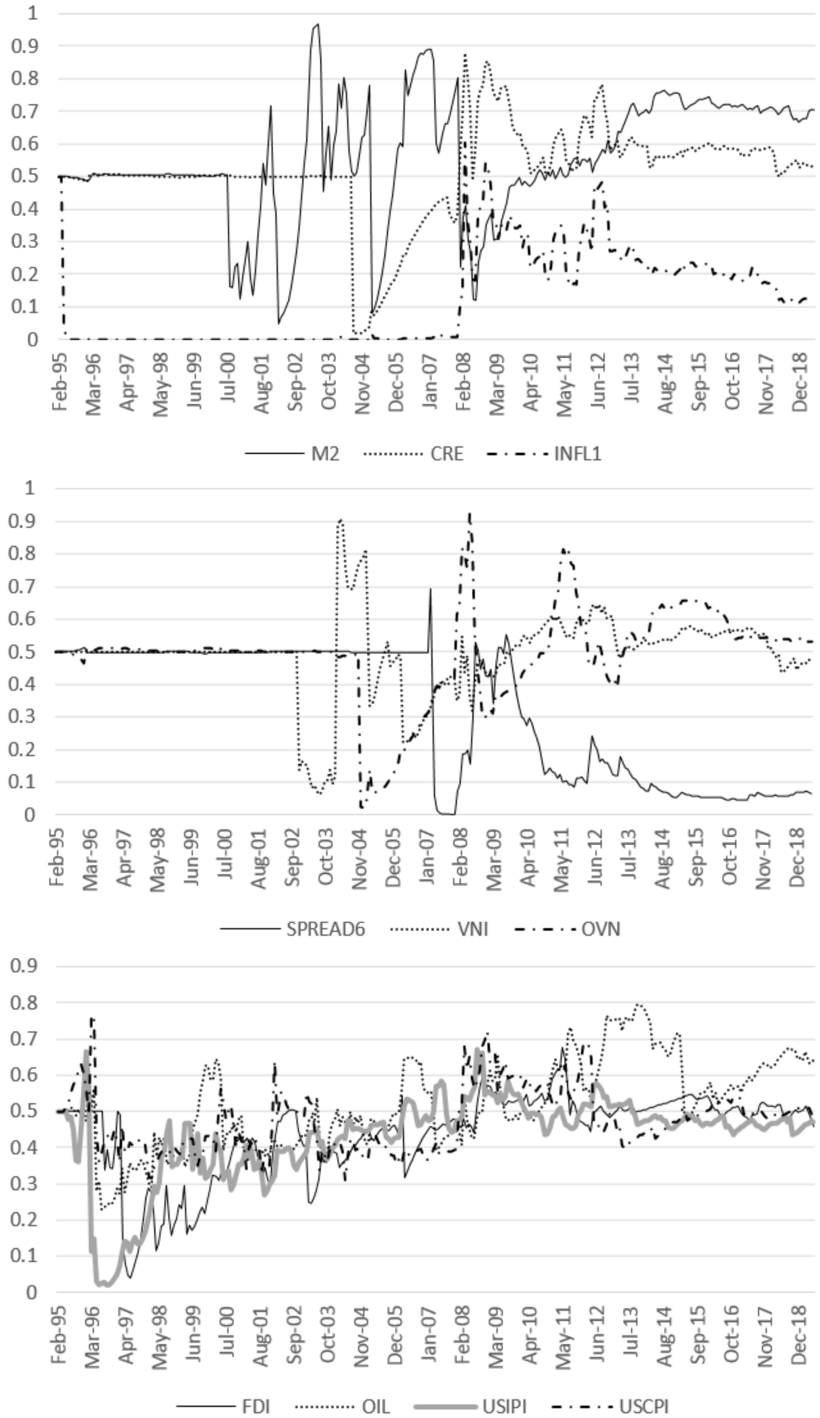

Figure 3.2: Posterior Inclusion Probability of Predictors (Inflation Rate, h = 1)

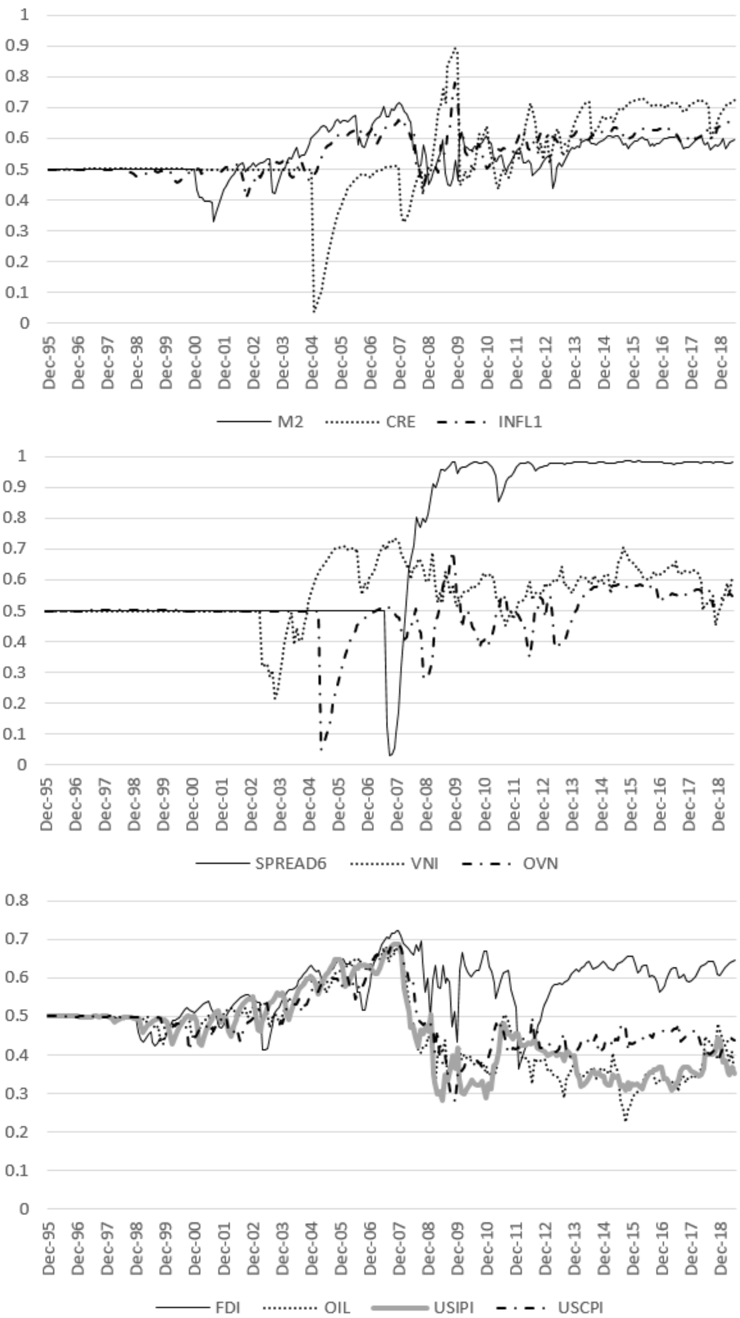

Figure 3.3: Posterior Inclusion Probability of Predictors (Inflation Rate, h = 6)

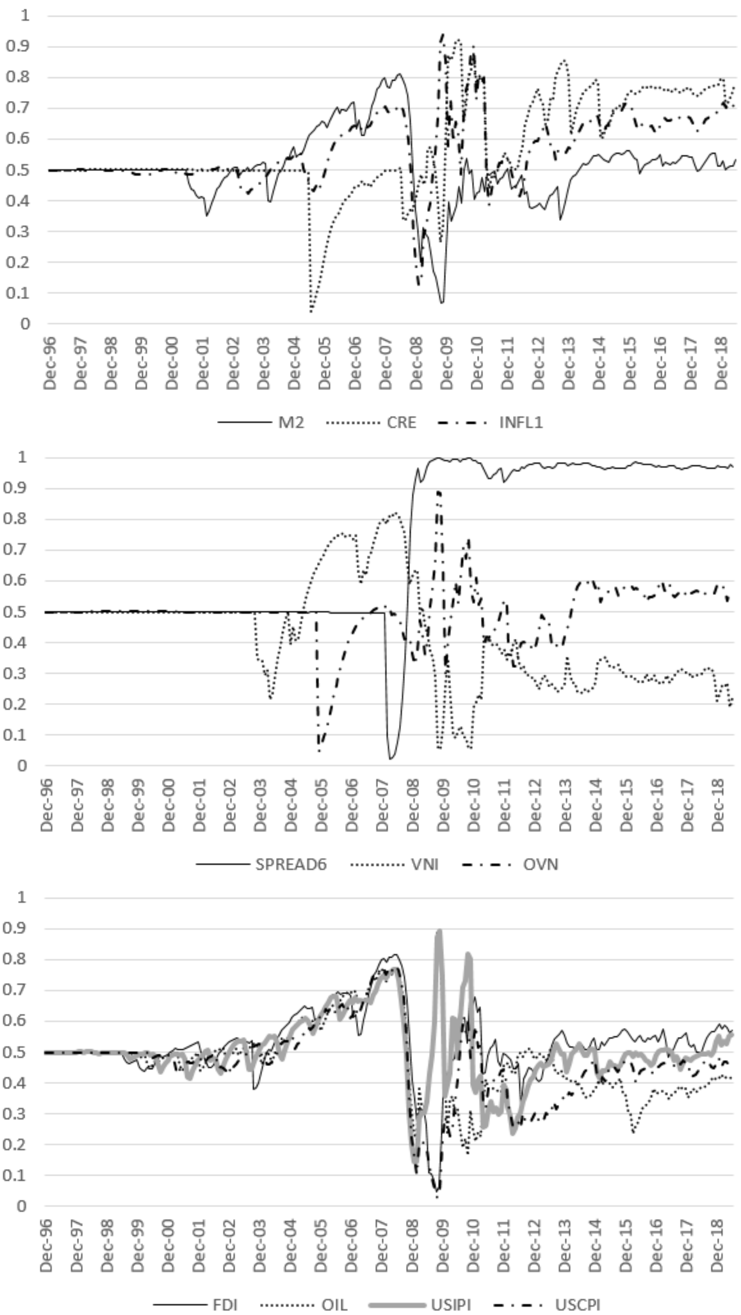

Figure 3.4: Posterior Inclusion Probability of Predictors (Inflation Rate, h = 12)

