Research on the Impact of Monetary Policy on CPI in China based on TVP-VAR Model

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***Abstract* — Stabilizing prices is the goal of macro-economy, and monetary policy has mutual effect with prices. Monetary policy is mainly manifested in the money supply and the interest rate level, and consumer price index (CPI) indicates prices. This paper applies a Time-Varying Parameter Vector Auto Regressive (TVP-VAR) approach to estimate the mutual effects of consumer price index on monetary policy over time. We use monthly data from January 1996 to December 2014, estimate ternary TVP-VAR model by Markov chain Monte Carlo (MCMC). Our empirical findings indicate the following conclusions: firstly, the growth rate of macroeconomic variables has the same characteristics as financial variables; secondly, all variables which include macroeconomic variables and financial variables have a different fluctuation at different time. In the end, the effect from M2 and SHIBOR on CPI is different between long term and short term. The empirical analysis in this paper indicate the quantity of monetary policy is more important because of significant effect relative to price in monetary policy, while CPI has minute effect on M2 and SHIBOR.**

Keywords - MCMC; TVP-VAR; monetary policy

I. INTRODUCTION

The central bank can't determine investment, consumption and foreign trade directly, but through monetary policy influence every aspect in economy indirectly. The ultimate purpose of central bank to implement monetary policy is improving macro-economic variables, and measuring index of monetary policy must possess metrizability, relativity and controllability. There is divergence with regard to index selection in academe; initially China has taken the money supply as the intermediate target of money policy. The change for the growth rate of money has a significant influence on price, and a pro cyclical effect, so it is reasonable to select money supply as the metrics. Transaction velocity of money is assumed to constant by Irving Fisher, Freedman denied the statement, which is false in reality. Intermediate target will be dynamic if money supply still is intermediate target when transaction velocity of money is instability. Researchers catch sight of the price of money in this context, the price of money must be market rate, not official rate, so Shanghai Inter-bank Offered Rate (SHIBOR) is the best candidate. In the end, money policy embodies two aspects: money supply is the hand, which mainly select M2(broad money) as index, money price is on the other hand, which SHIBOR represents.

II. LITERATURE REVIEW

In recent years, transmission mechanism between macro-economic variables each other is regardful focus of scholars, reached its peak in the 1970, simultaneous equations model is basically a champion in the field, no matter big or small country, regardless of the number of variables.10 years later, more and more theorists and practical experts found that there is discrepancy between the law in model and present world, question and excuse is coming soon after," Lucas critique" "The slope of the mystery" and so on. C. A. Sims establish Vector Auto-Regression(VAR) model in 1980, in the next 30 years, VAR model is springing up to major areas by scholars in different country, especially in macroeconomic terms, just like a standard tool. VAR model also has a non-negligible defect, it is necessary to estimate the parameters too much, that need a big length of data. There are only monthly or quarterly data for macro variable, and database construction is so late especially for developing countries, with a data capacity of approximately 100, is obviously very difficult to meet the valid estimate parameters. VAR model assumes that there are m endogenous variables, lagged number p, then we need to estimate m (mp + 1) parameters, it is astronomical figure. In VAR big family, to more fit actual situation, scholars expand the model in two ways, one side, put the change into the model, some of these model allow alterable parameters, this change can be abrupt or gradually; on the other side, the estimated methods of model are greatly improved such as the MCMC method by Bias theory.

In recent years, papers about the theme bring forth the new through the old, but relatively speaking, more achievements are from abroad. Blanchard and Quah (1990) proposed Structure VAR(SVAR), in 1996 Litterman proposed Minnesota conjugate prior distribution to VAR model, Bayes VAR (BVAR) was birth, Koop (2009,2010) introduced in detail the prediction of BVAR with different prior distribution [1]. Cogley and Sargent (2005) put forward time-varying parameters VAR (TVP-VAR) for the first time, the parameters of model are dynamic [2]. In the same year, Primiceri extend the model with random fluctuations of the

