Monetary Policy Rules and Business Cycle in China: Bayesian DSGE Model Simulation

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Abstract: In this paper, using a benchmark Bayesian Dynamic Stochastic General Equilibrium (Bayesian DSGE) model (Smets-Wouters Model) with Taylor’s rule and a modified Smets-Wouters model with a money growth rule, we have simulated China’s monetary policy transmission process and the roles of monetary variables and non monetary variables in China’s business cycle by incorporating many so-called New Keynesian Macroeconomic (NKM) approaches such as nominal stickiness and market imperfections in the model. The estimated values of the parameters in the model by Bayesian approach based on China’s quarterly time series data feature the unique characters of China’s economy compared with that in the US and the Euro area. The simulation results in terms of the Taylor’s rule and money growth rule (MacCullum Rule) highlight the monetary transmission mechanisms of China’s monetary policy and the diverse contributions of monetary shocks and non-monetary shocks to China’s business cycle.

Key Words: DSGE Model, Monetary Policy, China’s Business Cycle, Bayesian Approach, Taylor’s Rule, Money Growth Rule.

JEL Code: E3, E5, C5

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1 Introduction

Within the developments process of China’s economy, monetary policy has played important roles to stabilize the economy, which has spurred various academic debates on effects of the monetary policy regime in China. In this exercise, we use a standard DSGE model with alternative monetary policy rules to simulate the transmission mechanisms and business cycle in China. We also compare some different features between Chinese economy, American economy and Euro area based on the estimated values of the parameters in our model with Bayesian approach. The results of our study provide important implications to the operations of monetary policy in China.

The dynamic stochastic general equilibrium (DSGE) models are developed from RBC models by injecting some so-called New Keynesian Macroeconomic (NKM) approaches such as nominal stickiness and market imperfections into it. By incorporating many concepts, ideas and theories of microeconomics into macroeconomic dynamics, the DSGE models make the macroeconomic modeling more consistent and effective because its rigorous microfoundations link the development in macroeconomics to the advances in microeconomics, contributing its great success and attractiveness. The inclusion of nominal rigidities such as sticky prices and wages by Taylor (1980) and Calvo (1983) in DSGE models has proved to be extremely useful for explaining the empirical evidence of macroeconomics. Moreover, by introducing monetary variables in agent’s utility function (MIU model) and the monetary policy and fiscal rules, DSGE models provide powerful aspects on the monetary policy analysis and fiscal policy analysis as well as on many other theoretical issues. 3 As vast literatures have been dedicated to the shaping and developing of DSGE Models, progress has been made and the DSGE models have dominated many branches of macroeconomics, such as international macroeconomics, monetary economics, labour economics and public economics. As a consequent, many techniques have taken it to the data. Today, the DSGE models are not only attractive from a theoretical perspective, but also are emerging as useful tools for forecasting and quantitative policy analysis in macroeconomics.

Most DSGE models are developed for advanced economies, but this does not imply that DSGE models cannot capture the features of China’s economy. This is because the Chinese economy has become so marketised since 1978 that some of the macroeconomic models rooted in the developed economy can be applied to it, according to the arguments from Scheibe and Vines (2005) and Chow (2002) 4.

In this paper, following Smets and Wouters (2002) and Christiano et al (2001, 2005), we employ a standard DSGE model (Smets-Wouters model) and a modified S-W model to simulate China’s monetary policy transmission mechanism and the contributions of monetary shocks and non monetary shocks to China’s business cycle. Two scenarios are discussed and examined. First, in the benchmark Smets-Wouters model, money is endogenous in the system and the monetary authority follows a Taylor’s rule (Interest rate rule). Second, referring to the reality of China’s monetary operation, following Zhang (2009), we establish a modified Smets-Wouters model, in which money is injected explicitly into the utility function and the central

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4 See Zhang (2009).
bank of China follows a money growth rule. We have examined these two scenarios and compared the simulation results from them. The model economy consist of a utility-maximizing rational agent (households), profit-maximizing two-sector firms-private final good firms in competitive market and state owned monopolistic intermediate firms, and a monetary authority. By computing the first-order solutions to the behavioral equations and state equations, we obtain a group of nonlinear equations for the model economy. On the basis of regarding perturbation algorithms developed in the Matlab and Dynare software\textsuperscript{5}, the nonlinear equations can be solved and transformed to policy and transmission equations to simulate the monetary policy transmission and business cycle in China with real time series data.

The remainder of this paper is arranged as follows, Section 2 specifies the benchmark Smets-Wouters model with Taylor’s rule and a modified Smets-Wouters model with a money growth rule for China’s monetary policy operation and its first-order solutions. Section 3 estimates the parameters by a Bayesian approach. Section 4 presents the simulation results from two models for monetary policy transmission and business cycle in China. Section 5 concludes and summarizes. The results of estimated parameters are reported in Appendix.

2 The DSGE Models Specification for China’s Economy

Frank Smets and Raf Wouters (2002) developed a benchmark stochastic dynamic general equilibrium model for ECB’s monetary policy analysis. With reform and openness since 1978, China has transformed its economic system from a planned central-control regime to more market-oriented free economy, which is the first reason why I can choose this model designed for a developed economy to simulate China’s macro economy. Second, the Smets-Wouters model assumes two production sectors, the final firm in a perfect competition market and the intermediate firms in monopolistic market, which is in line with the realities of China’s economy: state owned companies have a monopolistic position by controlling the raw materials and energy sectors as intermediate firms, the private and small firms produce final consumption goods in competitive markets. Third, the Smets-Wouters model provides ten exogenous stochastic shocks, which compose of not only two monetary shocks (an interest rate shock and the money supply shock; with money supply shock this model is closer to the practical operations of China’s monetary policy), but also two fiscal policy shocks(investment shock and government expenditure shock). This coincides with the macro policy environment of China, in which not only monetary policy, but also fiscal policy play very important roles in stabilizing and promoting the growth of China’s economy. Finally, the elegance and complexity of the Smets-Wouters model can provide more aspects in simulating China’s macro economy.

In this model economy, a continuum of households supply labour services to the intermediate firms in a monopolistic competition market, they set wage with Calvo-stickiness, invest with adjustment cost and variable capital utilization, and consume final goods provided by the final firms with habit formation. The continuum of intermediate firms operates in monopolistic competition market, provide intermediate goods to the final firm and set prices with Calvo’s stickiness. The final goods are produced in a perfect competitive market. There exists a monetary authority following a Taylor’s rule in the implementation of monetary policy. Incorporating many other sources of exogenous shocks with monetary policy shocks, the model do simulate the business cycle of real economy and provide lots of implications for analyzing policies.

\textsuperscript{5} We use Dynare V4.02 on Matlab 2007a.
2.1 Households

The household agent $j$ from a continuum of households maximizes the present value of his stream of utilities in an infinite horizon

$$U = E \sum_{t=0}^{\infty} \beta^t U^j_{t+1}$$  \hspace{1cm} (2.1)

The preference of household $j$ is

$$U^j_t = \epsilon^j \left[ \frac{(C^j_t - H^j_t)^{1-\sigma}}{1-\sigma} + \frac{1}{1-\sigma_m} \left( \frac{M^j_t}{P_t} \right)^{1-\sigma_m} - \hat{\epsilon}^j (\hat{U}^j)^{\frac{1}{1+\nu}} \right]$$  \hspace{1cm} (2.2)

Where $0 < \beta < 1, \sigma > 0, \nu > 0$, $\beta$ is the discount factor or time preference, $\sigma$ is the inverse of the elasticity of inter-temporal substitution; $\epsilon^j$ is a stochastic shock of preference, $H^j_t = hC^j_{t-1}$, $h$ represents the consumption habit stock, $\frac{M^j_t}{P_t}$ denotes the real cash balance, $\sigma_m$ is the inverse of the elasticity of money holding with respect to the interest rate; $\epsilon^j$ denotes labour supply shocks, $\nu$ is the inverse of the elasticity of work efforts to the real wage. $C^j_t$ represents the consumption of the final good by agent $j$ at time $t$, $l_t$ represents the work hours provided by household agent, which contributes the disutility of works to the preference.

Household agent faces the following inter-temporal budget constraints

$$\frac{M^j_t}{P_t} + \frac{B^j_t}{R^j_t} = \frac{M^j_{t+1}}{P_t} + \frac{B^j_{t+1}}{R^j_t} + Y^j_t - C^j_t - I^j_t$$  \hspace{1cm} (2.3)

Where $B^j_t$ are nominal government bonds purchased by the household agent with market price $\frac{1}{R^j_t}$, $R^j_t$ denotes gross nominal rate of return. $I^j_t$ represents the investment of household agent. The real income $Y^j_t$ consists of following components

$$Y^j_t = (w^j_t l^j_t + A^j_t) + (r^j_z z^j_t K^j_{t-1} - \psi(z^j_t)K^j_{t-1}) + D^j_t - T^j_t$$  \hspace{1cm} (2.4)

Where $w^j_t$ is the real wage, $A^j_t$ represents the payoff from the state-contingent securities. The second term in (2.4) is the return on the real capital stock ($r^j_z z^j_t K^j_{t-1}$) minus the costs on the basis of the variation of capital utilization $z^j_t$, assuming that the cost function of the capital utilization is zero ($\psi(z^j_t) = 0$) when the utilization rate $z^j_t = 1$. $D^j_t$ denotes the dividends received from the state owned intermediate companies and $T^j_t$ is the lump sum tax paid to the government.

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6 This concept has a long history in macroeconomics, which argues that household’s utility is not only from the consumption of a bundle of goods, but also depends on his past consumption. The consumption-habit variable has been widely used in the New Business Cycle models, further discussion, see, for example, Dennis (2008).
The capital stock is owned by the households and rented out to the state owned intermediate goods producers at rental rate of $i^k_t$. The investment $I^j_t$ is conducted either by installing new capital or changing the utilization rate of installed capital stock $z^j_t$.

Following Christiano et al. (2001), the capital accumulation equation is given by

$$K^j_t = K^j_{t-1}(1 - \tau) + [1 - S(e^j_t I^j_t / I^j_{t-1})]I^j_t$$

(2.5)

Where $K^j_t$ is the capital stock and $\tau$ is the depreciation rate of capital. $S(.)$ represents a positive function associated with the change of investment, in steady state, $S = S' = 0$ and the adjustment costs only depend on the second derivative of $S$. $e^j_t$ is a shock to the investment cost following an AR (1) process.

Assuming that the wage is set with Calvo-stickiness, the probability that the households can change its wage equals to $1 - \omega$, and the new nominal wage is set at

$$W^j_t = \bar{W}^j_t.$$  

(2.6)

The wages which can not be re-optimized are indexed with the past inflation as

$$W^j_t = \left(\frac{P^t}{P^{t-1}}\right)^{\gamma} W^j_{t-1}$$

(2.7)

Where $\gamma$ is the degree of partial wage indexation between zero and one.