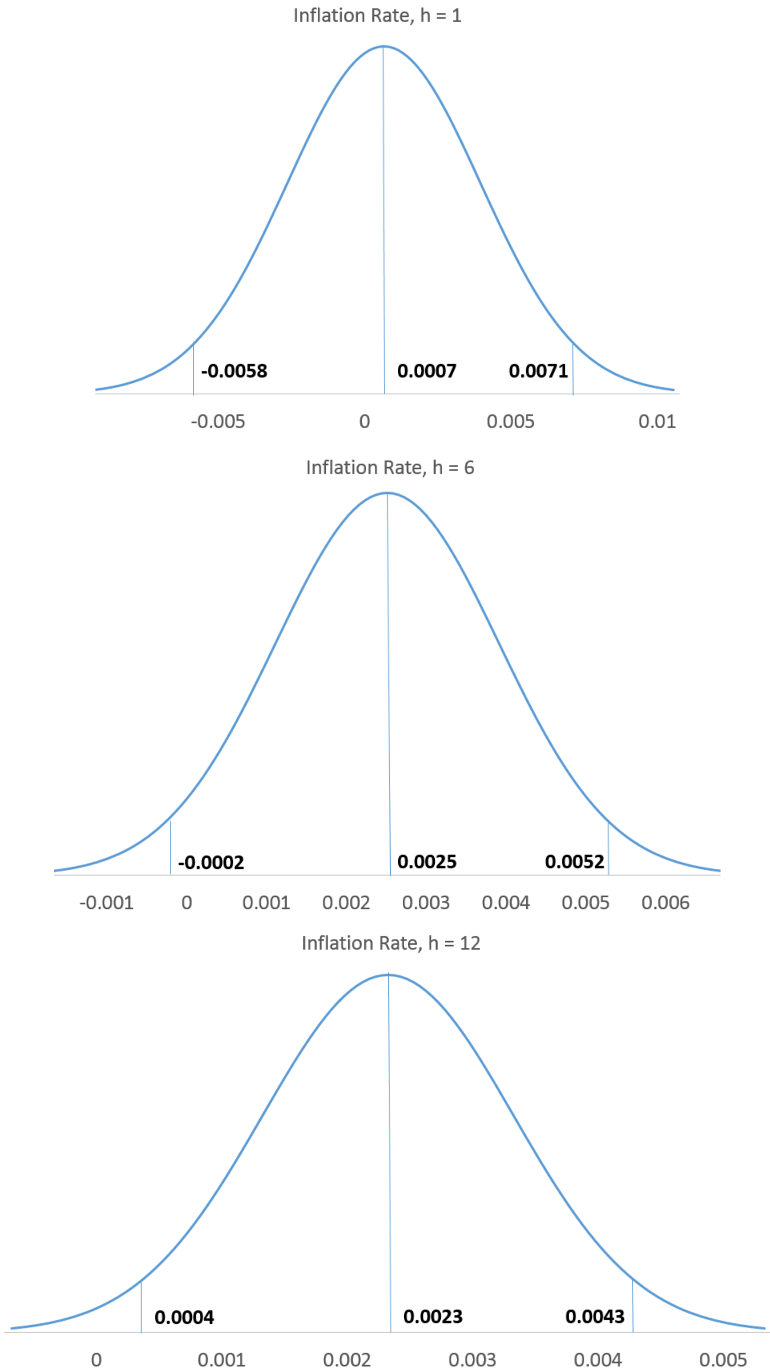

Figure 3.5: Predicted Value Beyond the Data Span and 95% Credible Interval (Inflation Rate)

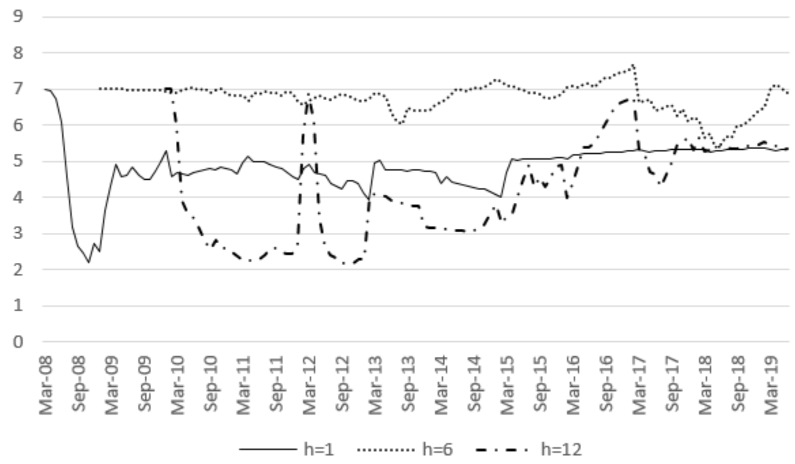

Figure 3.6: Averaged Number of Predictors for Economic Growth Forecast

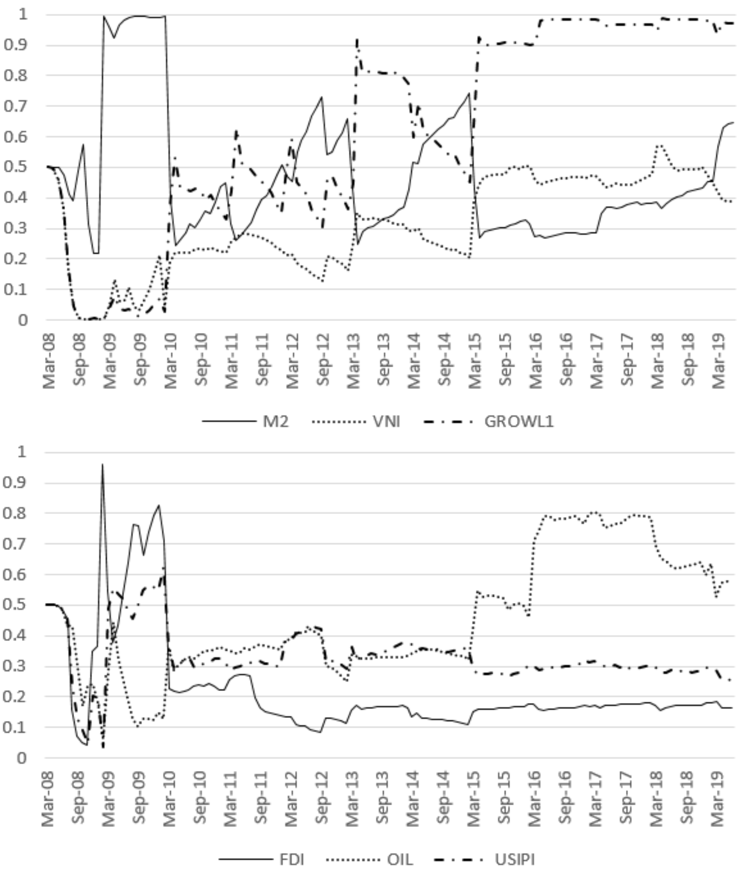

Figure 3.7: Posterior Inclusion Probability of Predictors (Economic Growth, h = 1)

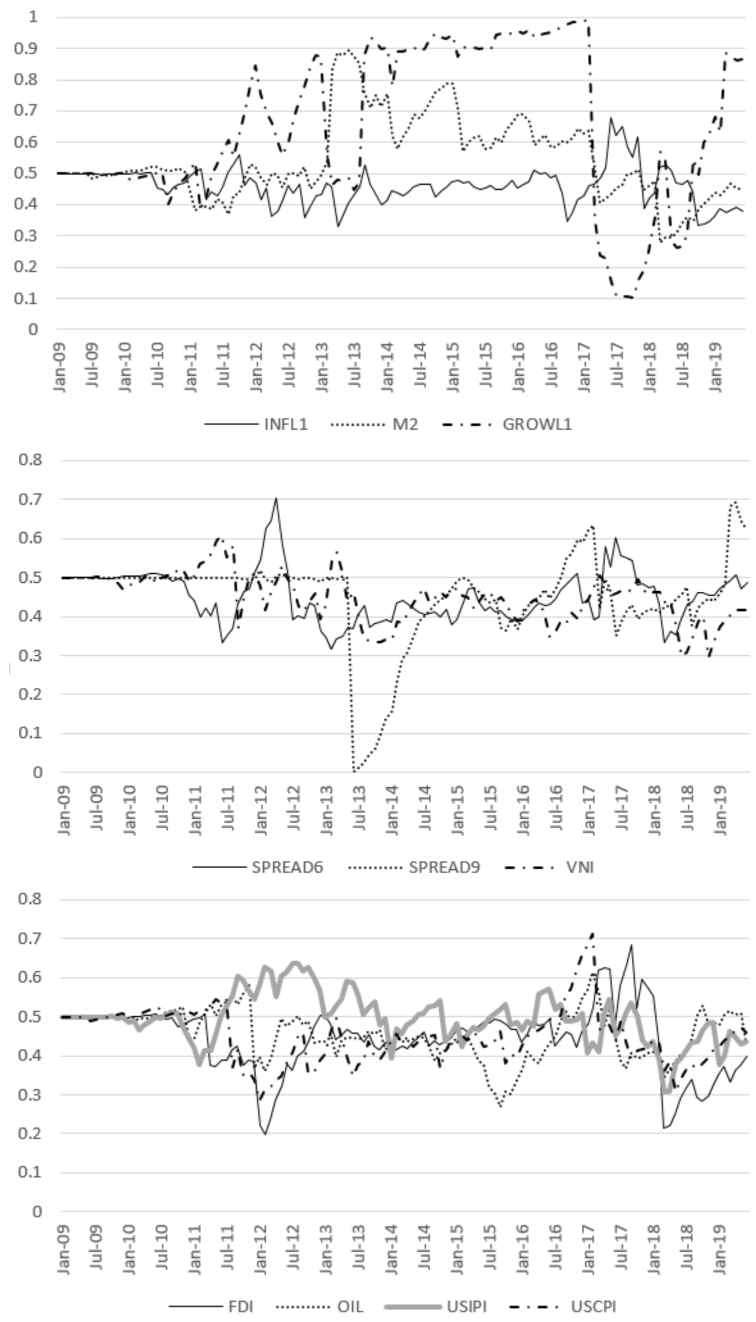

Figure 3.8: Posterior Inclusion Probability of Predictors (Economic Growth, h = 6)