time varying parameter form (TVP-VAR-SV) [3], subsequently, the author gathered a band of followers, among of them, Nakajima(2011) is the most loyal [4], he put the model in various economic sectors. Domestic scholars are fired with enthusiasm for constructing VAR and SVAR model, TVP-VAR model is rare. Zhu Huiming (2004) established a TVP-VAR model for predicting with a Minnesota prior distribution [5], compare it to AR (auto regression), VAR. Wu Jianfei and Fang Yong(2010) had a empirical analysis about the cause of inflation by BVAR, Luo Yidan and Fan Qi (2010) examined the effect of monetary policy shocks on inflation and gross domestic product (GDP) by BVAR model, Huang Wei and Lu Maozu (2011) have a empirical analysis for dynamic changes of shock effect by China's government spending through BVAR, the range of data is from 1995 to 2009. Sun Yan Lin, Chen Pu and Xiong Yiming (2011) explained the "slope puzzle" which proposed by Xu GAO (2008) by TVP-VAR [6, 7]. But the above analysis are based on the random disturbance obey normal distribution with the same variance, this assumption does not coincide with the actual, of course, a direct result of biased parameter estimates, so random fluctuation must be applied to TVP-VAR model, that TVP-VAR with Stochastic Volatility（TVP-VAR-SV）, This paper attempts to establish a TVP-VAR-SV of ternary which are SHIBOR, CPI and M2, discussing the monetary transmission mechanism. Then this paper introduces the model and estimation method.

III. MODEL AND ESTIMATION METHOD

A. VAR Model

Now we begin at VAR model, in the formula (1), y_t is $k\times 1$ dimension vector which can be obtained, $A, F_1, \cdots F_s$ are $k\times k$ rank coefficient matrix, u_t is $k\times 1$ dimension variable. We assume that the impact of the variables related to the same period of the structure is recursive form, that A is lower triangular matrix.

$$\begin{cases} Ay_t = F_1 y_{t-1} + \cdots + F_s y_{t-s} + u_t \\ t = s+1, \cdots, n \end{cases} \tag{1}$$

$$A = \begin{bmatrix} 1 & 0 & \cdots & 0 \\ a_{21} & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ a_{k1} & \cdots & ak, k-1 & 1 \end{bmatrix} \tag{2}$$

This paper will list the Formula (1) in the form of a simplified model of VAR.

$$\begin{cases} y_t = B_1 y_{t-1} + \cdots + B_s y_{t-s} + A^{-1}\Sigma\varepsilon_t,\ \varepsilon_t \sim N(0, I_k) \\ \Sigma = \begin{bmatrix} \sigma_1 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \sigma_k \end{bmatrix},\ \sigma_i (i = 1, \cdots, k) \end{cases} \tag{3}$$

$B_i = A^{-1}F_i$, for $i = 1, \cdots, s$, $\sigma_i (i = 1, \cdots, k)$ is the standard deviation of structure for shock variable, $B_i^{'}s$ will be organized into elongated elements in the $\beta(k^2 s \times 1)$ vector, define $X_t = I_k \otimes (y_{t-1}^{'}, \cdots, y_{t-k}^{'})$, the above model can be written as follows:

$$y_t = X_t \beta + A^{-1}\Sigma\varepsilon_t,\quad t = s+1, \cdots, n \tag{4}$$

All parameters in equation(4) are constant, next they will be allowed to time-varying, then equation (4) becomes the form of equation(5), β_t, A_t, Σ_t in equation(5) are all time-varying, according to Primiceri (2005), we assume the parameters in equation (5) obeys a random walk process.