The aggregate labour supply and aggregate wages are calculated by the following Dixit-Stiglitz technology

$$L_t = \left(\int_0^1 (l^j_t)^{1/(1+\lambda_{w,t})} dj\right)^{1/\lambda_{w,t}}$$

(2.8)

$$W_t = \left(\int_0^1 (W^j_t)^{-1/\lambda_{w,t}} dj\right)^{-\lambda_{w,t}}$$

(2.9)

Where $\lambda_{w,t}$ is the mark up of the real wage over the current ratio of the marginal disutility of labour and the marginal utility of the consumption.

$$\lambda_{w,t} = \lambda_w + \varepsilon^w_t.$$  

(2.10)

Where $\varepsilon^w_t$ is a wage mark up shock that is IID.

Household agent’s maximizing behaviour implies the following labour supply function

$$l^j_t = \left(\frac{W^j_t}{W_t}\right)^{1/\lambda_{w,t}} L_t$$

(2.11)

On the basis of (2.9), following Calvo (1983), the law of motion of the aggregate wage is

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\[(W^*)^{-1/\lambda_{t+1}} = \omega_n(P^{t+1}_{t+2})^{1/\lambda_{t+2}} + (1 - \omega_n)(\tilde{W}^*)^{-1/\lambda_{t-1}} \quad (2.12)\]

Also the mark-up equation for the re-optimise wage is given by the maximizing theory
\[
\tilde{W}^*_t = E_t \sum_{i=0}^{\infty} \beta^i \omega_n^i \left( \frac{P^i_t}{P^{t-i}_{t-i-1}} \right)^{\gamma_r} \frac{\epsilon'_r (C^j_{t+1} - hC^j_{t+1})^{-\gamma}}{1 + \lambda_{t+1}^{j_{t+1}}} = -E_t \sum_{i=0}^{\infty} \beta^i \omega_n^i \epsilon'_r \epsilon'_j (1 + \lambda_{t+1}^{j_{t+1}})^{-\gamma} \quad (2.13)
\]

Following Christiano et al. (2001, see Appendix 1) and Uhlig (2007), we have:
\[
\int_0^1 K^j_t = K_t, \int_0^1 C^j_t = C_t, \int_0^1 B^j_t = B_t, \int_0^1 D^j_t = D_t, \int_0^1 M^j_t = M_t
\]

We drop the superscripts in the above variables in the following.

The first-order conditions for the household can be obtained as follows

Euler equation: \[E_t (\beta \lambda_{t+1} P_{t+1}) = 1 \quad (2.14)\]

Where \[\hat{\lambda}_t = -\epsilon'_r (C^j_t - hC^j_t)^{-\gamma}, \quad \hat{\lambda}_t \] is the Lagrange multiplier which represents the marginal utility of income.

The demand for money is given by
\[\left( \frac{M_t}{P_t} \right)^{-\sigma_w} = \frac{R_{t-1} - 1}{R_t} (C_t - H_t)^{-\sigma} \quad (2.15)\]

First, following Smets and Wouters (2002), this equation is ignored in the Taylor’s rule model, which implies endogenous money in the system. Referring to the discussions on the Smets-Wouters Model provided by Professor Uhlig (his website: wiwi.hu-belin.de), this suggests a utility function without money. In the later works of Smets and Wouter (2005, 2007), they accept the suggestion of Professor Uhlig, taking a utility function without money. Some Chinese researchers also suggest a utility function without money (see Chen Kunting and Gong Liutang, 2006). By making these assumptions, the final ten linear equations in the Smets-Wouters model are kept unchanged when applied to simulate China’s economy in the first scenario.

Second, we include this money demand equation into a money growth rule model: this implies that money is injected explicitly into the system. By assuming that the PBC follows a money growth policy rule, a modified Smets-Wouters model will be set up to simulate the monetary policy transmission and business cycle in China.

The Lucas asset pricing equation for the real value of capital:
\[Q_t = E_t [\beta \lambda_{t+1} (Q_{t+1} (1 - \tau) + z_{t+1} r^k_{t+1} - \psi(z_{t+1}))] \quad (2.16)\]

The investment equation is
\[Q_t (1 - S \frac{\epsilon'_r I_{t-1}}{I_{t-1}}) = Q_t S \left( \frac{\epsilon'_r I_{t-1}}{I_{t-1}} \right) + 1 - E_t [\beta \lambda_{t+1} Q_{t+1} S \left( \frac{\epsilon'_r I_{t+1}}{I_{t+1}} \frac{\epsilon'_r I_{t+1}}{I_{t}} \right) \frac{I_{t+1}}{I_t}] \quad (2.17)\]

Following Smets and Wouters (2002), we have The equation for the rate of capital utilization:
\[r^k_t = \psi'(z_t) \quad (2.18)\]
2.2 Technologies and Firms

The economy produces a single final good by the final firm (private firms in China) and a continuum of intermediate goods (state owned firms) indexed by \( j (j \in (0,1)) \).

The final firm provide a single good by combining the intermediate goods in a perfect competitive market with Dixit-Stiglitz approach:

\[
Y_t = \left\{ \int_0^1 \left[ Y_t^j \right]^{1/(1+\lambda_{pt})} d\lambda_j \right\}^{1+\lambda_{pt}}
\]

(2.19)

Where \( Y_t^j \) denotes the inputs of intermediate good of type \( j \) at time \( t \); \( \lambda_{pt} \) is a stochastic parameter governing the time-variance mark-up in the goods market, the shock to which reflects a cost-push shock to the inflation equation.

The cost minimization or profits maximization implies the following standard relationships, which can be explained as intermediate-good demand curve,

\[
\frac{Y_t^j}{Y_t} = \left[ \frac{P_t^j}{P_t} \right]^{-1/\lambda_{pt}}
\]

(2.20)

And

\[
P_t = \left\{ \int_0^1 \left[ P_t^j \right]^{-1/\lambda_{pt}} d\lambda_j \right\}^{-\lambda_{pt}}
\]

(2.21)

Where \( P_t \) denotes the price of the final good; \( P_t^j \) is the price of the intermediate good of type \( j \).

The representative intermediate firm \( j \) produces goods in terms of the following technology in a monopolistic competition market.

\[
Y_t^j = e_t^a (z_t K_t^j)^{\alpha} (L_t^j)^{1-\alpha} - \Theta
\]

(2.22)

Where \( K_t^j \) is the capital stock, and \( L_t^j \) are the aggregate labours employed by firm \( j \), \( \alpha \) is share of the capital in the production function, \( e_t^a \) is the productivity shock, \( \Theta \) is the fixed cost.

The total cost of the intermediate firm is

\[
TC_t^j = r_t^k z_t K_t^j + W_t L_t^j
\]

(2.23)

Minimizing (2.23) subject to (2.22) produces

\[
\frac{r_t^k z_t K_t^j}{W_t L_t^j} = \frac{\alpha}{1-\alpha}
\]

(2.24)

Substituting the optimal ratio of capital to labour (2.24) into (2.22) and (2.23), then we can obtain the marginal cost of the intermediate firm as

\[
MC_t = \frac{\partial TC_t^j}{\partial Y_t^j} = \frac{1}{e_t^a} \left( \frac{1}{1-\alpha} \right)^{1-\alpha} \left( \frac{1}{\alpha} \right)^{\alpha} [r_t^k]^{\alpha} [W_t]^{1-\alpha}
\]

(2.25)

The nominal profit of intermediate firm \( j \) is
Following Calvo (1983) and Christiano et al. (2001), the probability of the firms that can re-optimize the price is $1 - \omega_p$, and the prices of the firms that cannot follow the price signal are indexed on the past inflation similar as in the wage setting.

Using $\tilde{P}_t^j$ to represent the re-optimized price, we have the following optimality relationship for setting $\tilde{P}_t^j$:

$$E_t[\sum_{i=0}^{\infty} B_t^i (\omega_p)^i \tilde{P}_t^j (\frac{P_{t-1}^j}{P_t^j})^i] = E_t[\sum_{i=0}^{\infty} B_t^i (\omega_p)^i \tilde{P}_t^j (1 + \lambda_{p,t})mc_{t-1}]$$

Also following Calvo (1983) and Christiano et al. (2001, Appendix 1), (2.21) implies the law of motion for the price:

$$(P_t)^{-1/2} = \omega_p((P_{t-1}^{-1})^{1/2} P_{t-1}^-)^{-1/2} + (1 - \omega_p)(\tilde{P}_t)^{-1/2}$$

2.3 Monetary Policy and the Government

The government expenditure is met by levying lump sum taxation on the households, bond issuing and seigniorage as

$$\frac{M_t - M_{t-1}}{P_t} + T_t + \frac{B_t - R_{t-1}}{P_t} = G_t$$

The PBC has never released its monetary policy model. There are different arguments on the China’s monetary policy rules. Some researchers have suggested that China’s monetary policy rule is close to a Taylor’s rule. For example, Yuan (2008) pointed out that China’s monetary policy rule based on some type rule such as Taylor’s rule on the basis of an empirical study by employing SV AR model. Zhang (2009) suggested that an interest rate rule is more effective than a quantity (money supply) rule in China. Burdekin and Silklos (2005) claimed that the PBC seems to follow a money growth rule like the McCallum rule.

As mentioned above, we consider both scenarios for the monetary policy rules which may be taken by the PBC.

In the first scenario, the monetary authority conducts its monetary policy by setting interest rates following a modified Taylor’s rule (Smets and Wouters, 2002) as follows:

$$\hat{R}_t = \rho \hat{R}_{t-1} + (1 - \rho) [\epsilon_t^T + r_x (\hat{\pi}_{t-1} - \hat{\pi}_t) + r_y (\hat{Y}_{t-1} - \hat{Y}_t) + r_{dx} (\hat{\pi}_t - \hat{\pi}_{t-1}) + r_{dy} (\hat{Y}_t - \hat{Y}_{t-1}) + \epsilon_t^R]$$

Where $\rho$ captures the persistence of interest rate, $\epsilon_t^T$ is a persistent shock to the inflation objective following an AR (1) process which implies a monetary supply shock in the benchmark Smets-Wouters model. $\epsilon_t^R$ is a monetary interest rate shock. $r_x$ is inflation coefficient, $r_y$ is the output gap coefficient, $r_{dx}, r_{dy}$ are coefficients of inflation growth and output gap growth respectively.