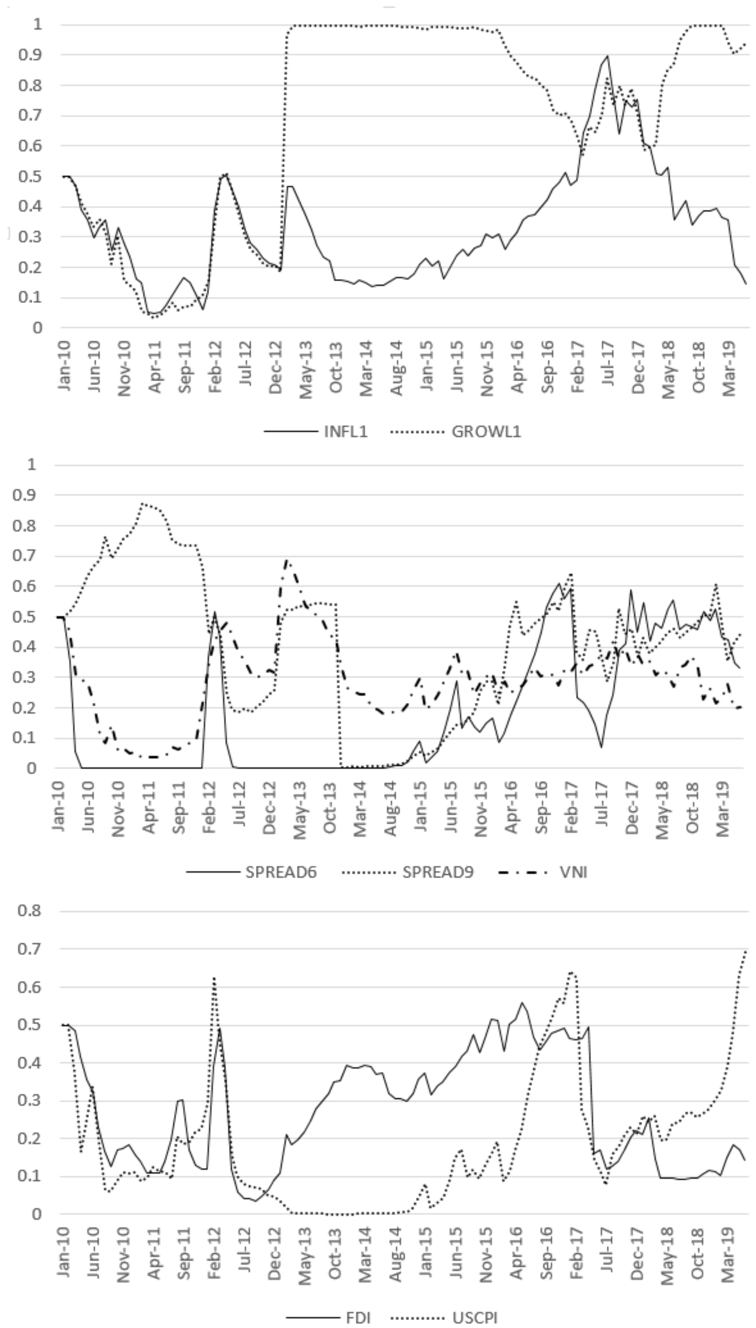

Figure 3.9: Posterior Inclusion Probability of Predictors (Economic Growth, h = 12)

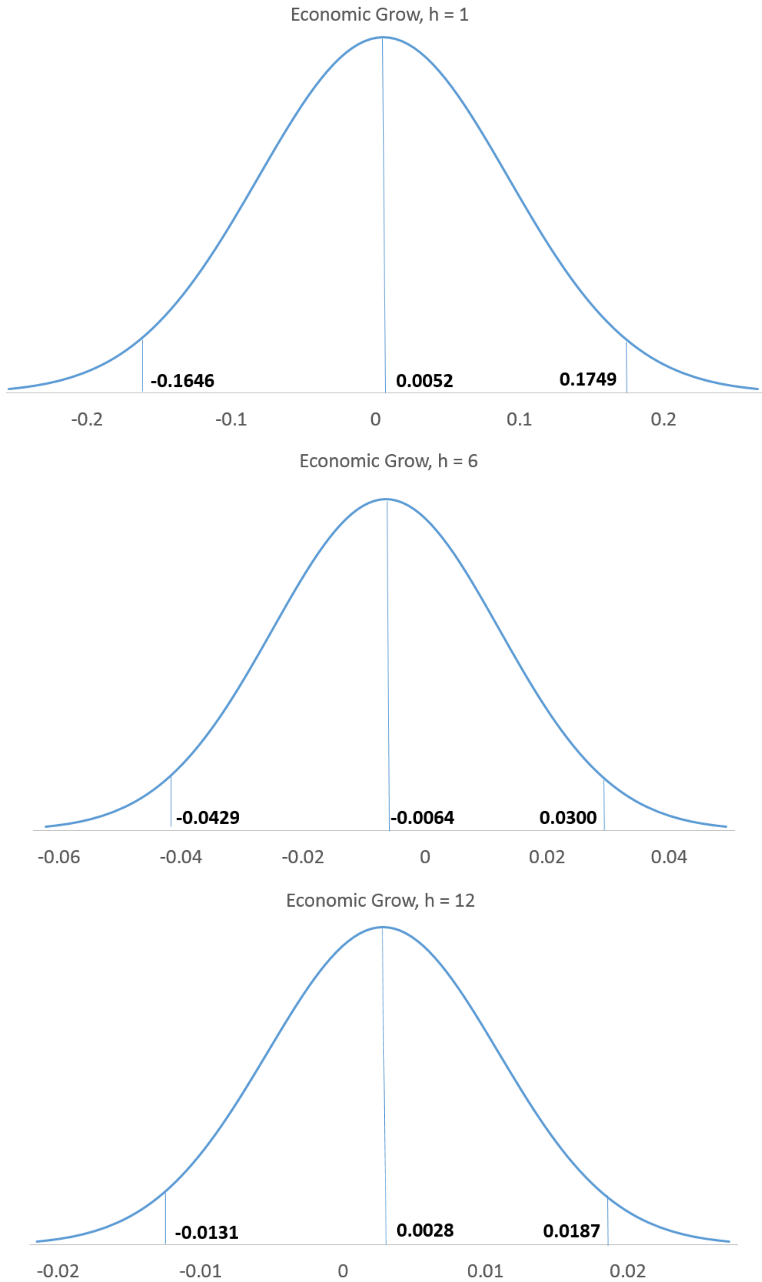

Figure 3.10: Predicted Value Beyond the Data Span and 95% Credible Interval (Economic Growth)

Table 4.1: Descriptive Statistics for Daily Interbank Rates

The table summarizes the descriptive statistics for the daily interbank rates of overnight, 1-week, 2-weeks, 1-month, 3-months and 6-months maturities. The data set consists of 3285 observations of Vietnam's interbank rates from January 2, 2007 to April 17, 2020, quoted in percentage point per annum. Only the days with all rates available are included in the data set. ρ_i denotes the i-th order serial correlation coefficient.

	i_t^{ovn}	i_t^{1w}	i_t^{2w}	i_t^{1m}	i_t^{3m}	i_t^{6m}
$Mean$	5.3740	5.8350	6.1042	6.6805	7.3264	7.7696
$Mean_{Mon}$	5.3932	5.8362	6.1219	6.7268	7.2752	7.7547
$Mean_{Tue}$	5.3834	5.8205	6.1065	6.6315	7.3067	7.8151
$Mean_{Wed}$	5.4224	5.9194	6.1716	6.7275	7.3627	7.8064
$Mean_{Thu}$	5.3394	5.8259	6.1007	6.6880	7.3325	7.7474
$Mean_{Fri}$	5.3130	5.7545	6.0049	6.6237	7.3430	7.7105
$Std\ Dev$	4.0917	4.2109	4.2139	4.0354	3.6281	3.4401
$Std\ Dev_{Mon}$	4.1453	4.2502	4.2900	4.0603	3.5950	3.4204
$Std\ Dev_{Tue}$	4.0681	4.1881	4.1883	4.0316	3.6305	3.4904
$Std\ Dev_{Wed}$	4.0843	4.2178	4.2188	4.0516	3.6476	3.4359
$Std\ Dev_{Thu}$	4.0730	4.2197	4.2039	4.0400	3.6379	3.4267
$Std\ Dev_{Fri}$	4.0801	4.1758	4.1675	4.0038	3.6470	3.4248
Min	0.36	0.37	0.45	1.14	2.04	3
Max	21.48	20.95	20.59	20.2	19.97	21
ρ_1	0.9897	0.9920	0.9925	0.9873	0.9834	0.9742
ρ_2	0.9802	0.9878	0.9886	0.9846	0.9814	0.9683
ρ_3	0.9701	0.9824	0.9840	0.9815	0.9793	0.9636
ρ_4	0.9616	0.9767	0.9800	0.9788	0.9789	0.9587
ρ_5	0.9540	0.9739	0.9764	0.9785	0.9778	0.9578