B. TVP-VAR Model

$$\begin{cases} y_t = X_t\beta_t + A_t^{-1}\Sigma_t\varepsilon_t,\quad t = s+1, \cdots, n \\ \beta_{t+1} = \beta_t + u_{\beta t}, \\ \alpha_{t+1} = \alpha_t + u_{\alpha t}, \\ h_{t+1} = h_t + u_{ht}, \\ \begin{pmatrix} \varepsilon_t \\ u_{\beta t} \\ u_{\alpha t} \\ u_{ht} \end{pmatrix} \sim N\left(0, \begin{pmatrix} I & 0 & 0 & 0 \\ 0 & \Sigma_\beta & 0 & 0 \\ 0 & 0 & \Sigma_\alpha & 0 \\ 0 & 0 & 0 & \Sigma_h \end{pmatrix}\right) \end{cases} \tag{5}$$

From the above equation, for $t = s+1, \cdots, n$, $\beta_{s+1} \sim N(\mu_{\beta_0}, \Sigma_{\beta_0})$, $\alpha_{s+1} \sim N(\mu_{\alpha_0}, \Sigma_{\alpha_0})$, $h_{s+1} \sim N(\mu_{h_0}, \Sigma_{h_0})$, to convenient estimate, we assume $\Sigma_\beta, \Sigma_\alpha$ and Σ_h as diagonal matrix. The structural shocks in the model are assumed to obey the random walk process, which is a classical random fluctuation.

C. Bayesian Inference

In many branches of existing international statistical circles, there are two evenly matched teams for classical statistics and Bayesian statistics, a long controversy is exist among the two teams, and there is no conclusion now, but scholars believe that the dispute contribute to the development of modern statistical theory. Opposite to classical statistics, Bayesian statistics is more convincing

because of more information (a priori to a posterior). Bayesian originated in a paper "on the theory of opportunity to solve a problem" which published in the Royal Society's paper in 1976. Bernoulli (1713), Laplace (1774), Jeffrey (1939) has improved the theory ,but is very seldom in academia, because it is difficult to determine a priori distribution, and even if assume a simple distribution, a complicated posterior distribution will get, even a posterior probability distribution without explicit expressions, computer simulation is applied, the distribution which is wait to simulate is multivariate, the ordinary simulation----Monte Carlo simulation can't be use, so Markov chain Monte Carlo(MCMC) simulation came into being.

D. MCMC Method

In the field of econometrics, MCMC method is becoming increasingly popular, especially in the past 10 years, a large number of empirical studies on the macroeconomic variables are preferred MCMC. MCMC is established under the framework of Bayesian inference, getting the posterior probability distribution from prior probability distribution. We assume the prior density as $\pi(\theta)$, θ is the unknown parameter vector data, $f(y|\theta)$ denote likelihood equation for data $y=\{y_1,\cdots,y_n\}$, $\pi(\theta|y)$ is posterior probability distribution, the formula about them is below, which is obtained by the Bayes' theorem,

$$\pi(\theta|y)=\frac{f(y|\theta)\pi(\theta)}{\int f(y|\theta)\pi(\theta)d\theta} \tag{7}$$

Based on this formula, the priori information about parameter θ is updated with observation data y , $m(y)=\int f(y|\theta)\pi(\theta)d\theta$ also known as the normalization constant or marginal distribution, posterior probability distribution. In the case where the likelihood function or the normalizing constant is intractable, the posterior distribution $\pi(\theta|y)$ does not have a closed form, in order to overcome this difficulty, a lot of numerical methods are based on the technique to sample from the posterior distribution, among them , MCMC sampling is the most popular, MCMC method use recursive conditional posterior sampling ,which can make the recent condition parameter value is used for simulation.

E. Gibbs Sampling

The key of MCMC method is how to construct a stable Markov chain, The Gibbs sampler is one of the famous MCMC methods, Consider a vector of unknown parameters $\theta=(\theta_1,\cdots,\theta_p)$, the process is as follow.

(1) Assume a initial value $\theta^{(0)}=(\theta_1^{(0)},\cdots,\theta_p^{(0)})$,and set $i=0$.