In the second scenario, due to the framework of China’s monetary policy, following Zhang (2009), the PBC is assumed to follow MacCullum rule, the money is supplied as

$$M_t = \kappa M_{t-1}$$
Where $M_t^s$ is the money supply at time $t$; $\kappa_t$ is the growth rate of money.

Defining $m_t = \frac{M_t}{P_t}$, we obtain form 2.31

$$m_t^s = \frac{\kappa_t m_{t-1}^s}{\pi_t}$$  \hspace{1cm} (2.32)

Because the PBC targets inflation and output, we can assume a monetary growth rule as following:

$$\hat{\kappa}_t = \rho_M \hat{\kappa}_{t-1} - \zeta_1 E_t \hat{\pi}_{t+1} - \zeta_2 \hat{Y}_t + \varepsilon_t^m$$ \hspace{1cm} (2.33)

Where $\rho_M$ is used to capture the persistence of the money growth, $\varepsilon_t^m$ is a money supply shock following an AR (1) process same as $\varepsilon_t^x$. \(\zeta_1\) and $\zeta_2$ are coefficients of inflation and output respectively.

2.4 Market Equilibriums

The equilibrium conditions for the model economy require clearing the labour market, goods market, capital rental market. The equilibriums include

Labour Market: the demand for the labour equals to labour supply,

$$\int_0^1 L_t' dj = L_t = \left(\int_0^1 \lambda_t^i (L_t')^{1+(1+\kappa_{t-1})} dj\right)^{1+\kappa_{t-1}}$$ \hspace{1cm} (2.34)

Goods Market:

$$Y_t = C_t + G_t + I_t + \psi(z_t) K_{t-1}$$  \hspace{1cm} (2.35)

Capital rent Market: capital demand equals capital supply

$$\int_0^1 K_t' dj = K_t$$ \hspace{1cm} (2.36)

In our second scenario, money is injected by the PBC, the money market equilibrium is

$$M_t = M_t^s$$ \hspace{1cm} (2.37)

2.5 The Linearised Models and the Exogenous Shocks

From the Euler equation (2.14), the long-term steady state interest rate is $\bar{R} = \frac{1}{\beta}$ and the steady state rental rate of capital equals $\bar{\rho} = \frac{1}{\beta} - 1 + \tau$, the steady state inflation is set at the inflation objective $\bar{\pi}$. The steady values of capital, investment, consumption, government expenditure to GDP are defined by the empirical time series data. We log linearise above equations so the steady state values of other variables are zeros.

The principle of log-linearization is to use a Taylor approximation around the steady state to approximate all the equations with linear functions, for example, for a vector of variables $Z_t$, let $\bar{Z}$ denote their steady state, and then $\hat{z}_t = \log Z_t - \log \bar{Z}$ represents the vector of log-deviations from the steady state.

First, we use the benchmark Smets-Wouters, which consists of ten linear equations (log-linearized) as follows
The benchmark Smets-Wouters model with Taylor’s Rule:

The consumption equation is:

$$\hat{C}_t = \frac{1}{1+h} \hat{C}_{t-1} + \frac{1}{1+h} E_t \hat{C}_{t+1} - \frac{1}{(1+h)\sigma} (\hat{R}_t - E_t \hat{R}_{t+1}) + \frac{1}{(1+h)\sigma} \hat{\sigma}$$  (2.38)

The investment equation is given by:

$$\hat{I}_t = \frac{1}{1+\beta} \hat{I}_{t-1} + \frac{\beta}{1+\beta} E_t \hat{I}_{t+1} + \frac{\varphi}{1+\beta} \hat{Q}_t + \hat{\epsilon}_i$$  (2.39)

Where $\varphi = 1/S_t$, capturing the capital adjustment costs as a function of the change in investment.\(^9\)

The Q equation (Tobin’s Q) is:

$$\hat{Q}_t = (\hat{R}_t - E_t \hat{R}_{t+1}) + \frac{1}{1-\tau + \tau_k} E_t \hat{Q}_{t+1} + \frac{\tau_k}{1-\tau + \tau_k} E_t \hat{r}_k + \hat{\epsilon}_q$$  (2.40)

Where $\epsilon_q$ is a shock to the required rate of return on equity investment.

The standard capital accumulation equation:

$$\hat{K}_t = (1-\tau) \hat{K}_{t-1} + \tau \hat{I}_{t-1}$$  (2.41)

The labour demand equation:

$$\hat{L}_t = \psi - (1 + \psi) \hat{r}_k + \hat{\hat{K}}_{t-1}$$  (2.42)

Where $\psi = \varphi'(1)/\varphi'(1)$ is the inverse of elasticity of the capital utilization cost function.

The production function is standard:

$$\hat{Y}_t = \phi \hat{e}_p + \phi \alpha \hat{K}_{t-1} + \phi \alpha \psi \hat{r}_k + \phi (1-\alpha) \hat{\hat{L}}_t$$  (2.43)

Where $\phi$ is inverse of one plus the share of the fixed cost in production.

The goods market equilibrium condition:

$$\hat{Y}_t = (1-\tau k_y - g_y) \hat{C}_t + \tau k_y \hat{I}_t + \hat{\epsilon}_c$$  (2.44)

Where $k_y$ is the steady state ratio of capital to output, $g_y$ is the steady state government expenditure-output ratio, $\epsilon_c$ is government expenditure shock following AR(1) process.

The inflation equation or the New Keynesian Philips Curve is given by

$$\hat{\pi}_t = \frac{\beta}{1+\beta \gamma_p} E_t \hat{\pi}_{t+1} + \frac{\gamma_p}{1+\beta \gamma_p} \hat{\pi}_{t-1} + \frac{1}{1+\beta \gamma_p} \left[ (1-\beta \omega_p)(1+\beta \omega_p) \right] \frac{\alpha_r}{\omega_p} \hat{\pi}_{t+1} + \alpha_\gamma \hat{\hat{W}}_t - \hat{\epsilon}_p$$  (2.45)

Where $\epsilon_p$ is a price mark-up shock.

The wage equation is:

\(^9\) The meanings of $\varphi$ and $S$ refer to Christiano, Eichenbaum and Evans (2001)
\[ \hat{W}_t = \frac{\beta}{1+\beta} \hat{W}_{t+1} + \frac{1}{1+\beta} \hat{W}_{t-1} + \frac{\beta}{1+\beta} E_t \hat{π}_{t+1} - \frac{1+\beta\gamma_w}{1+\beta} \hat{π}_t + \frac{\gamma_w}{1+\beta} \hat{π}_{t-1} \]
\[ - \frac{1}{1+\beta} \left(1-\beta\omega_w \right) \left[ \hat{W}_t - \nu \hat{L}_t - \nu \left( \hat{C}_t - \hat{h} \hat{C}_{t-1} \right) + \hat{e}_L + \hat{e}_w^w \right] \]
\[ (2.46) \]

Where \( e^w_t \) is the wage mark-up shock.

The monetary policy reaction function is
\[ \hat{R}_t = \rho \hat{R}_{t-1} + (1-\rho) \left[ e^p_t + r_x (\hat{π}_{t-1} - \hat{π}_t) + r_y \hat{Y}_t \right] + r_d (\hat{x}_t - \hat{x}_{t-1}) + r_f (\hat{Y}_t - \hat{Y}_{t-1}) + e^r_t \]
\[ (2.47) \]

The modified Smets-Wouters model with a money growth rule:

In the second scenario, the money is injected into the system by the PBC, the Taylor’s rule is replaced by a money growth rule, and the equation 2.47 is replaced by the following three equations:
\[ \hat{m}_t = \frac{\sigma}{(1-h)\sigma_M} \hat{C}_t - \frac{\sigma h}{(1-h)\sigma_M} \hat{C}_{t-1} - \frac{1}{\sigma_M} \hat{R}_t \]
\[ (2.48) \]
\[ \hat{m}_t = \hat{m}_{t-1} - \hat{π}_t + \hat{κ}_t \quad (\text{From 2.32}) \]
\[ (2.49) \]
\[ \hat{κ}_t = \rho_M \hat{κ}_{t-1} - \zeta_1 E_t \hat{x}_{t+1} - \zeta_2 \hat{Y}_t + \epsilon^a_t \]
\[ (2.50) \]

Where 2.48 comes from money demand function (2.15).

The Exogenous shocks

There are ten exogenous shocks in this regime, the preference shock \( \epsilon^c_t \) follows,
\[ \epsilon^c_t = \rho_c \epsilon^c_{t-1} + \epsilon^c_t, \text{ where } \rho_c < 1, \epsilon^c_t \in IID, (0, \sigma_c) \]

The productivity shock, \( \epsilon^a_t \) is
\[ \epsilon^a_t = \rho_a \epsilon^a_{t-1} + \epsilon^a_t, \text{ where } \rho_a < 1, \epsilon^a_t \in IID, (0, \sigma_a) \]

The labour supply shock \( \epsilon^L_t \) follows,
\[ \epsilon^L_t = \rho_l \epsilon^L_{t-1} + \epsilon^L_t, \text{ where } \rho_l < 1, \epsilon^L_t \in IID, (0, \sigma_l) \]

The investment shock, \( \epsilon^I_t \)
\[ \epsilon^I_t = \rho_I \epsilon^I_{t-1} + \epsilon^I_t, \text{ where } \rho_I < 1, \epsilon^I_t \in IID, (0, \sigma_I) \]

The government expenditure shock, \( \epsilon^G_t \)
\[ \epsilon^G_t = \rho_G \epsilon^G_{t-1} + \epsilon^G_t, \text{ where } \rho_G < 1, \epsilon^G_t \in IID, (0, \sigma_G) \]

The three “cost-push” shocks, the wage mark-up shock, \( \epsilon^W_t \), the price mark-up shock, \( \epsilon^p_t \) and the return on equity market shock, \( \epsilon^Q_t \) are IID.

One of monetary policy shock, the interest rate shock, \( \epsilon^r_t \) is IID, another shock to the inflation target can be explained as a monetary supply shock, \( \epsilon^\pi_t \) (or \( \epsilon^M_t \)) also follows AR (1) process:
\[ e_t^T = \rho_x e_{t-1}^T + \varepsilon_t^T, \text{ where } \rho_x < 1, \varepsilon_t^T \sim IID, (0, \sigma_\varepsilon^T) \] in Taylor’s rule model,

Or \[ e_t^M = \rho_m e_{t-1}^M + \varepsilon_t^M \] in the money growth model, two equations are completely same.

On the basis of ten exogenous shocks, the singular problem can be avoided for solving the system consisting of ten endogenous variables \((Y_t, C_t, W_t, L_t, K_t, I_t, Q_t, \pi_t, R_t, r_t^k)\) for the benchmark Smets-Wouters Model with Taylor’s rule.