Table 4.2: Descriptive Statistics for Daily Changes of Interbank Rates

The table summarizes the descriptive statistics for the daily changes of interbank rates of overnight, 1-week, 2-weeks, 1-month, 3-months and 6-months maturities. The daily change is measured from the indicated day to the next business day. The data set consists of 3285 observations of Vietnam's interbank rates from January 2, 2007 to April 17, 2020, quoted in percentage point per annum. Only the days with all rates available are included in the data set. ρ_i denotes the i-th order serial correlation coefficient.

	i_t^{ovn}	i_t^{1w}	i_t^{2w}	i_t^{1m}	i_t^{3m}	i_t^{6m}
$Mean$	-0.0019	-0.0019	-0.0018	-0.0016	-0.0016	-0.0014
$Mean_{Mon}$	0.0008	0.0007	-0.0083	-0.0907	0.0374	0.0431
$Mean_{Tue}$	-0.0246	0.0428	0.0156	0.0365	-0.0072	-0.0528
$Mean_{Wed}$	-0.0584	-0.0819	-0.0555	-0.0292	-0.0315	-0.0556
$Mean_{Thu}$	-0.0399	-0.0719	-0.1021	-0.0660	0.0267	-0.0326
$Mean_{Fri}$	0.1107	0.1014	0.1395	0.1349	-0.0330	0.0905
$Std\ Dev$	0.5868	0.5312	0.5174	0.6435	0.6703	0.7811
$Std\ Dev_{Mon}$	0.6471	0.5277	0.5686	0.6639	0.6310	0.8048
$Std\ Dev_{Tue}$	0.5889	0.5351	0.5098	0.5806	0.5869	0.7906
$Std\ Dev_{Wed}$	0.4731	0.5489	0.4264	0.6293	0.6504	0.8331
$Std\ Dev_{Thu}$	0.6260	0.5248	0.5006	0.5679	0.7044	0.6979
$Std\ Dev_{Fri}$	0.5710	0.4999	0.5434	0.7345	0.7449	0.7675
Min	-6.14	-4.79	-5.46	-5.25	-6.75	-8.42
Max	8.15	4.97	5.34	5.81	8.62	8
ρ_1	-0.0394	-0.2352	-0.2406	-0.3956	-0.4416	-0.3855
ρ_2	0.0303	0.0766	0.0394	0.0206	0.0030	-0.0228
ρ_3	-0.0755	0.0136	-0.0322	-0.0207	-0.0488	0.0024
ρ_4	-0.0486	-0.1769	-0.0255	-0.0912	0.0178	-0.0757
ρ_5	-0.0087	0.1927	0.0030	0.1237	0.0403	0.0296

Table 4.3: Term Premiums for Different Maturities

The table shows term premiums between overnight rate and other interest rates of longer maturities in the interbank market of Vietnam. Term premium is calculated as the difference between the interest rate of indicated maturity and the average overnight rate during the maturity of that interest rate.

Maturity	**Average term rate**	**Average overnight rate**	**Term premium**	**Obs.**
1 week	5.8350	5.3748	0.4602	3281
2 weeks	6.1042	5.3756	0.7285	3276
1 month	6.6805	5.3773	1.3032	3264
3 months	7.3264	5.3946	1.9317	3220
6 months	7.7696	5.4319	2.3377	3154

Table 4.4: Unconstrained VAR Estimation

The table shows the estimated parameters of unconstrained VAR. i_t^n and i_t^m denote the long-term and short-term interest rates, respectively. The estimation of unconstrained VAR process of each combination of long- and short-term interbank rates where $k = n/m$ is an integer is shown in each panel. Standard errors are reported in parentheses.

	i_{t-1}^m	i_{t-1}^n	i_{t-2}^m	i_{t-2}^n	i_{t-3}^m	i_{t-3}^n	i_{t-4}^m	i_{t-4}^n	i_{t-5}^m	i_{t-5}^n
Panel A: Overnight - 1 week										
i_t^m	0.4122	-0.0027	0.2337	-0.0036	0.0841	0.0163	0.1352	0.0204	0.1255	-0.0247
	(0.004)	(0.003)	(0.004)	(0.003)	(0.004)	(0.003)	(0.004)	(0.003)	(0.004)	(0.003)
i_t^n	-0.0225	0.6759	0.0104	0.1910	0.0259	0.0640	-0.0017	-0.0297	0.0199	0.0595
	(0.005)	(0.004)	(0.006)	(0.005)	(0.006)	(0.005)	(0.006)	(0.005)	(0.005)	(0.004)
Panel B: Overnight - 2 weeks										
i_t^m	0.4119	0.0465	0.2310	-0.0325	0.0872	0.0014	0.1395	-0.0118	0.1227	0.0010
	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.005)	(0.004)	(0.005)	(0.004)	(0.004)
i_t^n	0.0222	0.9975	-0.0209	-0.0031	-0.0337	-0.0015	0.0072	0.0001	0.0320	-0.0035
	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.005)	(0.004)	(0.005)	(0.004)	(0.004)
Panel C: Overnight - 1 month										
i_t^m	0.4121	0.0590	0.2336	-0.0068	0.0872	-0.0255	0.1387	-0.0579	0.1230	0.0276
	(0.004)	(0.012)	(0.004)	(0.019)	(0.004)	(0.020)	(0.004)	(0.019)	(0.004)	(0.012)
i_t^n	0.0003	1.2770	-0.0008	-0.37367	-0.0035	0.0505	0.0067	-0.0415	-0.0054	0.0408
	(0.001)	(0.004)	(0.001)	(0.006)	(0.001)	(0.006)	(0.001)	(0.006)	(0.001)	(0.004)
Panel D: Overnight - 3 months										
i_t^m	0.3798	0.1095	0.2180	-0.0397	0.0797	0.0101	0.1380	0.0155	0.1273	-0.0447
	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.005)	(0.004)	(0.005)	(0.004)	(0.004)
i_t^n	-0.0117	0.9343	0.0077	0.0897	0.0120	-0.1086	-0.0085	0.0178	0.0310	0.0349
	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.005)	(0.004)	(0.005)	(0.004)	(0.004)
Panel E: Overnight - 6 months										
i_t^m	0.3681	0.0937	0.2145	0.0480	0.0859	-0.0028	0.1407	-0.0669	0.1242	-0.0151
	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.005)	(0.004)	(0.005)	(0.004)	(0.004)
i_t^n	-0.0028	0.7661	-0.0308	0.2706	0.0277	-0.0314	0.0537	-0.1783	-0.0442	0.1661
	(0.003)	(0.004)	(0.003)	(0.005)	(0.004)	(0.005)	(0.003)	(0.005)	(0.003)	(0.004)
Panel F: 1 week - 2 weeks										
i_t^m	0.6831	0.0473	0.1934	-0.0865	0.0691	0.0305	-0.0294	0.0048	0.0678	0.0096
	(0.004)	(0.005)	(0.005)	(0.008)	(0.005)	(0.008)	(0.005)	(0.008)	(0.004)	(0.005)
i_t^n	0.0212	0.9983	-0.0153	-0.0049	0.0046	0.0011	-0.0145	-0.0021	0.0090	-0.0015
	(0.003)	(0.004)	(0.003)	(0.005)	(0.003)	(0.005)	(0.003)	(0.005)	(0.003)	(0.004)
Panel G: 1 month - 3 months										
i_t^m	1.2700	0.0119	-0.3332	-0.0088	0.0547	-0.0059	-0.0425	0.0038	0.0422	-0.0031
	(0.004)	(0.001)	(0.006)	(0.002)	(0.006)	(0.002)	(0.006)	(0.002)	(0.004)	(0.001)
i_t^n	0.3759	0.9151	-0.4003	0.1023	0.0575	-0.1008	-0.0319	0.0226	-0.0157	0.0517
	(0.012)	(0.004)	(0.019)	(0.005)	(0.020)	(0.005)	(0.019)	(0.005)	(0.012)	(0.004)
Panel H: 1 month - 6 months										
i_t^m	1.2680	0.0182	-0.3344	-0.0088	0.0536	-0.0051	-0.0388	-0.0043	0.0429	-0.0020
	(0.004)	(0.001)	(0.006)	(0.002)	(0.006)	(0.002)	(0.006)	(0.002)	(0.004)	(0.001)
i_t^n	0.3867	0.7319	-0.3364	0.2713	-0.0421	-0.0156	0.0401	-0.1666	-0.0590	0.1733
	(0.010)	(0.004)	(0.016)	(0.005)	(0.017)	(0.005)	(0.016)	(0.005)	(0.010)	(0.004)
Panel I: 3 months - 6 months										
i_t^m	0.8290	0.2213	0.0573	0.0127	-0.0882	-0.1174	0.0143	0.0143	0.0249	0.0204
	(0.004)	(0.005)	(0.005)	(0.006)	(0.005)	(0.006)	(0.005)	(0.006)	(0.004)	(0.005)
i_t^n	0.2975	0.5548	-0.0619	0.2281	-0.0472	0.0057	0.0151	-0.0830	-0.1702	0.2592
	(0.003)	(0.004)	(0.004)	(0.005)	(0.004)	(0.005)	(0.004)	(0.005)	(0.004)	(0.004)

Table 4.5: Constrained VAR Estimation

The table shows the estimated parameters of constrained VAR. i_t^n and i_t^m denote the long-term and short-term interest rates, respectively. The estimation of constrained VAR process of each combination of long- and short-term interbank rates where $k = n/m$ is an integer is shown in each panel. Standard errors are reported in parentheses.