(2) Given $\theta^{(i)}=(\theta_1^{(i)},\cdots,\theta_p^{(i)})$,

(a) Generate $\theta_1^{(i+1)}$ from the conditional posterior distribution $\pi(\theta_1^{(i+1)}|\theta_2^{(i)},\cdots,\theta_p^{(i)})$,

(b) Generate $\theta_2^{(i+1)}$ from the conditional posterior distribution $\pi(\theta_2^{(i+1)}|\theta_1^{(i+1)},\theta_3^{(i)}\cdots,\theta_p^{(i)})$,

(c) Generate $\theta_3^{(i+1)}$ from the conditional posterior distribution $\pi(\theta_3^{(i+1)}|\theta_1^{(i+1)},\theta_2^{(i+1)},\theta_4^{(i)}\cdots,\theta_p^{(i)})$,

(d) Generate $\theta_4^{(i+1)},\cdots,\theta_p^{(i+1)}$, in the same way.

(3) Set $i=i+1$,and go to (2).

The estimation of parameter in TVP-VAR model need MCMC method ,which is because of following reasons: ① stochastic volatility assumption makes the state space is nonlinear, that is bring trouble to maximum likelihood estimation(MLE); ② MCMC can estimate not only the unknown parameters but also the state variable; ③we can obtain the impulse response function of TVP-VAR model conveniently. Gibbs sampling is used in this paper by means which invented by Jouchi Nakajima, we can acquire the detail process from his paper (2011).

IV. EMPIRICAL ANALYSIS

A. Data

This paper choose broad money---M2, Shanghai Interbank Offered Rate interest(SHIBOR) and Consumer price Index(CPI) three index as the symbol of monetary policy and macro-economic. We find monthly data from January 1996 to December 2014; the number of data is 228. In order to build the model conveniently, all data are relatively data, that is growth rate, for getting the stable series, but the sample size will be reduced to 227. M2 represents the monetary policy of money supply, it is very popular to select the bank base rate as the symbol of currency prices, but in China interest rate marketization reform has not ended, so this paper select the substitution variables---SHIBOR, the most important aspect in macro-economic is price, so CPI is selected as variable which delegates macro-economic. The transmission mechanism of monetary policy is follow：in the recession, the central bank take measures to either lower interest rate or higher the money supply, which to stimulate investment and net export, increase aggregate demand, that is expansionary policy, and vice versa.

From the table I, we can find the monthly data of macroeconomic variables have the same characteristics of the other financial time series, high peak and fat tail, and there is significant difference with normal distribution. Next I calculate the simple correlation among above three index, all the correlation is less than 0.2, clearly shows the extent of three-variable linear correlation is very low, the result is not consistent with the economic theory, we guess the related structures about them is nonlinear correlation, therefore, this

paper estimate the correlation among them by time-varying parameter model.

This paper select the data between January 1996 to December as advance sample, which is responsible for an estimated prior distribution, this paper estimate the prior distribution by advance sample with ordinary least squares(OLS). Monthly data may need to select a relatively

TABLE I DESCRIPTIVE STATISTICS OF MACRO-ECONOMIC VARIABLE

variable	mean	S.D	skew	kurtosis	J-B	P value（J-B）
M2	1.3956	1.2856	1.3814	10.8571	583.84	0.000
SHIBOR	-0.04658	0.4067	-0.02780	6.1559	83.85	0.000
CPI	-0.03075	0.6183	-0.2515	4.2958	16.26	0.000

TABLE II ESTIMATION RESULTS OF PARAMETERS IN THE TVP-VAR MODEL FOR VARIABLE SET OF（M2，SHIBOR, CPI)

parameter	mean	S.D	95%lower interval	95%upper interval	CD	Inefficiency
$(\Sigma_\beta)_1$	0.0631	0.0142	0.0422	0.0943	0.544	34.83
$(\Sigma_\beta)_2$	0.0481	0.0086	0.0341	0.0673	0.274	13.71
$(\Sigma_\alpha)_1$	0.07	0.0238	0.0394	0.1281	0.966	70.37
$(\Sigma_\alpha)_2$	0.0843	0.0361	0.0415	0.1785	0.170	112.54
$(\Sigma_h)_1$	0.0877	0.0318	0.0468	0.1681	0.329	106.56
$(\Sigma_h)_2$	0.1698	0.0591	0.0791	0.3092	0.000	96.8