For the modified Smets-Wouters model, we have nine exogenous shocks (without interest rate shock) for solving twelve endogenous variables \((Y_t, C_t, W_t, L_t, K_t, I_t, Q_t, \pi_t, R_t, r_t^k, m_t, \kappa_t)\)

Before employing Dynare v4 and Matlab R2007a to solve our model, \(^{10}\) we estimate the parameters in the model based on Bayesian approach in term of China’s quarterly data from 1995 to 2006.

3. Bayesian Estimation of the Parameters for Taylor’s Rule Model

To solve the above system, we need to estimate the parameters of the model. Many econometric methods can be employed to estimate them, such as the minimum distance approach in Christiano et al (2001), GMM approach, classical maximum likelihood methods in Ireland (1999), Bayesian approach in An and Schorfheide (2007). We use Bayesian technique with maximum likelihood method to estimate the parameters for the benchmark Smets-Wouters model (Taylor’s rule model). Because the values of these parameters are estimated in terms of real macroeconomic quarterly time series from 1996 to 2006, they are independent of the monetary policy rules and the behavioral equations, therefore, we can use these estimated parameters as the calibration in the second scenario (the modified Smets-Wouters model with the money growth rule) to conduct simulation.

Following Smets-Wouters (2002), Christiano et al (2001) and Rotemberg and Woodford (1998), the parameters in the Taylor’s rule model are divided into two groups.

The First group of parameters consists of \((\beta, \tau, c_v, inv_j, k_j, g_y, \bar{r}^k)\), which can be fixed by setting according to the regressed results by many other researchers and observations from the empirical data. Following Smets and Wouters (2002), Christiano et al (2001), Chen Kunting and Gong Liutang (2006), Zhang (2009) and other Chinese economists, \(\beta\) is set to be 0.99, regarding to a steady state real annual interest rate as 0.04; the depreciation rate of capital stock, \(\tau\), is set equal to 0.025 per quarter, implying that the annual depreciation rate is 0.10; given \(\beta, \tau\), the steady state value of capital rental rate is 0.0351 by calculating \((\bar{r}^k = \frac{1}{\beta} - 1 + \tau)\); the share of consumption in GDP, \(c_v\) is set to 0.38 according to the actual time series data of China’s economy; the share of private investment is assumed to equal 0.22 following Uhlig (2006/2007) and Smets and Wouters (2002)(the ratio of investment to GDP is between 0.18-0.50 in China by calculation), so the capital-output ratio \(k_j\) is 8.8 \((k_j = inv_j / \tau)\) and the government expenditure-output ratio \(g_y = 0.40\), in line with the great weights of government investment in China’s output. The parameters by setting are shown by Table 1.

\(^{10}\) Since Blanchard and Kahn (1980), many algorithms have been developed to solve the rational-expectation models, including Anderson and Moore (1983), Binder and Pesaran (1994), Sims (1996), King and Watson (1998), Klein (1999) and Uhlig (1999).
The second group is composed of 32 other model parameters in Taylor’s rule Model. We use China’s quarterly time series data from 1995q1 to 2006q4 to estimate the second group of parameters by Bayesian approach. The quarterly time series data from 1996 to 2006 are obtained from the National Bureau of Statistics of China, CEN(China Economic Network) and IFS; In estimating, the seven observable variables including output, consumption, investment, employment, wage level and CPI inflation rate are used. On the non stationary variables in the model, we estimate their growth rate, namely log-differences of consumption, GDP, investment, employment and wage; the interest rate is in nominal term, no transformation is conducted to CPI inflation.

In our case, the priors of second group parameters for Taylor’s rule model are determined and presented in Table 2.

The inter-temporal elasticity of substitution \( \sigma \) locates between 0.5-1.50 generally according to the results of other research, which is assumed to be distributed as a normal distribution; its precise mean was based on previous outcomes and trials. The inverse elasticity of labour supply, \( \nu \), following Smets and Wouters (2002), is set to 2.0 as normal distribution. The output elasticity of capital, \( \alpha \), is set to 0.30 as beta distribution (Beta distribution ranges from 0 to 1) following most researchers. The inverse elasticity of capital utility cost, \( \psi \) is normal distribution, prior mean is assumed to 5.917 following Uhlig (2006/2007); the share of fixed cost in production, \( \phi \) is set to 0.408 as normal distribution; the inverse of investment adjustment cost, \( \varphi \), following a normal distribution with prior mean 0.15; All the coefficients for inflation, inflation growth, output gap and output gap growth \( [r_p, r_y, r_{d\pi}, r_{d\delta}] \) are assumed to be normal distribution and the priors for them are set following Uhlig (2006/2007); the habit coefficient of historical consumption has a prior mean 0.5 with standard error 0.10 in beta distribution; the degree of price indexation, the Calvo stickiness of price and wage, and the wage mark up are set to be equal or greater than 0.5 with a beta distribution based on Euro data following Smets and Wouters (2002); All AR coefficients of lagged variables for interest rate and stochastic shocks are assumed to follow a beta distribution (stationary) following Smets and Wouters (2002), their standard errors are set to make the domain covers a reasonable band. Following Smets and Wouters (2002), the variance of ten shocks are assumed to be inverse Gamma distribution, which guarantees the positive variance.

Using the Bayesian technology, the posterior modes of the parameters are estimated with China’s time series quarterly data from 1995q1 to 2006 q4. We estimated these parameters using MCMC approach with Metropolis-Hastings algorithm (100000 draws) in dynare v4.02. We also exploit the maximum likelihood methods to estimate the parameters for a robust check. The results are also shown in Table 3, which is consistent with the results of Bayesian estimation.

From table 3, overall, most posterior modes of parameters estimated are significantly different from zero, except the coefficients for the output gap and output gap growth, implying that the deviation of the interest rate

**Table 1** The Values of Parameters by setting for Taylor’s rule model

<table>
<thead>
<tr>
<th>Parameters</th>
<th>( \beta )</th>
<th>( \tau )</th>
<th>( c_y )</th>
<th>( inv_y )</th>
<th>( k_y )</th>
<th>( g_y )</th>
<th>( \bar{r}^k )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>0.99</td>
<td>0.025</td>
<td>0.38</td>
<td>0.22</td>
<td>8.8</td>
<td>0.40</td>
<td>0.0351</td>
</tr>
</tbody>
</table>
rule in China’s implementation of monetary policy from the Taylor’s rule. Generally, China’s monetary authority exploits quantity tools to promote economy growth rather than the interest rate, which is often used to be against the inflation. The standard errors of all the shocks are also significant, especially the large value of government expenditure shock, which is in line with the real economic situation in China, where government consumption and investment play great roles in economic growth; the big value of wage mark up shock reflects a flat or elastic upward labour supply curve in China, demonstrating that the abundant of labours in China; the great shock of productivity demonstrates that huge technology progress took place in China in the last decade.

Focusing on the parameters governing the characteristics of price and wage stickiness in China’s economy, we find that the 4 parameters \( \gamma_p, \omega_p, \gamma_w, \omega_w \) are estimated to be greater than that in prior distribution, especially the considerable degree of Calvo price and wage stickiness \( \omega_p = 0.9529, \omega_w = 0.7947 \), implying a long period of wage and price contracts more than two years.