	i_{t-1}^m	i_{t-1}^n	i_{t-2}^m	i_{t-2}^n	i_{t-3}^m	i_{t-3}^n	i_{t-4}^m	i_{t-4}^n	i_{t-5}^m	i_{t-5}^n
Panel A: Overnight - 1 week										
i_t^m	0.5911	0.6082	-0.1184	-0.9603	-0.5426	0.2671	0.6592	-0.0050	0.4092	0.0835
	(0.297)	(0.251)	(0.311)	(0.281)	(0.308)	(0.281)	(0.329)	(0.265)	(0.294)	(0.235)
i_t^n	0.9761	0.5943	-1.2090	-0.0248	-0.9229	-0.0340	0.8892	0.0368	0.2735	0.4102
	(0.317)	(0.224)	(0.320)	(0.269)	(0.352)	(0.265)	(0.319)	(0.266)	(0.314)	(0.221)
Panel B: Overnight - 2 week										
i_t^m	0.7066	0.6785	0.2876	-0.4299	0.1823	-0.1501	0.0291	-0.0120	-0.2135	-0.0770
	(0.225)	(0.261)	(0.242)	(0.315)	(0.248)	(0.323)	(0.243)	(0.301)	(0.229)	(0.247)
i_t^n	-0.4733	1.997	-0.1521	-0.7999	0.6078	0.1980	0.3206	-0.0983	-0.3250	-0.2764
	(0.081)	(0.098)	(0.103)	(0.151)	(0.102)	(0.161)	(0.093)	(0.175)	(0.082)	(0.103)
Panel C: Overnight - 1 month										
i_t^m	0.4922	-2.0320	0.3428	3.8810	0.0298	-1.6180	0.1592	-1.2650	-0.0278	1.0330
	(0.161)	(0.533)	(0.164)	(1.042)	(0.165)	(1.159)	(0.164)	(1.051)	(0.151)	(0.550)
i_t^n	0.1891	3.0310	-0.6559	-4.4000	1.5600	4.1720	-1.3340	-2.1660	0.2289	0.3374
	(0.173)	(0.699)	(0.197)	(1.140)	(0.191)	(1.119)	(0.194)	(1.080)	(0.184)	(0.650)
Panel D: Overnight - 3 months										
i_t^m	0.4726	0.3201	0.2839	0.0488	0.1304	0.1035	0.2363	-0.2906	-0.2599	-0.0520
	(0.178)	(0.156)	(0.170)	(0.208)	(0.171)	(0.205)	(0.173)	(0.204)	(0.168)	(0.164)
i_t^n	-0.0122	1.0120	-0.0004	0.0002	-0.0001	0.0003	0.0000	0.0004	0.0003	0.0000
	(0.142)	(0.146)	(0.151)	(0.192)	(0.153)	(0.184)	(0.157)	(0.191)	(0.150)	(0.146)
Panel E: Overnight - 6 months										
i_t^m	0.2883	0.3435	0.1962	0.1870	0.1586	-0.0372	0.3307	-0.3300	-0.1091	-0.0425
	(0.175)	(0.178)	(0.165)	(0.226)	(0.168)	(0.229)	(0.167)	(0.223)	(0.171)	(0.187)
i_t^n	-0.0058	1.0060	-0.0002	0.0000	-0.0001	0.0001	0.0000	0.0001	0.0000	0.0000
	(0.129)	(0.124)	(0.135)	(0.171)	(0.132)	(0.169)	(0.142)	(0.156)	(0.121)	(0.137)
Panel F: 1 week - 2 weeks										
i_t^m	2.1860	-2.3660	-0.5464	1.8540	-1.2330	1.2280	-0.8124	-1.8380	1.3700	1.1580
	(0.420)	(0.779)	(0.524)	(1.016)	(0.494)	(0.954)	(0.518)	(0.961)	(0.427)	(0.739)
i_t^n	0.0575	1.3030	-0.1044	-0.4193	-0.0260	0.1377	-0.0572	0.0142	0.1423	-0.0469
	(0.107)	(0.163)	(0.117)	(0.228)	(0.115)	(0.235)	(0.107)	(0.227)	(0.110)	(0.144)
Panel G: 1 month - 3 months										
i_t^m	3.2580	-0.1356	-2.0860	0.1867	-1.3080	0.0247	1.6880	-0.1183	-0.5438	0.0447
	(0.235)	(0.059)	(0.380)	(0.078)	(0.384)	(0.079)	(0.383)	(0.082)	(0.220)	(0.066)
i_t^n	4.3820	-0.1730	-9.5680	0.7855	8.3100	0.5762	-3.2740	-0.3119	0.1464	0.1155
	(0.471)	(0.143)	(0.804)	(0.189)	(0.820)	(0.188)	(0.815)	(0.190)	(0.460)	(0.137)
Panel H: 1 month - 6 months										
i_t^m	1.1460	-0.1179	-0.0048	0.0893	0.1763	0.0570	-0.4799	0.0601	0.1539	-0.0913
	(0.182)	(0.051)	(0.283)	(0.060)	(0.283)	(0.065)	(0.284)	(0.064)	(0.161)	(0.057)
i_t^n	1.0730	-0.4358	-1.3790	1.8700	0.8467	-0.6298	0.0211	-0.6303	-0.5679	0.8165
	(0.631)	(0.179)	(1.072)	(0.234)	(1.114)	(0.232)	(1.069)	(0.224)	(0.634)	(0.175)
Panel I: 3 months - 6 months										
i_t^m	0.7350	0.3819	-0.0040	-0.0230	-0.1711	-0.2825	0.4043	-0.2556	-0.1924	0.3923
	(0.192)	(0.185)	(0.211)	(0.230)	(0.210)	(0.228)	(0.218)	(0.227)	(0.191)	(0.199)
i_t^n	-0.1332	1.1920	-0.0020	-0.0115	-0.0855	-0.1413	0.2021	-0.1278	-0.0962	0.1961
	(0.223)	(0.189)	(0.227)	(0.205)	(0.218)	(0.188)	(0.233)	(0.194)	(0.222)	(0.172)

Table 4.6: Statistical Tests on Expectation Hypothesis

The table reports the p-values of the Lagrange multiplier (LM) and distance metric (DM) statistics under the null hypothesis that the EH holds for each combination of long-term rate i_t^n and short-term rate i_t^m such that $k = n/m$ is an integer. 0 denotes p-values below 0.0001.

	i_t^{1w}/i_t^{ovn}	i_t^{2w}/i_t^{ovn}	i_t^{1m}/i_t^{ovn}	i_t^{3m}/i_t^{ovn}	i_t^{6m}/i_t^{ovn}	i_t^{2w}/i_t^{1w}	i_t^{3m}/i_t^{1m}	i_t^{6m}/i_t^{1m}	i_t^{6m}/i_t^{3m}
LM	0	0	0	0	0	0	0	0	0.0001
DM	0	0	0	0	0	0	0	0	0

Table 5.1: Statistical Summary of Variables

Variable	**Mean**	**Std. Dev.**	**Min**	**Max**	**ADF**
GDP	0.9666	8.6555	-29.8022	28.3742	-7.0424***
INF	0.5997	0.7696	-0.7629	3.8355	-4.3747***
CRE	1.7138	1.1607	-1.8650	4.4909	-3.5621**
M2	1.7598	1.7136	-1.7549	11.5329	-6.1833***

Note: ADF means the statistics from the augmented Dickey-Fuller unit root tests. *, ** and *** denote rejections of non-stationarity at the 10%, 5% and 1% significance levels, respectively.

Table 5.2: Statistical Summary of GDP Data

Data	**Period**	**Mean**	**Std. Dev.**	**Min**	**Max**
Real GDP growth rate	2004Oct-2007Dec	1.1019	7.5348	-18.2494	17.9671
IPI growth rate	2008Jan-2019Dec	0.9299	8.9587	-29.8022	28.3742

Table 5.3: Log-likelihood and BIC Values of Models with Different Numbers of Heteroskedastic Error

	$r_1 = 0$	$r_1 = 1$	$r_1 = 2$	$r_1 = 3$	$r_1 = 4$
Log-likelihood	-1404.56	-1351.1	-1363.69	-1331.11	-1320.54
BIC	-1404.56	-1356.3	-1371.49	-1341.51	-1333.54

Note: r_1 is the number of heteroskedastic component in error term ϵ_t, therefore r_1 is an integer and $r_1 \leq 4$