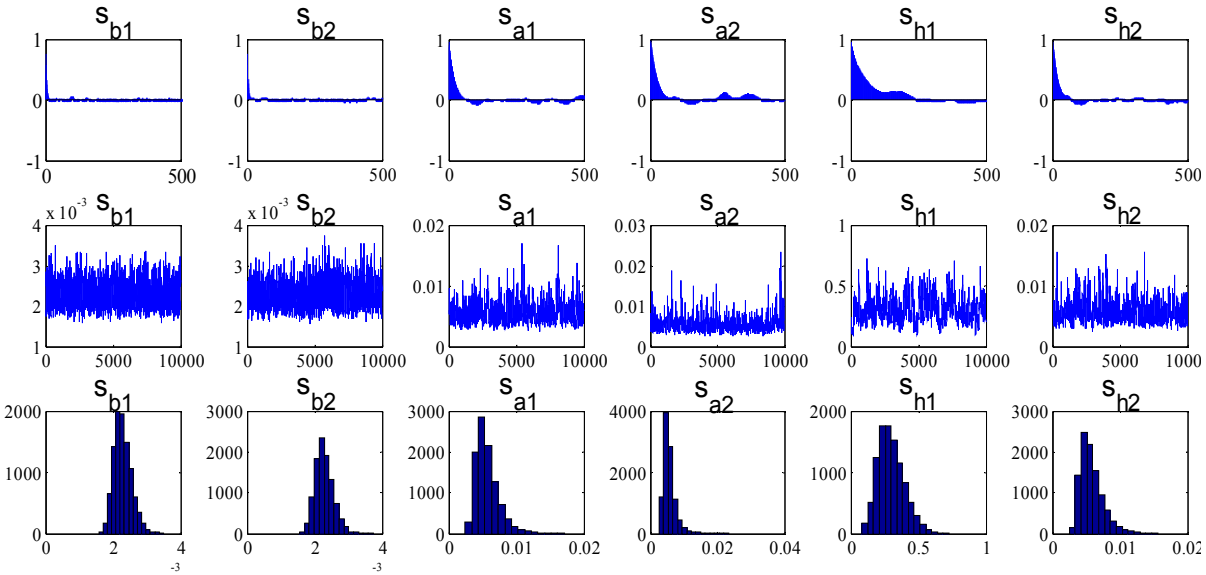

Fig. 1 Estimation Results of TVP-VAR Model for the Variable Set of (M2, SHIBOR, and CPI). Note Sample autocorrelations (top), sample paths (middle), and posterior densities (bottom). The estimated results of Σ_β, Σ_α are multiplied by 100.

Large lag in the model and large lag will lead to the geometric number of parameters which will be estimated.

To solve the problem, this paper does the best to collect more data, and confirm the lag as 3, which decide by ordinary VAR model. In order to research conveniently, this paper assume Σ_β, Σ_α, Σ_h as diagonal matrix, a lot of practice proved this assumption has no effect on the result, the conclusion is universal. Next this paper will introduce some assumption about a few information with prior distribution: $(\Sigma_\beta)_i^{-2} \sim Gamma(40, 0.02)$, $(\Sigma_\alpha)_i^{-2} \sim Gamma(4, 0.02)$, $(\Sigma_h)_i^{-2} \sim Gamma(4, 0.02)$, time-varying parameters on

the initial state, $\mu_{\beta_0} = \mu_{\alpha_0} = \mu_{h_0} = 0$, and $\Sigma_{\beta_0} = \Sigma_{\alpha_0} = \Sigma_{h_0} = 4 \times I$.