Comparing the values of our estimated parameters from China’s economic data with that from Euro area and US data based on the same model and same estimating approach from Table 4, we can draw some interesting conclusions. The external habit formation of past consumption in China is the greatest, saying that Chinese have biggest habit consumption, which implies that an expected one percent increase in the short-term interest rate for four quarters has more impact on consumption in the Euro area and the US than in China according to the consumption equation. China has the biggest output elasticity of capital. This is in line with the large share of investment in GDP formation in China, but the adjustment cost parameter in China is also the biggest, showing lowest efficiency of capital utilization. China’s elasticity of labour supply is relatively smaller than that in Europe and US. Among three economies, US hold the biggest elasticity of capital utility cost, China’s elasticity of capital utility cost is close to Europe’s. China’s interest rate is more persistent than that in Europe and US. This implies that China has a higher inertia in the implementation of monetary policy when the interest rate is taken as main policy tool. Our estimation delivers very lower values for the coefficients in the reaction function of China’s monetary authority than that in US and Europe, implying that China’s central bank does not completely follow Taylor’s rule, although the response of interest rate to inflation is greater than and close to the values in Europe and US which is consistent with the Taylor’s principle, the response of interest rate to output gap is very weaker in China than that in US and Europe. This result consists with the reality that the main policy tool is a quantity tool rather than a price tool in China. China has the biggest degree of price indexation \( \gamma_p \), two times as in Europe and US, implying that inflation depends more on past inflation than expected future inflation in China according to the inflation equation, namely, backward-looking plays more roles than forward looking in inflation formation process in China. Moreover, China has the most considerable degree of Calvo price stickiness among three economies, reflecting that underdevelopment of market mechanism and high degree of regulation on the prices by the government. Finally, China’s government expenditure shock, productivity shock, preference shock, investment shock and mark up in price and wage shocks are very significant compared with that in Europe and US, which are shaping the special characteristics of China’s economy since 1978.
### Table 2: The priors of the parameters for Taylor’s Rule model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Type</th>
<th>Prior Distribution Mean (1st)</th>
<th>St. error</th>
<th>Prior Distribution Mean (2nd)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \sigma )</td>
<td>Normal</td>
<td>1.2000</td>
<td>0.25</td>
<td>1.20</td>
<td>coefficient of relative risk aversion</td>
</tr>
<tr>
<td>( \nu )</td>
<td>Normal</td>
<td>2.0</td>
<td>0.75</td>
<td>2.0</td>
<td>inverse elasticity of labour supply</td>
</tr>
<tr>
<td>( \alpha )</td>
<td>Beta</td>
<td>0.3</td>
<td>0.1</td>
<td>0.3</td>
<td>output elasticity of capital</td>
</tr>
<tr>
<td>( \psi )</td>
<td>Normal</td>
<td>5.917</td>
<td>0.05</td>
<td>6.0</td>
<td>inverse elasticity of capital utility cost</td>
</tr>
<tr>
<td>( \phi )</td>
<td>Normal</td>
<td>1.408</td>
<td>0.25</td>
<td>3.0</td>
<td>share of fixed cost in production</td>
</tr>
<tr>
<td>( \varphi )</td>
<td>Normal</td>
<td>0.15</td>
<td>0.05</td>
<td>0.15</td>
<td>inverse of investment adjustment cost</td>
</tr>
<tr>
<td>( \rho )</td>
<td>Beta</td>
<td>0.93</td>
<td>0.03</td>
<td>0.95</td>
<td>AR for lagged interest rate</td>
</tr>
<tr>
<td>( r_{\pi} )</td>
<td>Normal</td>
<td>1.68</td>
<td>0.05</td>
<td>1.68</td>
<td>Inflation coefficient</td>
</tr>
<tr>
<td>( r_y )</td>
<td>Normal</td>
<td>0.10</td>
<td>0.05</td>
<td>0.01 (0.005)</td>
<td>output gap coefficient</td>
</tr>
<tr>
<td>( r_{\pi t} )</td>
<td>Normal</td>
<td>0.15</td>
<td>0.10</td>
<td>0.10 (0.005)</td>
<td>Inflation growth coefficient</td>
</tr>
<tr>
<td>( h )</td>
<td>Beta</td>
<td>0.50</td>
<td>0.10</td>
<td>0.70</td>
<td>habit coefficient of past consumption</td>
</tr>
<tr>
<td>( \gamma_p )</td>
<td>Beta</td>
<td>0.50</td>
<td>0.15</td>
<td>0.80</td>
<td>degree of partial indexation of price</td>
</tr>
<tr>
<td>( \omega_p )</td>
<td>Beta</td>
<td>0.9</td>
<td>0.05</td>
<td>0.9</td>
<td>Calvo price stickiness</td>
</tr>
<tr>
<td>( \gamma_w )</td>
<td>Beta</td>
<td>0.75</td>
<td>0.15</td>
<td>0.75</td>
<td>degree of partial indexation of wage</td>
</tr>
<tr>
<td>( \omega_w )</td>
<td>Beta</td>
<td>0.70</td>
<td>0.15</td>
<td>0.70</td>
<td>Calvo wage stickiness</td>
</tr>
<tr>
<td>( \lambda_w )</td>
<td>Beta</td>
<td>0.5</td>
<td>0.15</td>
<td>0.5</td>
<td>markup in wage setting</td>
</tr>
<tr>
<td>( \rho_c )</td>
<td>Beta</td>
<td>0.85</td>
<td>0.10</td>
<td>0.85</td>
<td>AR for preference shock</td>
</tr>
<tr>
<td>( \rho_a )</td>
<td>Beta</td>
<td>0.80</td>
<td>0.10</td>
<td>0.80</td>
<td>AR for productivity shock</td>
</tr>
<tr>
<td>( \rho_i )</td>
<td>Beta</td>
<td>0.85</td>
<td>0.10</td>
<td>0.85</td>
<td>AR for investment shock</td>
</tr>
<tr>
<td>( \rho_L )</td>
<td>Beta</td>
<td>0.85</td>
<td>0.10</td>
<td>0.85</td>
<td>AR for labour supply shock</td>
</tr>
<tr>
<td>( \rho_G )</td>
<td>Beta</td>
<td>0.85</td>
<td>0.10</td>
<td>0.85</td>
<td>AR for government expenditure shock</td>
</tr>
<tr>
<td>( \rho_R )</td>
<td>Beta</td>
<td>0.85</td>
<td>0.10</td>
<td>0.85</td>
<td>AR for money supply shock</td>
</tr>
<tr>
<td>( \varepsilon_i^{\pi} )</td>
<td>Inv gamma</td>
<td>0.336</td>
<td>Inf.</td>
<td>1.2</td>
<td>Preference shock</td>
</tr>
<tr>
<td>( \varepsilon_i^{\alpha} )</td>
<td>Inv gamma</td>
<td>0.598</td>
<td>Inf.</td>
<td>3.0</td>
<td>Productivity shock</td>
</tr>
<tr>
<td>( \varepsilon_i^L )</td>
<td>Inv gamma</td>
<td>3.52</td>
<td>Inf.</td>
<td>3.52</td>
<td>Labour supply shock</td>
</tr>
<tr>
<td>( \varepsilon_i^G )</td>
<td>Inv gamma</td>
<td>0.325</td>
<td>Inf.</td>
<td>8.0</td>
<td>Government expenditure shock</td>
</tr>
<tr>
<td>( \varepsilon_i^I )</td>
<td>Inv gamma</td>
<td>0.085</td>
<td>Inf.</td>
<td>1.2</td>
<td>Investment shock</td>
</tr>
<tr>
<td>( \varepsilon_i^\pi )</td>
<td>Inv gamma</td>
<td>0.017</td>
<td>Inf.</td>
<td>0.017</td>
<td>Money supply shock</td>
</tr>
<tr>
<td>( \varepsilon_i^R )</td>
<td>Inv gamma</td>
<td>0.081</td>
<td>Inf.</td>
<td>0.15</td>
<td>Interest rate shock</td>
</tr>
<tr>
<td>( \varepsilon_i^W )</td>
<td>Inv gamma</td>
<td>0.289</td>
<td>Inf.</td>
<td>5.0</td>
<td>Wage mark up shock</td>
</tr>
<tr>
<td>( \varepsilon_i^Q )</td>
<td>Inv gamma</td>
<td>0.604</td>
<td>Inf.</td>
<td>0.70</td>
<td>Return on equity shock</td>
</tr>
<tr>
<td>( \varepsilon_i^P )</td>
<td>Inv gamma</td>
<td>0.16</td>
<td>Inf.</td>
<td>0.50</td>
<td>Price mark up shock</td>
</tr>
</tbody>
</table>