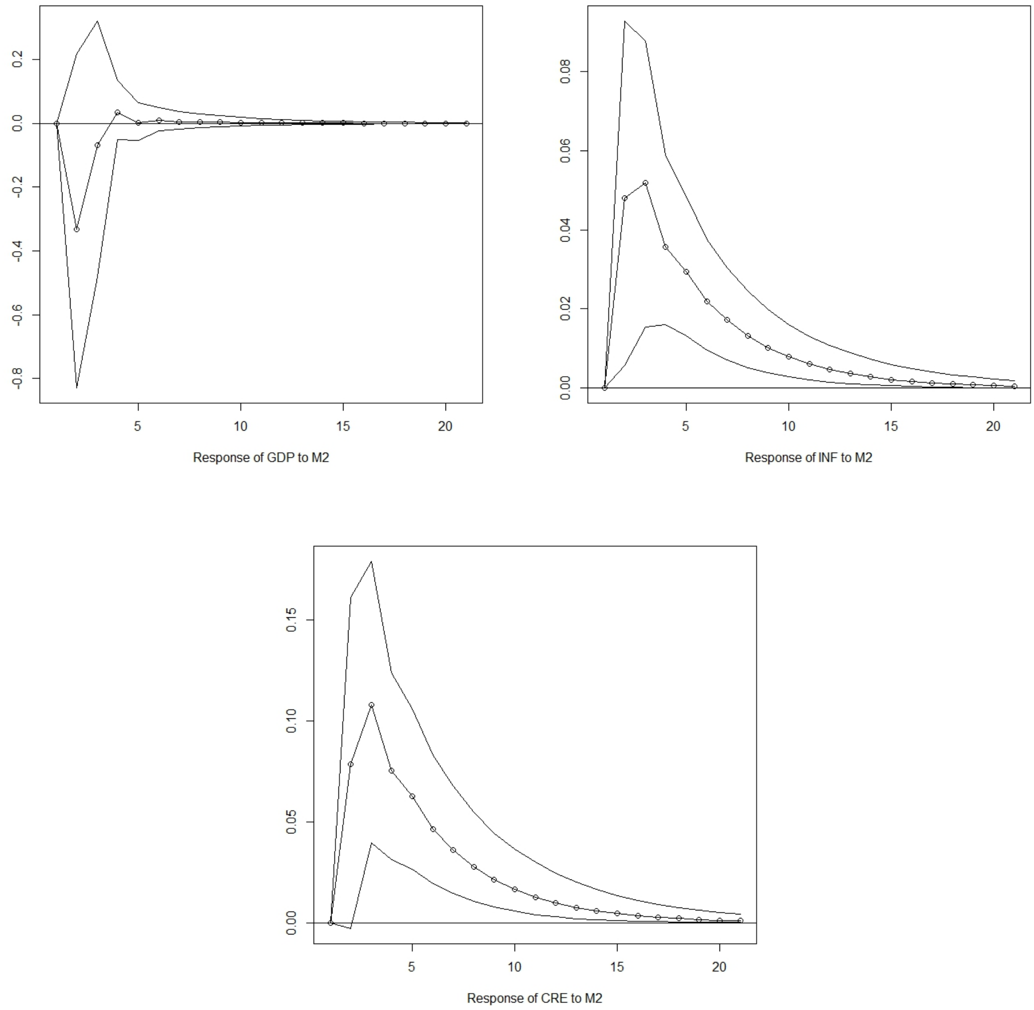

Figure 5.1: Response of Variables to the Shock to M2 in BVAR (x-axis is horizon measured in months, y-axis shows responses of variables measured in percentage points)

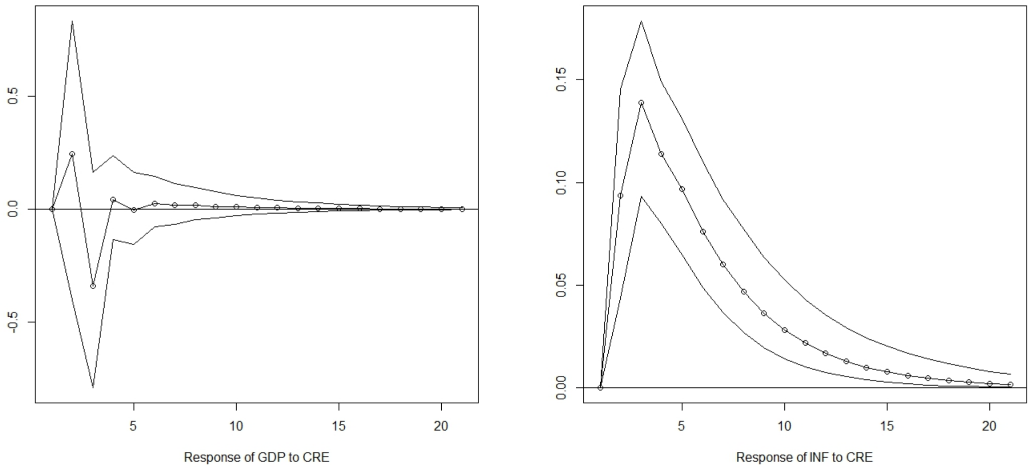

Figure 5.2: Response of Variables to the Shock to CRE in BVAR (x-axis is horizon measured in months, y-axis shows responses of variables measured in percentage points)