B. Simulation of the Effect for Parameters

In order to obtain the posterior distribution, this paper sample 10000 times after discard 1000 sample ahead which be called burning period. Figure 1 and table II are the results for TVP-VAR estimation which include M2, SHIBOR and CPI, there are evidence that posterior distribution obtained MCMC algorithm is effective in table I and figure1. we can find it is so successful with MCMC algorithm, firstly, sample autocorrelation(figure 1(top)) is coming to weak gradually with the number of simulation, that indicate there is no significant correlation between self-sample, the sample is random, which is very important for independent samples. Secondly, the parameter value in the sample changes in a small range, that indicate as long as the number of simulations reach big enough after abandoning the burning sample period, the simulated sample obey smooth Markov chains, which explain that Gibbs sampling is effective. Finally, the posterior distribution is relatively concentrated, similarly shows it is perfect sampling. Next this paper will show a estimation of parameter in detail in table II. Note: The estimates of Σ_β and Σ_α are multiplied by 100, S.D is standard deviation, to check the convergence of Markov chain, Geweke (1992) suggests the comparison between the first n_0 draws and the last n_1 draws, dropping out the middle draws. We can check Geweke (1992) for the formula of CD statistics.

Table II gives the estimates for posterior means, standard deviations, the 95 percent credible intervals, the convergence diagnostics (CD) of Geweke (1992), and inefficiency factors, which are computed using the MCMC sample. In the estimated result, the null hypothesis of the convergence to the posterior distribution is not rejected for the parameters at 5 percent significance level based on CD statistics, and the inefficiency factors are quite low, which indicates an efficient sampling for the parameters and state variables. The CD and inefficiency are the same group indices, when the inefficiency factor is equal to m , we need to draw the MCMC sample m times as many as the uncorrelated sample, so the inefficiency of all parameters are no more than 120, the number of sample is enough.

C. Historical Information of the Three Variables

Next this paper will show the trend of growth rate for M2, SHIBOR and CPI that do well for us to comprehend the variables independently. Figure 2 is divided into two parts up and down, and each part has left and right three blocks, the upper part is the history growth rate data for three variables, the left one is for M2, the middle is for SHIBOR, the right one is for CPI. From the figure, we can find the fluctuate of M2 is bigger than others, SHIBOR change in a small range smoothly, and CPI has a asymmetric fluctuation with gradually larger, that explain the change of price is bigger than before, maybe it is the consequence of monetary policy. The lower part show the mean and the range of fluctuation at 95 percent interval, the red active line indicate mean, and the blue dotted lines are confidence interval of mean, the conclusion is the same as above, it is worth to note of price changes recently, perhaps connect with the rapid development of economy.

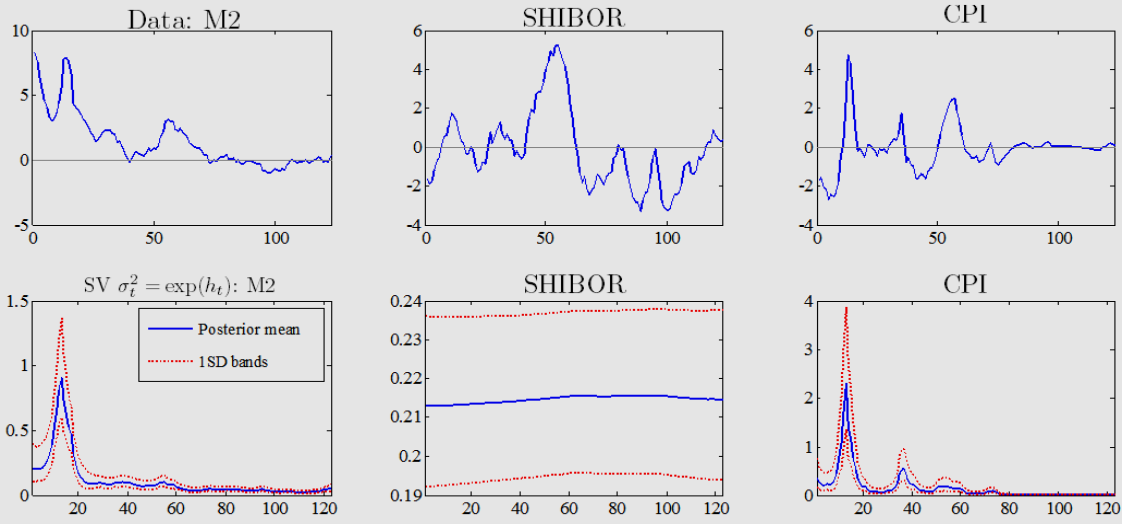

Fig. 2 History information for the set of variables (M2, SHIBOR, CPI)