---

11 We set first prior distribution mean referring to the results of Smets and Wouters (2002) and Chen and Gong (2006), and then set the second priors in accordance with our estimation.
<table>
<thead>
<tr>
<th>Parameters</th>
<th>Prior distribution</th>
<th>Posterior distribution MH</th>
<th>Maximum likelihood</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>pdf type</td>
<td>Mean</td>
<td>St. error</td>
</tr>
<tr>
<td>( \sigma )</td>
<td>coeff. of relative risk aversion</td>
<td>normal</td>
<td>1.20</td>
</tr>
<tr>
<td>( \psi )</td>
<td>inverse elasticity of labour supply</td>
<td>normal</td>
<td>2.0</td>
</tr>
<tr>
<td>( \alpha )</td>
<td>output elasticity of capital</td>
<td>beta</td>
<td>0.3</td>
</tr>
<tr>
<td>( \psi^1 )</td>
<td>inverse elasticity of capital utility cost</td>
<td>normal</td>
<td>6.0</td>
</tr>
<tr>
<td>( \phi_1 )</td>
<td>1-share of fixed cost in production</td>
<td>normal</td>
<td>3.0</td>
</tr>
<tr>
<td>( \varphi )</td>
<td>inverse of invest. adjustment cost</td>
<td>normal</td>
<td>0.15</td>
</tr>
<tr>
<td>( \rho )</td>
<td>AR for lagged interest rate</td>
<td>beta</td>
<td>0.95</td>
</tr>
<tr>
<td>( r_g )</td>
<td>inflation coefficient</td>
<td>normal</td>
<td>1.68</td>
</tr>
<tr>
<td>( r_p )</td>
<td>output gap coefficient</td>
<td>normal</td>
<td>0.01</td>
</tr>
<tr>
<td>( r_{d1} )</td>
<td>inflation growth coefficient</td>
<td>Normal</td>
<td>0.10</td>
</tr>
<tr>
<td>( r_{d2} )</td>
<td>output gap growth coefficient</td>
<td>Normal</td>
<td>0.01</td>
</tr>
<tr>
<td>( h )</td>
<td>habit coefficient of past consumption</td>
<td>Beta</td>
<td>0.70</td>
</tr>
<tr>
<td>( \gamma_p )</td>
<td>degree of partial indexation of price</td>
<td>Beta</td>
<td>0.80</td>
</tr>
<tr>
<td>( \omega_p )</td>
<td>calvo price stickiness</td>
<td>Beta</td>
<td>0.9</td>
</tr>
<tr>
<td>( \gamma_w )</td>
<td>degree of partial indexation of wage</td>
<td>Beta</td>
<td>0.75</td>
</tr>
<tr>
<td>( \omega_w )</td>
<td>calvo wage stickiness</td>
<td>Beta</td>
<td>0.70</td>
</tr>
<tr>
<td>( \lambda_m )</td>
<td>markup in wage setting</td>
<td>Beta</td>
<td>0.5</td>
</tr>
<tr>
<td>( \rho_p )</td>
<td>AR for preference shock</td>
<td>Beta</td>
<td>0.85</td>
</tr>
<tr>
<td>( \rho_a )</td>
<td>AR for productivity shock</td>
<td>Beta</td>
<td>0.80</td>
</tr>
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<td>( \rho_i )</td>
<td>AR for investment shock</td>
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<td>( \rho_l )</td>
<td>AR for labour supply shock</td>
<td>Beta</td>
<td>0.85</td>
</tr>
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<td>( \rho_g )</td>
<td>AR for government expenditure shock</td>
<td>Beta</td>
<td>0.85</td>
</tr>
<tr>
<td>( \rho_s )</td>
<td>AR for money supply shock</td>
<td>Beta</td>
<td>0.85</td>
</tr>
<tr>
<td>( \epsilon_p^\sigma )</td>
<td>Preference shock</td>
<td>Inv gamma</td>
<td>1.2</td>
</tr>
<tr>
<td>( \epsilon_p^\psi )</td>
<td>Productivity shock</td>
<td>Inv gamma</td>
<td>3.0</td>
</tr>
<tr>
<td>( \epsilon_p^\alpha )</td>
<td>Labour supply shock</td>
<td>Inv gamma</td>
<td>3.52</td>
</tr>
<tr>
<td>( \epsilon_p^\psi^1 )</td>
<td>Government expenditure shock</td>
<td>Inv gamma</td>
<td>8.0</td>
</tr>
<tr>
<td>( \epsilon_p^\gamma )</td>
<td>Investment shock</td>
<td>Inv gamma</td>
<td>1.2</td>
</tr>
<tr>
<td>( \epsilon_p^\mu )</td>
<td>Money supply shock</td>
<td>Inv gamma</td>
<td>0.017</td>
</tr>
<tr>
<td>( \epsilon_p^q )</td>
<td>Interest rate shock</td>
<td>Inv gamma</td>
<td>0.15</td>
</tr>
<tr>
<td>( \epsilon_p^\omega )</td>
<td>Wage mark up shock</td>
<td>Inv gamma</td>
<td>5.0</td>
</tr>
<tr>
<td>( \epsilon_p^\psi^2 )</td>
<td>Return on equity shock</td>
<td>Inv gamma</td>
<td>0.70</td>
</tr>
<tr>
<td>( \epsilon_p^\rho )</td>
<td>Price mark up shock</td>
<td>Inv gamma</td>
<td>0.50</td>
</tr>
<tr>
<td>Parameters</td>
<td>Euro Area</td>
<td>China</td>
<td>US</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------</td>
<td>--------------------</td>
<td>------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Mean</td>
<td>Conf. interval</td>
<td>Mean</td>
<td>Conf. interval</td>
</tr>
<tr>
<td>( \sigma ) coeff. of relative risk aversion</td>
<td>1.613</td>
<td>1.126-2.106</td>
<td>1.358</td>
</tr>
<tr>
<td>( U ) inverse elasticity of labour supply</td>
<td>1.265</td>
<td>0.439-2.365</td>
<td>2.2095</td>
</tr>
<tr>
<td>( \alpha ) capital output ratio</td>
<td>0.3</td>
<td>By setting</td>
<td>0.4209</td>
</tr>
<tr>
<td>( \psi ) inverse elasticity of capital utility cost</td>
<td>5.714</td>
<td>3.46-16.129</td>
<td>6.1839</td>
</tr>
<tr>
<td>( \phi ) 1+share of fixed cost in production</td>
<td>1.499</td>
<td>1.199-1.835</td>
<td>3.4945</td>
</tr>
<tr>
<td>( \varphi ) inverse of invest. adjustment cost</td>
<td>0.165</td>
<td>0.1254-0.2314</td>
<td>0.0633</td>
</tr>
<tr>
<td>( \rho ) AR for lagged interest rate</td>
<td>0.928</td>
<td>0.901-0.946</td>
<td>0.9835</td>
</tr>
<tr>
<td>( r_\pi ) inflation coefficient</td>
<td>1.668</td>
<td>1.537-1.821</td>
<td>1.6731</td>
</tr>
<tr>
<td>( r_y ) output gap coefficient</td>
<td>0.144</td>
<td>0.079-0.215</td>
<td>0.0090</td>
</tr>
<tr>
<td>( r_\pi ) inflation growth coefficient</td>
<td>0.222</td>
<td>0.134-0.313</td>
<td>0.0906</td>
</tr>
<tr>
<td>( r_\sigma ) output gap growth coefficient</td>
<td>0.174</td>
<td>0.131-0.219</td>
<td>0.0037</td>
</tr>
<tr>
<td>( h ) habit coefficient of past consumption</td>
<td>0.551</td>
<td>0.416-0.681</td>
<td>0.8142</td>
</tr>
<tr>
<td>( \gamma_p ) degree of partial indexation of price</td>
<td>0.429</td>
<td>0.268-0.597</td>
<td>0.9657</td>
</tr>
<tr>
<td>( \omega_p ) calvo price stickiness</td>
<td>0.909</td>
<td>0.890-0.927</td>
<td>0.9529</td>
</tr>
<tr>
<td>( \gamma_w ) degree of partial indexation of wage</td>
<td>0.655</td>
<td>0.383-0.900</td>
<td>0.6093</td>
</tr>
<tr>
<td>( \omega_w ) calvo wage stickiness</td>
<td>0.756</td>
<td>0.690-0.817</td>
<td>0.7947</td>
</tr>
<tr>
<td>( \lambda_w ) markup in wage setting</td>
<td>0.593</td>
<td>0.503-0.671</td>
<td>0.2667</td>
</tr>
<tr>
<td>( \rho_c ) AR for preference shock</td>
<td>0.882</td>
<td>0.817-0.931</td>
<td>0.9332</td>
</tr>
<tr>
<td>( \rho_a ) AR for productivity shock</td>
<td>0.822</td>
<td>0.712-0.912</td>
<td>0.9228</td>
</tr>
<tr>
<td>( \rho_i ) AR for investment shock</td>
<td>0.914</td>
<td>0.856-0.961</td>
<td>0.7810</td>
</tr>
<tr>
<td>( \rho_L ) AR for labour supply shock</td>
<td>0.952</td>
<td>0.916-0.98</td>
<td>0.8533</td>
</tr>
<tr>
<td>( \rho_G ) AR for government expenditure shock</td>
<td>0.952</td>
<td>0.912-0.982</td>
<td>0.9019</td>
</tr>
<tr>
<td>( \rho_e ) AR for inflation objective shock</td>
<td>0.847</td>
<td>0.658-0.970</td>
<td>0.8429</td>
</tr>
<tr>
<td>( \beta_1 ) Preference shock</td>
<td>0.324</td>
<td>Inf.</td>
<td>1.2392</td>
</tr>
<tr>
<td>( \beta^a_1 ) Productivity shock</td>
<td>0.628</td>
<td>Inf.</td>
<td>2.7720</td>
</tr>
<tr>
<td>( \beta^L_1 ) Labour supply shock</td>
<td>1.709</td>
<td>Inf.</td>
<td>3.6627</td>
</tr>
<tr>
<td>( \beta^G_1 ) Government expenditure shock</td>
<td>0.331</td>
<td>Inf.</td>
<td>8.7388</td>
</tr>
<tr>
<td>( \beta^f_1 ) Investment shock</td>
<td>0.140</td>
<td>Inf.</td>
<td>1.2805</td>
</tr>
<tr>
<td>( \beta^\pi_1 ) Inflation objective shock</td>
<td>0.028</td>
<td>Inf.</td>
<td>0.0149</td>
</tr>
<tr>
<td>( \beta^R_1 ) Interest rate shock</td>
<td>0.140</td>
<td>Inf.</td>
<td>0.1457</td>
</tr>
<tr>
<td>( \beta^W_1 ) Wage mark up shock</td>
<td>0.286</td>
<td>Inf.</td>
<td>5.0508</td>
</tr>
<tr>
<td>( \beta^Q_1 ) Return on equity shock</td>
<td>0.614</td>
<td>Inf.</td>
<td>0.6511</td>
</tr>
<tr>
<td>( \beta^P_1 ) Price mark up shock</td>
<td>0.163</td>
<td>Inf.</td>
<td>0.4482</td>
</tr>
</tbody>
</table>

12 The estimated results for Euro area are from Smets and Wouters (2002) and for US are from Smets and Wouters (2007)
For the money growth rule model, besides the estimated parameters in the Taylor’s rule model, following Zhang (2009) and other Chinese economists, the money growth parameters are set in Table 5.

**Table 5** The Values of parameters by setting for Money growth rule model

<table>
<thead>
<tr>
<th>Parameters</th>
<th>(\rho_M)</th>
<th>(\zeta_1)</th>
<th>(\zeta_2)</th>
<th>(\sigma_M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>0.8</td>
<td>1.0</td>
<td>0.5</td>
<td>3.13</td>
</tr>
</tbody>
</table>

4. The Simulation Results

In this section, we use the estimated DSGE models with the Taylor’s rule and money growth rule to conduct analysis on the impulse responses of the endogenous economic variables to the various structural shocks, especially the monetary policy shocks and productivity shocks to uncover the transmission mechanism of monetary policy in China and the characteristics of China’s business cycles respectively.

4.1 Impulse Response Analysis on Two Monetary Policy Rules

The impulse responses of endogenous variables on the exogenous shocks—two monetary policy shocks, three cost-push shocks, technology shocks, preference shocks, government expenditure shock, investment shock will be presented and discussed as follows. Before discussion, we provide a notation table for the variables in the model system.

**Table 6** Notation Table

<table>
<thead>
<tr>
<th>Variables</th>
<th>Notation</th>
<th>Variables</th>
<th>Notation</th>
<th>Variables</th>
<th>Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real consumption</td>
<td>c</td>
<td>Labour hours</td>
<td>l</td>
<td>Interest rate</td>
<td>r</td>
</tr>
<tr>
<td>Real investment</td>
<td>i</td>
<td>Real Wage</td>
<td>w</td>
<td>Rent rate of capital</td>
<td>rk</td>
</tr>
<tr>
<td>Real output</td>
<td>y</td>
<td>Inflation rate</td>
<td>pi</td>
<td>Asset price(Tobin’s Q)</td>
<td>q</td>
</tr>
<tr>
<td>Growth of money</td>
<td>kai</td>
<td></td>
<td></td>
<td>Money supply</td>
<td>m</td>
</tr>
</tbody>
</table>

The Effects of Monetary Policy Shocks and the Transmission Channels of China’s Monetary Policy

Figure 1 shows the effects of the money supply shock. In Taylor’s rule model shown by Panel A, the real wage, labour hours, capital stock, consumption, investment, and output rise, which is in line with the canonical conclusions. The real interest rate falls immediately, demonstrating a liquidity effect following an inflation effect: two years later the real interest rate begins to rise against the increase of inflation. These results are different from that in Euro Area from Smets and Wouters (2002), where no liquidity effect is found without persistent monetary policy shock.

The increase of money supply causes the fall of the interest rate and thereby the rises of consumption, investment and then the output, these results provide the evidence of an *interest rate channel* of MTM in China. Also, the immediate rise of asset price (q, Tobin’s q) caused by a money supply shock following the gradual rise of consumption (*Wealth Effect*) and investment (*Tobin’s Q*) supports the existence of an *asset price channel* of MTM in China.
channel in MTM in China. Moreover, the inflation equation (2.41) incorporates the effects of expectations in the monetary policy transmission implies the expectation channel).

In money growth rule model shown by panel B, a money supply shock increases money growth rate and the money supply, and makes inflation rate rise. Consumption, investment and capital all rise and thereby raising the output. The interest rate rises initially and then falls quickly. These effects confirm the existence of the monetary channel (interest rate channel) and the liquidity effect in China. The rise in the asset price (q) shows the evidence of the asset price channel. The labour supply and the wage rate also rise after a money supply shock.

Comparing the effects of money supply shock in Taylor’s rule and the money growth rule, we can find the responses of all variables to money supply shocks are similar. The differences are the magnitude of the effects.

The effects of an interest rate shock in Taylor’s rule model are presented in Figure 2. A positive interest rate shock makes real interest rate rise, and thereby reduces the consumption, investment, output, capital stock, labour supply, real wage level and the rate of inflation, but the rental rate of capital soon rebound after temporary decrease. This clearly suggests the existence of the interest rate channel of monetary policy in China. The immediate fall of asset price following the fall in consumption and investment also implies the existence of an asset price channel through Tobin’s effect and Wealth effect. Moreover, the above effects uncover the role of monetary policy in China’s business cycles.

The Effects of Cost-push Shocks

Figure 3 shows the effects of the price mark-up shocks in Taylor’s rule model (Panel A) and a money growth rule model (Panel B). In the Taylor’s rule model, a price mark up shock increases the rate of inflation immediately, and then the interest rate to be against the inflation, the immediate fall in output comes from two sides: the left shift of the aggregate demand curve because of the decline of consumption and investment (Interest rate channel); the left shift of the aggregate supply curve because of the fall of labour hours and wages. At the outset, the labour supply and equity premium rise and then begin to fall after 3 years. Panel B (Money growth rule) shows that a price mark up shock increases the inflation immediately like in the Taylor’s rule. The interest rate is raised soon by the PBC and the money supply decreases to depress the inflation, all other macroeconomic variables excluding the asset price fall following the contractionary policy operation (The interest rate channel). The wage rate falls and increases the labour supply later.