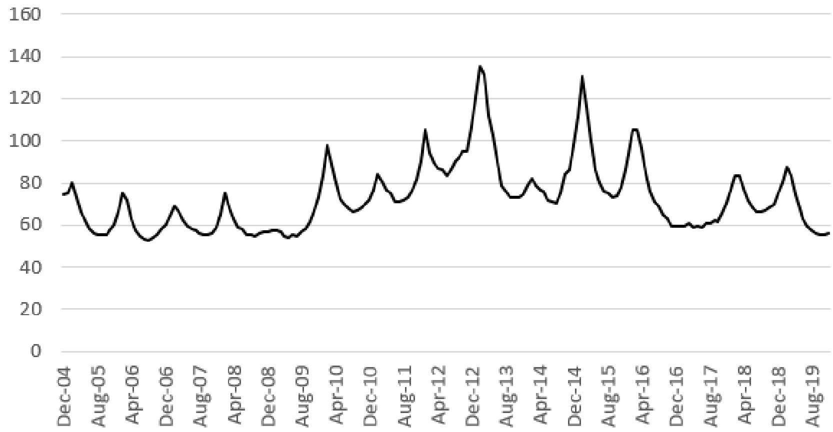

Figure 5.3: Estimated Volatility of GDP

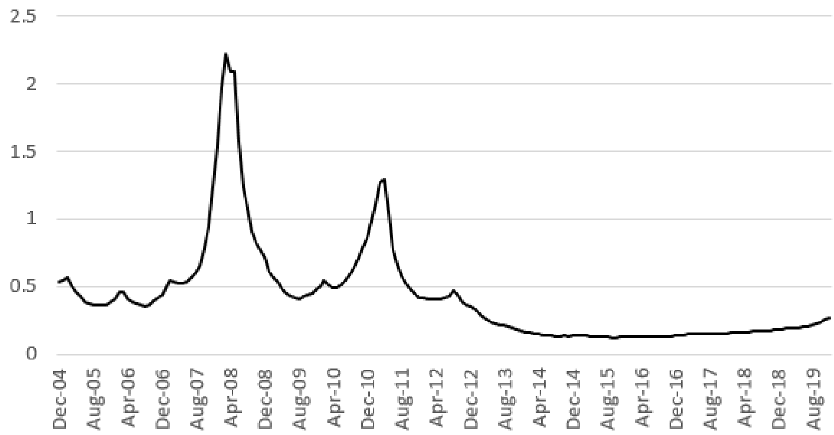

Figure 5.4: Estimated Volatility of INF

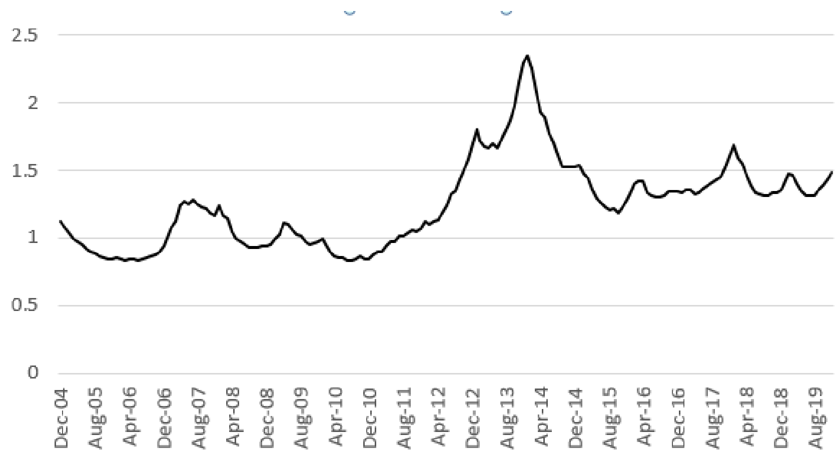

Figure 5.5: Estimated Volatility of CRE

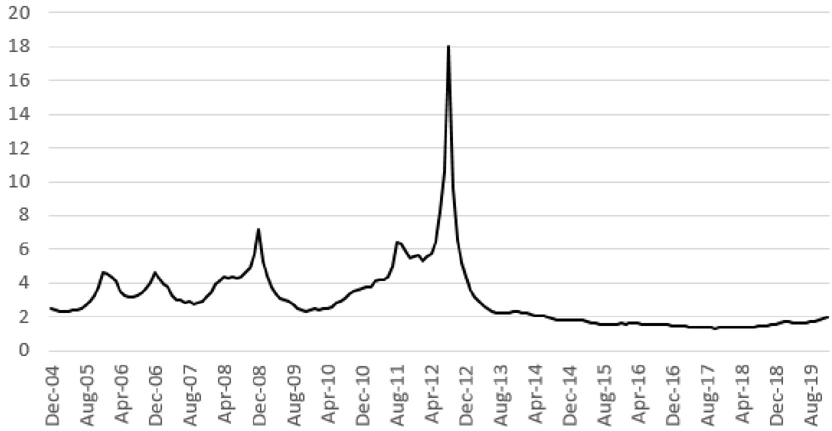

Figure 5.6: Estimated Volatility of M2

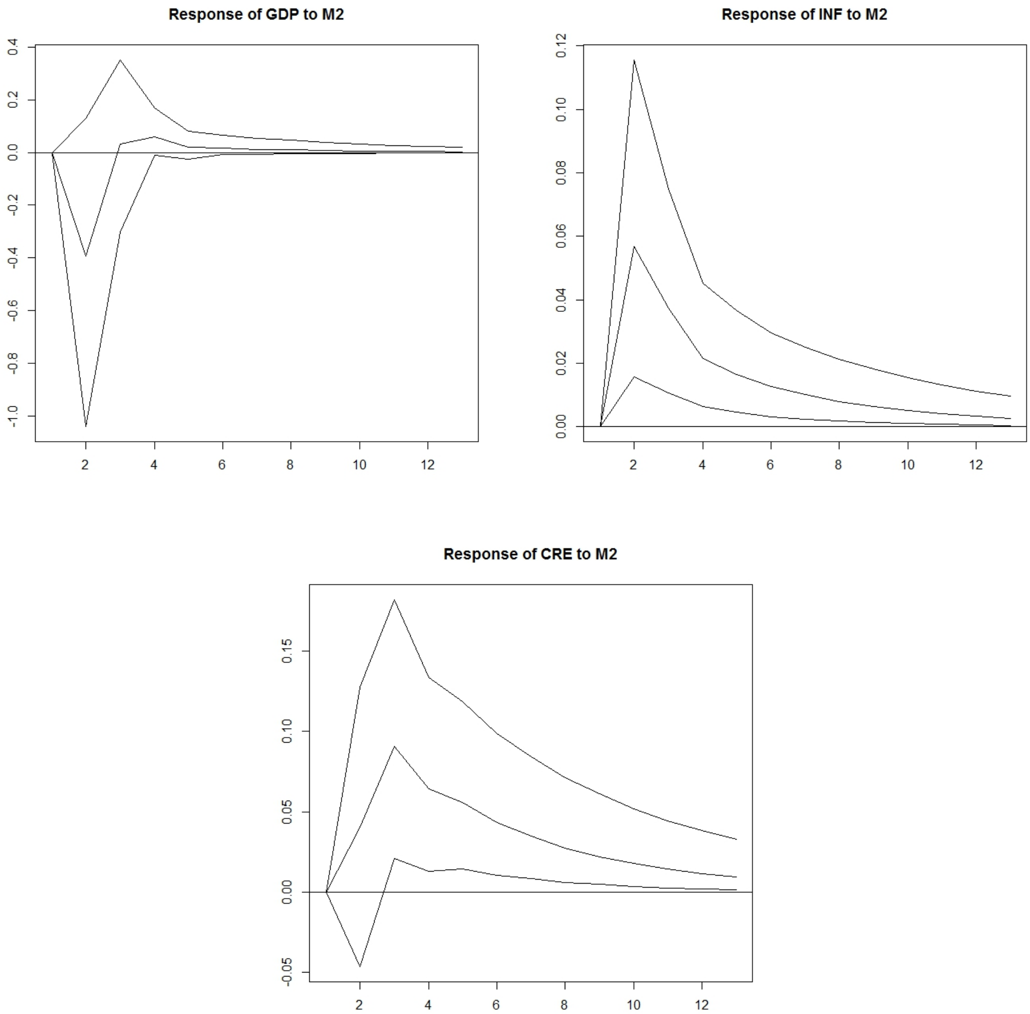

Figure 5.7: Responses of Variables to the Shock to M2 in BVAR-SV Using Stationary Var-Cov Matrix (x-axis is horizon measured in months, y-axis shows responses of variables measured in percentage points)

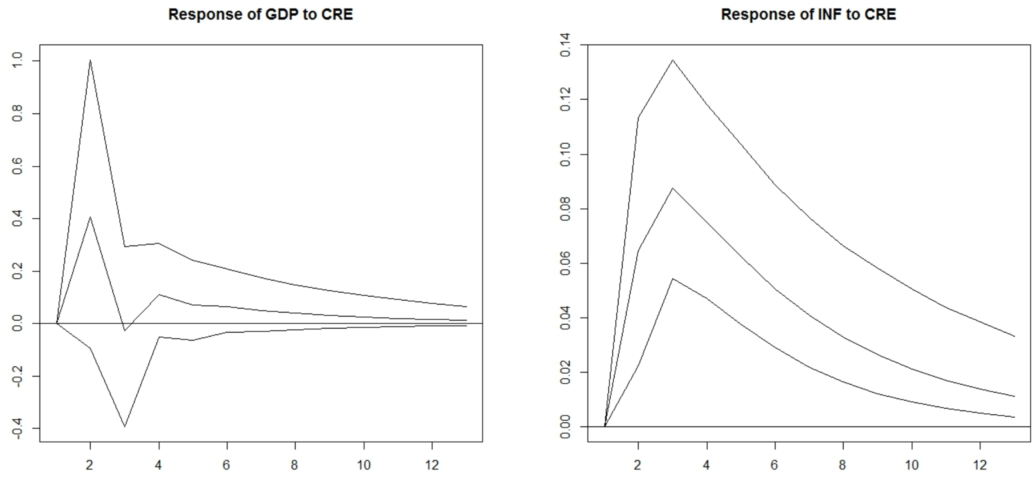

Figure 5.8: Responses of Variables to the Shock to CRE in BVAR-SV Using Stationary Var-Cov Matrix (x-axis is horizon measured in months, y-axis shows responses of variables measured in percentage points)

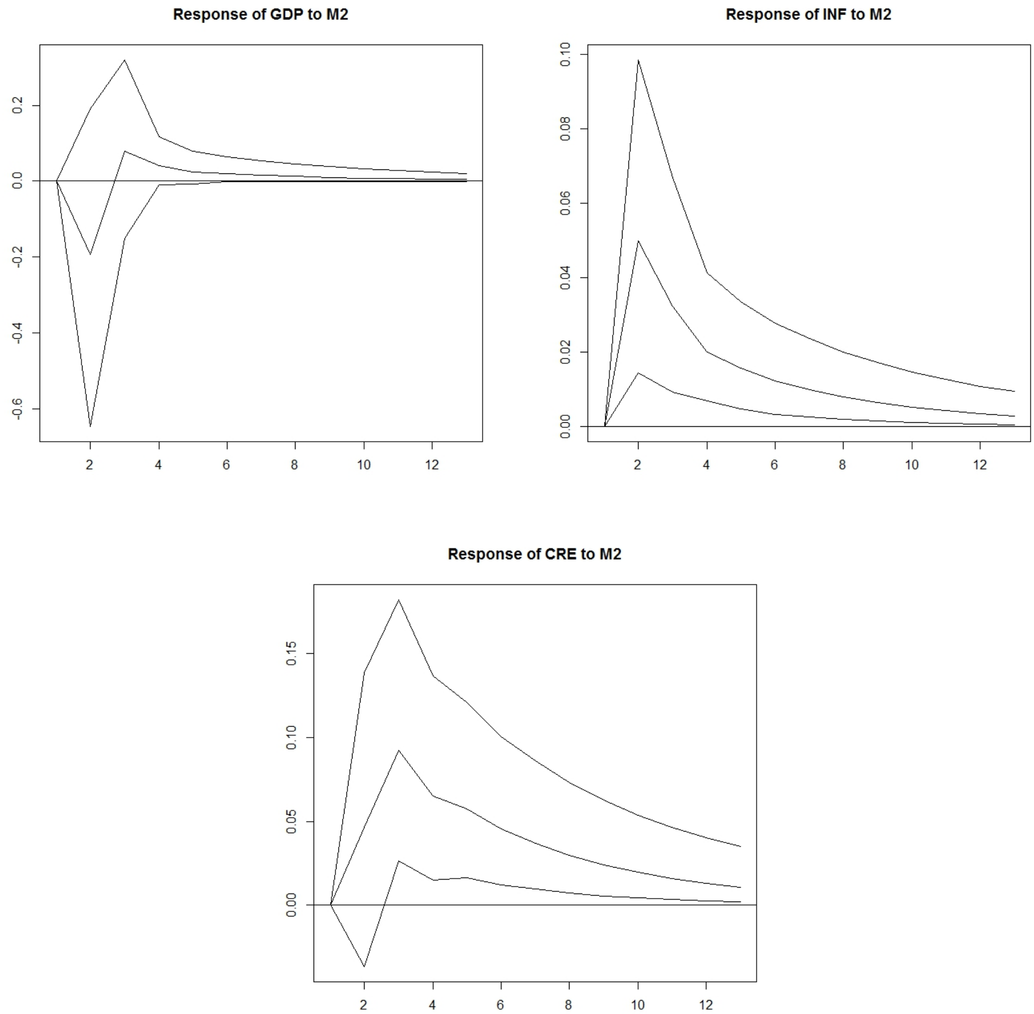

Figure 5.9: Responses of Variables to the Shock to M2 in BVAR-SV Using Var-Cov Matrix in 2008 March (x-axis is horizon measured in months, y-axis shows responses of variables measured in percentage points)

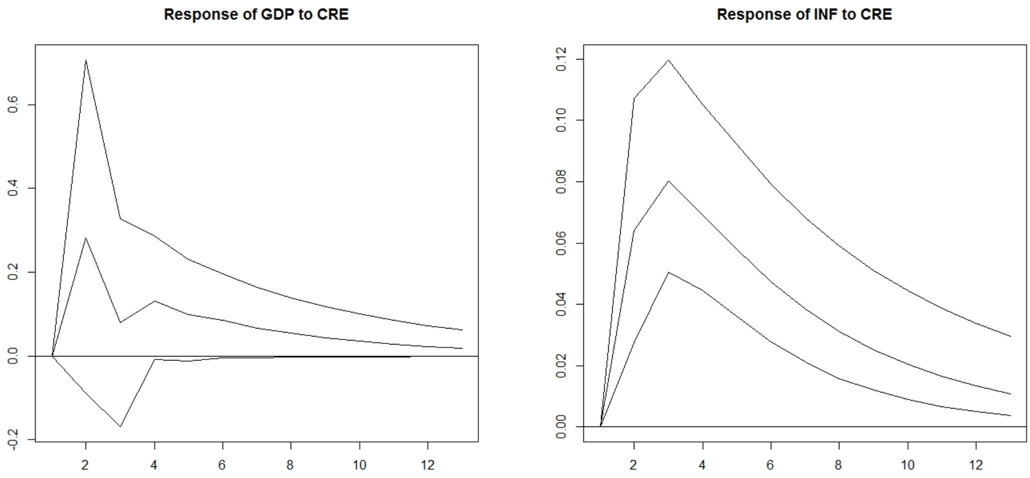

Figure 5.10: Responses of Variables to the Shock to CRE in BVAR-SV Using Var-Cov Matrix in 2008 March (x-axis is horizon measured in months, y-axis shows responses of variables measured in percentage points)