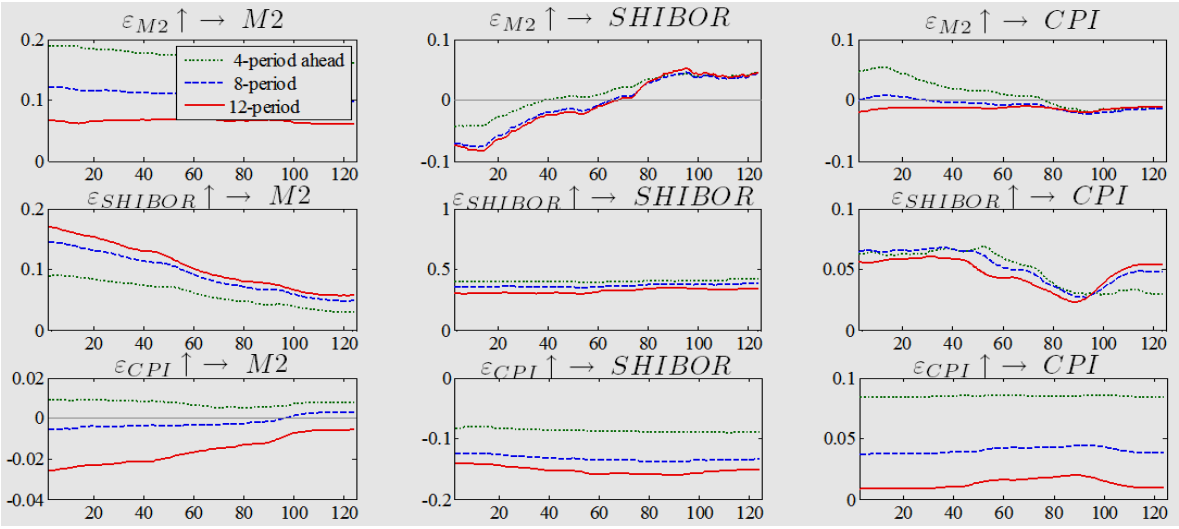

Fig. 3 Impulse Responses of TVP-VAR Models for the Variable Set of (M2, SHIBOR, CPI)

Note: Time-varying responses for four-months (dotted line), eight-months (dashed line), one-year (solid line)

D. Result of the Estimation

From the above graph, the impulse response of M2 to a positive CPI shock are estimated as being insignificantly difference from zero using TVP-VAR model, and the influence get bigger as the more time. Basic economic theory tells us that M2 shock affects price no significantly in short term, but positive in long term, that in accord with empirical results. The impulse responses of SHIBOR to a process from a small negative to a large positive in the short term, but a persistent litter positive in the long term. The two aspects of monetary policy, the quantity and price of monetary policy, the former has the long effect on CPI, but not in short term, on the contrary, the latter has short effect but not long. About the counterforce from CPI to M2 and SHIBOR, CPI do bigger long effect than short effect on M2, and there are both positive and negative effects of value. CPI has a bigger effect in short term than long term, but all the counterforce are insignificant.

V. CONCLUSION

This paper provided an overview of the empirical methodology of TVP-VAR model with stochastic volatility as well as its application to the Chinese data. The technique of the TVP-VAR model has been extended to the factor-augmented VAR (FAVAR) model. The MCMC algorithm illustrated in this paper can be straightforwardly applied to the TVP-FAVAR models. The TVP-VAR model has great potential as a very flexible toolkit to analyze the evolving structure of the modern economy. As the same time, the quantity and the price of monetary policy does significant effect on CPI, in contrast, CPI do no significant effect on M2 and SHIBOR, especially, the quantity of money, so the government should pay more attention to changing the money supply, which will be more useful for control the macro-economy.

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