In Figure 4, Panel A reflects the results from the Taylor’s rule model: a wage mark up shock also increases the rate of inflation and interest rate with the rise of real wage, the consumption, investment, output and equity premium have similar responses as that to the price mark up shock excluding opposite responses of the labour supply and capital rental rate and the similar mechanism. In Panel B for money growth rule, a wage mark up shock raises the wage rate and inflation, depresses the labour supply, the rise in the interest rate soon depressed the consumption, investment, money supply, capital and thereby the output. A similar effect is demonstrated as the price mark up shock. These effects are similar in two models; excluding the asset price response is opposite in the Taylor’s rule model.
Figure 1 The effects of money supply shocks

Panel A Taylor’s Rule

Panel B Money Growth Rule
In Figure 5, Panel A is for Taylor’s rule model: a positive equity premium shock (asset price rise) increases the investment and consumption (gradually) and thereby the output, which supports the evidence of an asset price channel. The capital stock, labour supply, real wage, and interest rate also increase, which reduces inflation rate and capital rental rate. Panel B (Money growth rule model) shows that a positive equity premium shock increases the asset price, the investment and thereby the output (the asset price channel), but decreases the consumption (crowding out effect). This shock decreases the money supply and the inflation and raises the interest rate. In the Taylor’s rule model, no crowding effect can be found in this case. The responses of wage rate in two scenarios are different.

The Effects of Other Shocks

Panel A (Taylor’s rule) in Figure 6 shows, following a positive productivity shock, the consumption, investment, output, capital stock and real wage rise, while labour supply (employment) falls. The rental rate of capital, return on equity market, interest rate and inflation rate also fall. These effects tell the same story identified as in US and Euro Area. As Smets and Wouters (2002) pointed out, the rise in productivity causes the fall in marginal cost, because the monetary policy does not reacts timely and strongly (interest rate falls slowly) to offset this fall in marginal cost, which decreases inflation gradually; In Panel B (Money growth rule), following a positive productivity shock, similarly as in Taylor’s rule, the consumption, investment, asset price,
money supply, capital increase and thereby the output increase. But the wage rate declines, which is different from that in the Taylor’s rule model. The inflation, interest rate and capital rent rate decrease which are similar as in Taylor’s rule.

Panel A (Taylor’s rule) in Figure 7 demonstrates the effects of a positive labour supply shock. The qualitative effects of this shock on consumption, investment, output, capital stock, inflation and interest rate are similar to those of a productivity shock. But the employment and real wage have opposite responses as those of a productivity shock. Panel B (Money growth rule) also shows the effects of a positive labour supply shock. The consumption, investment and thereby the output rise after this shock, similar effects as the productive shock. The wage rate declines and the labour supply rises. The effects are qualitatively same as in the Taylor’s rule model. The difference is that the asset price increases in the money growth rule model.

Following a preference shock shown by Panel A (Taylor’s rule) in Figure 8, the consumption and output increase significantly, while the investment increases initially and then begin to fall, demonstrating a delay significant crowding out effects; the labour supply and real wage also increase, which cause the rise in marginal cost and thereby increase the inflation rate, the interest rate rise following the rise in inflation. Panel B shows the responses to a preference shock in the money growth rule model. Although consumption increases but the fall in the investment crowds out this effect and the output decreases, this is different from the Taylor’s rule model, where the output increases. Also a different response in the asset price can be found here. The rises in the inflation and interest rate are same as that in the Taylor’s rule model.

The government expenditure shock has significant effects in China, as shown by Panel A in Figure 9: increasing the labour supply, real wage and output immediately and thereby causing demand-pull inflation gradually. It decreases the private consumption and investment, implying a significant crowding out effect on private consumption and private investments. The fall in consumption leads to the rise of marginal utility of working, which increases the labour supply. The return on equity market rises while the capital stock falls. The interest rate and rental rate of capital also increase. In panel B, following a positive government expenditure shock in the money growth rule model, the capital, private investment and consumption decrease but output increases, showing a significant crowding out effects. The responses are qualitatively similar in two models.

Panel A (Taylor’s rule) in Figure 10 shows the effects of a positive investment shock. Investment, the capital stock and output increase significantly with a weak crowding out effect on consumption, which has a similar result as government expenditure shocks: labour supply and real wage also rise. The investment shock causes a weak rise in inflation, while the equity premium and capital rental rate falls. Panel B demonstrates the effects of a positive investment shock under a money growth rule. The investment, labour supply and output increase with a significant crowding out effect on consumption (In Taylor’s rule the crowding out effect is weak). The wage rate, inflation rate and interest rate decline, showing different effects from that in Taylor’s rule model.
Figure 3 Responses to Price Mark up Shocks

Panel A Taylor’s Rule

Panel B Money Growth Rule
Figure 4 Responses to Wage Mark up Shocks

Panel A  Taylor’s Rule

Panel B  Money Growth Rule
Figure 5 Responses to Return on Equity Market Shocks

Panel A  Taylor’s Rule

Panel B  Money Growth Rule
Figure 6 Responses to Productivity Shock

Panel A Taylor’s Rule

Panel B Money Growth Rule
Figure 7 Responses to Labour Supply Shocks

Panel A Taylor’s Rule

Panel B Money Growth Rule
Figure 8 Responses to Preference Shocks

Panel A Taylor’s Rule

Panel B Money Growth Rule
Figure 9 Responses to Government Expenditure Shocks

Panel A Taylor’s Rule

Panel B Money Growth Rule
Figure 10 Responses to Investment Shocks

Panel A  Taylor’s Rule

Panel B  Money Growth Rule
4.2 Variance Decomposition for China’s Business Cycle

Table 7 shows the variance decomposition in infinite horizon for the Taylor’s rule model.

<table>
<thead>
<tr>
<th></th>
<th>$\varepsilon^L_t$</th>
<th>$\varepsilon^a_t$</th>
<th>$\varepsilon^k_t$</th>
<th>$\varepsilon^G_t$</th>
<th>$\varepsilon^\pi_t$</th>
<th>$\varepsilon^I_t$</th>
<th>$\varepsilon^P_t$</th>
<th>$\varepsilon^W_t$</th>
<th>$\varepsilon^Q_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>0.04</td>
<td>10.83</td>
<td>35.14</td>
<td>0.64</td>
<td>0.00</td>
<td>4.54</td>
<td>28.01</td>
<td>6.88</td>
<td>13.93</td>
</tr>
<tr>
<td>L</td>
<td>0.03</td>
<td>24.91</td>
<td>12.26</td>
<td>0.00</td>
<td>3.06</td>
<td>17.22</td>
<td>1.99</td>
<td>32.69</td>
<td>0.00</td>
</tr>
<tr>
<td>W</td>
<td>0.03</td>
<td>11.77</td>
<td>14.48</td>
<td>0.26</td>
<td>0.00</td>
<td>2.97</td>
<td>6.01</td>
<td>14.05</td>
<td>50.44</td>
</tr>
<tr>
<td>Rk</td>
<td>0.04</td>
<td>10.60</td>
<td>34.75</td>
<td>0.90</td>
<td>0.00</td>
<td>4.60</td>
<td>28.36</td>
<td>6.75</td>
<td>14.01</td>
</tr>
<tr>
<td>I</td>
<td>0.03</td>
<td>9.81</td>
<td>26.67</td>
<td>0.55</td>
<td>0.00</td>
<td>6.12</td>
<td>33.79</td>
<td>9.05</td>
<td>13.97</td>
</tr>
<tr>
<td>Y</td>
<td>0.04</td>
<td>11.53</td>
<td>22.23</td>
<td>10.40</td>
<td>0.00</td>
<td>7.39</td>
<td>22.96</td>
<td>9.79</td>
<td>15.66</td>
</tr>
<tr>
<td>C</td>
<td>0.04</td>
<td>11.72</td>
<td>52.60</td>
<td>0.76</td>
<td>0.00</td>
<td>8.21</td>
<td>5.14</td>
<td>7.70</td>
<td>13.84</td>
</tr>
<tr>
<td>R</td>
<td>0.04</td>
<td>11.83</td>
<td>45.41</td>
<td>1.26</td>
<td>0.00</td>
<td>10.63</td>
<td>4.84</td>
<td>11.05</td>
<td>14.94</td>
</tr>
<tr>
<td>$\pi\pi$</td>
<td>0.04</td>
<td>12.06</td>
<td>20.42</td>
<td>0.22</td>
<td>0.00</td>
<td>8.45</td>
<td>2.47</td>
<td>36.20</td>
<td>20.15</td>
</tr>
</tbody>
</table>
| Q     | 0.03             | 7.78             | 15.34            | 0.15             | 0.00             | 24.05            | 27.31            | 13.09            | 12.24            | 0.02

Focusing on the contribution of each of the structural shocks to output, we can find that in the long run, the investment and preference shocks drives the forecasted GDP variances, which can explain about 20% of output forecast error respectively; technology shock, monetary policy shock (interest rate shock), government expenditure shock and cost-push shocks (price mark up, wage mark up) also play distinguished roles, each contributes about 10% respectively. Money supply shocks have no impact on output variance in the long run. This is in line with the assumption that the money is neutral in our utility function. These conclusions are very different from that in Euro Area from Smets and Wouters (2002).

Turning to the determinants of inflation, it shows that the cost-push shock dominates the forecast errors, which contributes about 50% of inflation variance, uncovering the special characteristics of inflation formulation in China. Preference shocks also account for 20%, technology shocks account for 12%, whereas monetary policy shocks also contribute about 10%.

The interest rate is mainly driven by the preference shock (45%), cost-push shocks and technology shocks also account for above 10%.

Obviously, the consumption variance is dominated by preference shock (50%); whereas technology shock, cost-push shock and monetary policy shocks also have impact.

In summary, the preference shock and investment shock play significant roles in China’s business cycle, cost-push shocks, technology shock, government expenditure shock and monetary policy (interest rate) shock also explain distinguished fraction of output, inflation, interest rate and consumption.

It is worth noting that the wage mark-up shock and technology shock determinant 50% of labour supply variance in the long run. Investment and government expenditure shocks also play important roles in labour supply in China.
Table 8 shows the variance decomposition in infinite horizon for the money growth rule model.