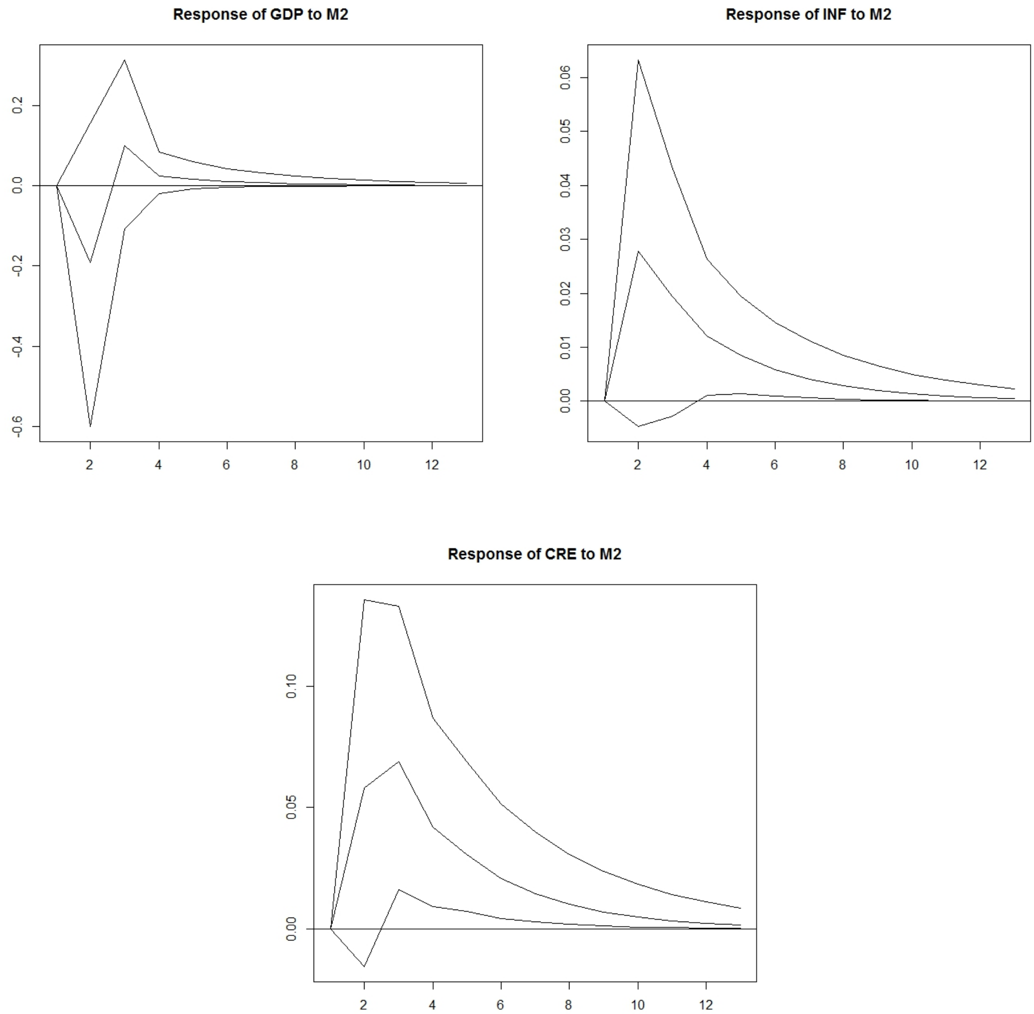

Figure 5.11: Responses of Variables to the Shock to M2 in BVAR-SV Using Only IPI Data (x-axis is horizon measured in months, y-axis shows responses of variables measured in percentage points)

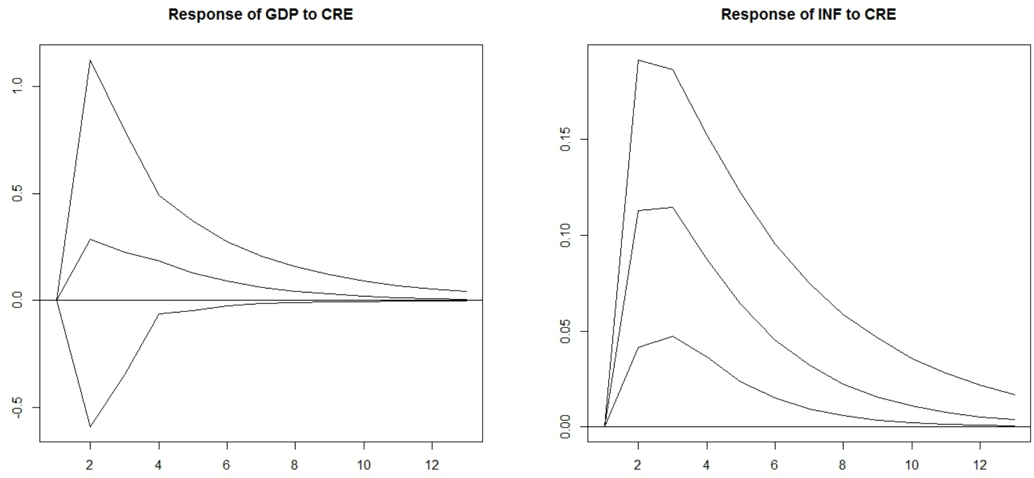

Figure 5.12: Responses of Variables to the Shock to CRE in BVAR-SV Using Only IPI Data (x-axis is horizon measured in months, y-axis shows responses of variables measured in percentage points)

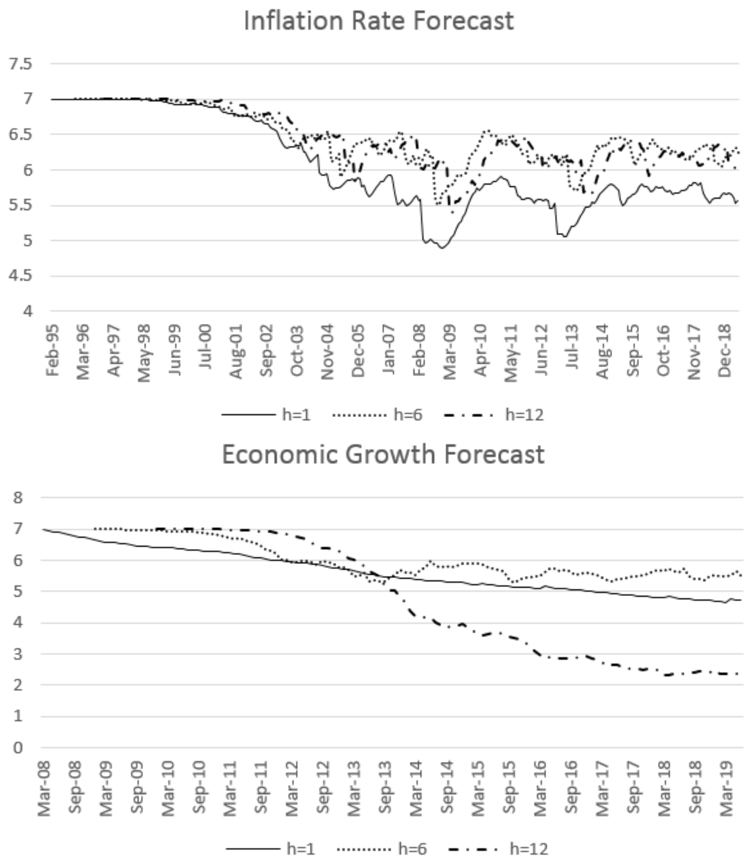

Figure A.1: Averaged Number of Predictors for Each Forecasting Exercise

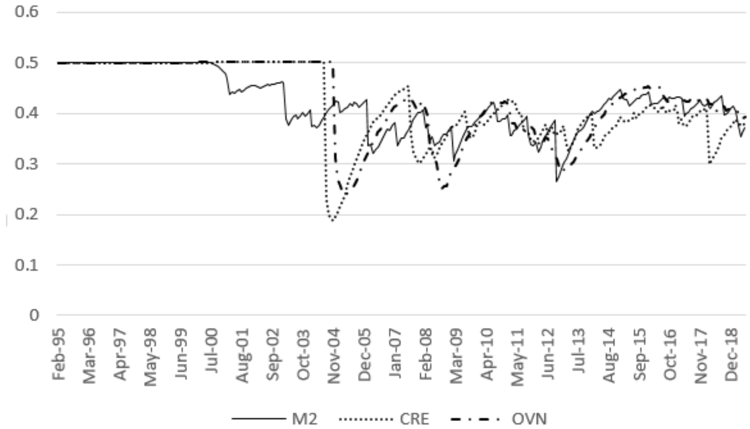

Figure A.2: Posterior Inclusion Probability of Predictors (Inflation Rate, h = 1)

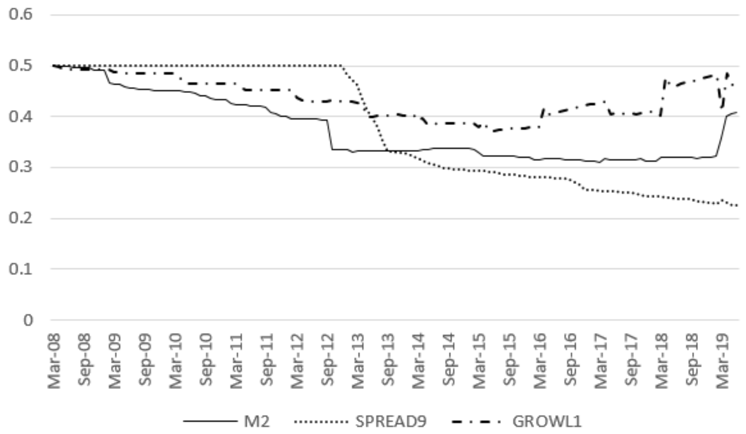

Figure A.3: Posterior Inclusion Probability of Predictors (Economic Growth, h = 1)