Table 8 Variance Decomposition (in percentage) (Money Growth Rule)

<table>
<thead>
<tr>
<th></th>
<th>$\varepsilon^L_t$</th>
<th>$\varepsilon^a_t$</th>
<th>$\varepsilon^c_t$</th>
<th>$\varepsilon^G_t$</th>
<th>$\varepsilon^M_t$</th>
<th>$\varepsilon^i_t$</th>
<th>$\varepsilon^p_t$</th>
<th>$\varepsilon^W_t$</th>
<th>$\varepsilon^Q_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>0.03</td>
<td>8.44</td>
<td>53.61</td>
<td>18.71</td>
<td>0.00</td>
<td>12.40</td>
<td>0.88</td>
<td>5.92</td>
<td>0.00</td>
</tr>
<tr>
<td>L</td>
<td>0.08</td>
<td>34.33</td>
<td>7.67</td>
<td>5.70</td>
<td>0.00</td>
<td>2.04</td>
<td>1.18</td>
<td>49.01</td>
<td>0.00</td>
</tr>
<tr>
<td>W</td>
<td>0.10</td>
<td>2.19</td>
<td>6.67</td>
<td>1.76</td>
<td>0.00</td>
<td>2.44</td>
<td>4.95</td>
<td>81.89</td>
<td>0.00</td>
</tr>
<tr>
<td>Rk</td>
<td>0.03</td>
<td>9.98</td>
<td>49.56</td>
<td>17.65</td>
<td>0.00</td>
<td>12.06</td>
<td>0.72</td>
<td>10.00</td>
<td>0.00</td>
</tr>
<tr>
<td>l</td>
<td>0.03</td>
<td>7.26</td>
<td>43.82</td>
<td>26.59</td>
<td>0.00</td>
<td>14.88</td>
<td>1.72</td>
<td>5.70</td>
<td>0.00</td>
</tr>
<tr>
<td>Y</td>
<td>0.06</td>
<td>17.62</td>
<td>21.98</td>
<td>31.30</td>
<td>0.00</td>
<td>4.72</td>
<td>10.03</td>
<td>14.28</td>
<td>0.00</td>
</tr>
<tr>
<td>C</td>
<td>0.01</td>
<td>2.27</td>
<td>17.90</td>
<td>55.78</td>
<td>0.00</td>
<td>17.21</td>
<td>4.79</td>
<td>2.04</td>
<td>0.00</td>
</tr>
<tr>
<td>r</td>
<td>0.01</td>
<td>2.11</td>
<td>6.67</td>
<td>72.81</td>
<td>0.00</td>
<td>7.69</td>
<td>8.66</td>
<td>2.06</td>
<td>0.00</td>
</tr>
<tr>
<td>M</td>
<td>0.01</td>
<td>1.83</td>
<td>5.38</td>
<td>71.59</td>
<td>0.00</td>
<td>11.76</td>
<td>7.64</td>
<td>1.78</td>
<td>0.00</td>
</tr>
<tr>
<td>Pi $\pi$</td>
<td>0.10</td>
<td>26.09</td>
<td>33.80</td>
<td>1.18</td>
<td>0.00</td>
<td>4.82</td>
<td>13.21</td>
<td>20.82</td>
<td>0.00</td>
</tr>
<tr>
<td>Q</td>
<td>0.00</td>
<td>0.46</td>
<td>6.32</td>
<td>72.20</td>
<td>0.00</td>
<td>13.22</td>
<td>7.11</td>
<td>0.69</td>
<td>0.01</td>
</tr>
<tr>
<td>Kai</td>
<td>0.03</td>
<td>7.33</td>
<td>8.58</td>
<td>62.68</td>
<td>0.00</td>
<td>6.12</td>
<td>9.07</td>
<td>6.19</td>
<td>0.00</td>
</tr>
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</table>

From Table 8, on the contribution of each of the structural shocks to output, it can be found that the government expenditure, preference and productive shocks drive the forecasted GDP variances. They can explain about 31.3%, 21.98% and 17.62 of the output forecast error respectively (total 70%). The cost-push shocks (price mark up, wage mark up) also play distinguished roles; each contributes about 10% respectively. Money supply shock has no impact on output variance in the long run. These are different from that in Taylor’s rule model, in which investment and preference shocks play significant roles.

On the determinants of inflation, the preference and technology shocks also contribute significantly to the variations of the inflation. The cost-push shocks contribute about 40% of inflation variance. The results are different from that in Taylor’s model, in which the cost-push shocks dominate the variations of the inflation.

The consumption variance is also dominated by the government expenditure shock (56%). The preference shock contributes about 20%.

Similarly, the wage mark-up shock determines 50% of labour supply variance in the long run. The productive shock also play important role in the labour supply in China.

5 Summary and Conclusions

In this paper, we employ the bench-mark New Keynesian Model-The Smets-Wouters model with Taylor’s rule and a modified Smets-Wouters model with a money growth rule to simulate the effects of monetary policy shocks on China’s economy and the contributions of the diverse macroeconomic shocks to business cycle in China. This model incorporates many frictions which are enough to capture the empirical persistence in the main China’s macro economic data.

We estimate this DSGE model using Bayesian approach following Smets and Wouters (2002) with China’s
macro time series data from 1996q1-2006q4. The parameters estimated feature the unique characteristics and determinants of developments in China’s macro economics. Comparing the estimated results with the parameters estimation for Europe and US with the same model, we find the following special characters for China’s economy: Chinese have the biggest habit consumption, which implies that an expected one percent increase in the short-term interest rate for four quarters has more impact on consumption in Euro area and US than in China according to the consumption equation. China also has the biggest output elasticity of capital. This is in line with the large share of investment in GDP formation in China, but the adjustment cost parameter in China is also the biggest, showing the lowest efficiency of capital utilization. China’s elasticity of labour supply is relatively smaller than that in Europe and US. China’s interest rate is more persistent than that in Europe and US. This implies that China has a higher inertia in the implementation of monetary policy when the interest rate is taken as main policy tool. Our estimation delivers very lower values for the coefficients in the reaction function of China’s monetary authority than that in US and Europe, implying that China’s central bank does not completely follow Taylor’s rule, which consists with the reality that the main policy tool is quantity tools rather than price tools in China. China has the biggest degree of price indexation ($\gamma_P$), two times as in Europe and US, implying that inflation depends more on past inflation than expected future inflation in China referring to the inflation equation, namely, backward-looking plays more roles than forward-looking in inflation formation process. Moreover, China has the most considerable degree of Calvo price stickiness among three economies, reflecting that underdevelopment of market mechanism and high degree of regulation on the prices by the government. Finally, China’s government expenditure shock, productivity shock, preference shock, investment shock and mark up in price and wage shocks are very significant compared with that in Europe and US.

Turning to simulation results of the benchmark Smets-Wouters model with Taylor’s rule, several points are worth highlighting. First, the transmission of monetary policy shocks and the liquidity effect through the interest rate channel and asset price channel have been identified in China. Our estimates of the effects of an inflation objective shock (money supply shock) is in line with the canonical conclusion: the capital stock, consumption, investment and output rise, the real interest rate falls immediately, demonstrating a liquidity effect following an inflation effect: two years later the real interest rate begins to rise against the increase of inflation, which supports the existence of interest rate channel in the monetary policy transmission. This result is different from that in Euro Area from Smets and Wouters (2002), where no liquidity effects are found without persistent monetary policy shock. The interest rate shock makes real interest rate rise, and thereby reduces the consumption, investment, output, capital stock, labour supply, real wage level and the rate of inflation, but the rental rate of capital soon rebound after temporary decrease. This clearly confirms the existence of interest rate channel of monetary policy in China. The immediate decline in asset price (Q) following the decline of investment and consumption and thereby the output supports the existence of asset price channel in China’s monetary transmission. The incorporation of rational expectation in inflation equation implies the effects of expectation in the monetary transmission. (Expectation channel)

Second, the transmission of non-monetary shocks is also significant. The cost-push shocks increase the rate of inflation significantly; a positive productivity shock makes the consumption, investment, output, capital
stock and real wage rise, while labour supply (employment) falls. The rental rate of capital, return on equity market, interest rate and inflation rate also fall. These effects tell the same story identified as in US and Euro Area. As Smets and Wouters (2002) pointed out, the rise in productivity causes the fall in marginal cost, because the monetary policy does not react timely and strongly (interest rate falls slowly) to offset this fall in marginal cost, which decreases inflation gradually; the effects of a positive labour supply shock on consumption, investment, output, capital stock, inflation and interest rate are similar to those of a productivity shock. A preference shock increases the consumption and output significantly, while the investment increases initially and then begin to fall, demonstrating a delay significant crowding out effects; the labour supply and real wage also increase, which cause the rise in marginal cost and thereby increase the inflation rate, the interest rate rise following the rise in inflation. The government expenditure shock has significant effects in China: increase the labour supply, real wage and output immediately and thereby cause demand-pull inflation gradually. It decreases the private consumption and investment, also implying a significant crowding out effects on private consumption and private investments. The fall in consumption leads to the rise of marginal utility of working, which increases the labour supply. The return on equity market rises while the capital stock falls. The interest rate and rental rate of capital also increase. The effects of a positive investment shock are qualitatively similar as the government expenditure shock.

Third, we have measured the contributions of monetary policy shocks and non-policy shocks to the business cycle developments in China’s economy. Depending on the results of variance decomposition in infinite horizon, we find that preference shock and investment shock play significant roles in China’s business cycle, besides, the cost-push shocks, the technology shock, and the monetary policy (interest rate) shock also explain distinguished fraction of output, inflation, interest rate and consumption. To the variance decomposition of the inflation, it shows that the cost-push shock dominates the forecast errors of the inflation, which contributes about 50% of inflation variance, uncovering the special characteristics of inflation formulation in China. Preference shocks also account for 20%, technology shocks account for 12%, whereas monetary policy shock also contributes about 10%. On the determinants of labour supply, the wage mark-up shock and technology shock dominate 50% of labour supply variance in the long run, Investment and government expenditure shocks also play important role in labour supply in China.

The modified Smets-Wouters model with a money growth rule uncovers the same monetary policy transmission mechanisms: the existence of the monetary channel, the asset price channel and the expectation channel. The responses to the monetary policy shocks and non monetary policy shocks are qualitatively similar as in the Taylor’s rule although there are some differences. The main differences emerge in the variance decomposition or the contributions to the business cycle of China’s economy. In the money growth rule model, the government expenditure, preference and productive shocks play significant rules in the variations of output. On the determinants of inflation, the preference and technology shocks also contribute significantly to the forecast errors. The cost-push shocks contribute about 40% of inflation variance.
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Appendix Bayesian Estimation Results for the parameters

Figure 11: The Priors and Posteriors of Parameters (dark line is the posteriors)
Figure 12 Smoothed Shocks
Figure 13 Historical and Smoothed Variables