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A DSGE Model for China's Monetary and Macroprudential Policies

Peter Sinclair¹, Lixin Sun²

Abstract: This paper develops a calibrated DSGE model for simulating China's monetary policy and macroprudential policy. The empirical results show, first, that the interest rate is a better instrument for China's monetary policy than the required reserve ratio when the central bank is solely concerned by the price stability; second, that the loan-to-value (LTV) ratio is a very useful macroprudential tool for China's financial stability, and the required reserve ratio could be used as an instrument for both objectives. Whether macroprudential policy complements or conflicts with monetary policy depends upon the instruments choices of two policies. Our policy experiments suggest three combination choices of instruments for China's monetary and macroprudential policies.

Keywords: DSGE Model, Monetary Policy, Macroprudential Policy, China's Economy

JEL Code: E52, E61, G18

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1. Introduction

The Great Recession of 2008-2009 ignited research interests on the systemic risks and financial stability, which is the main objective of the macroprudential policy implemented by the central bank in most countries, as the price stability to monetary policy. This triggers the debate on the interactions and the coordination between monetary and macroprudential policies, because two policies could be either complements or substitutes, which is a dilemma to the policymakers (Borio et al., 2002). In this paper, a New Keynesian DSGE model is developed to analyse the interdependencies of China's monetary policy and macroprudential policy. The model borrows the spirits of Iacoviello (2005) and Chen et al. (2012) by incorporating a banking sector and some unique features of China's macroeconomic policies.

DSGE models are main toolkits employed by the economists to study the interactions between monetary and macroprudential policies. Woodford (2010), and Curdia and Woodford (2010) discuss the financial instability under Taylor rule by using a simple DSGE model. Using DSGE models incorporating financial frictions, heterogenous agents and housing for US and Euro Area, Bean et al. (2010), and Gertler and Karadi (2009) analyse the interactions between monetary and macroprudential policies. Kannan et al. (2009) shows that macroprudential policy is helpful to monetary policy in stabilizing the price level in a DSGE model. Angelini et al. (2011) find that macroprudential policy complements monetary policy under a DSGE model with a banking sector. Glocker and Towbin (2012) investigate the

circumstances under which reserve requirements are an appropriate instrument for price or financial stability by building a small open-economy DSGE model. Quint and Rabanal (2013) estimate an open-economy DSGE model for Euro Area to study the interdependencies of monetary and macroprudential policies. They find that the introduction of a macroprudential rule would help in reducing macroeconomic volatility, improving welfare, and partially substituting for the lack of national monetary policies. DSGE models are also introduced to simulate China's monetary and macroprudential policies. A successful DSGE model for China's monetary policy was developed by Chen et al. (2012), which captures many special features of China's monetary policy. Ma and Chen (2012) provide a calibrated DSGE model for the coordination of China's macroprudential policy. They find that Friedman's simple rule is also fit for the implementation of China's macroprudential policy, and a reasonable combination of monetary, credit and macroprudential policies can do a good job in stabilizing economy and finance. Chen (2013) investigates the effects of monetary and macroprudential policies targeting on China's real estate market.

Our DSGE model, which follows Iacoviello (2005) and Chen et al. (2012), captures many unique characters of China's monetary and financial systems. We find that the required reserve ratio as an important monetary policy tool employed by the PBOC over decades could also be a very useful instrument of China's macroprudential policy, and the loan-to-value (LTV) ratio is another good macroprudential tool for China's financial stability. The empirical results show that whether the monetary policy and the macroprudential policy are complements or substitutes in China depends upon the

choice of the policy instruments. Our policy experiments suggest three combination choices of instruments for China's monetary and macroprudential policies.

The remainder of the paper is structured as follows. Section 2 outlines China's monetary policy and financial regulation system. Section 3 describes the DSGE model in detail. Section 4 provides the model calibration according to the time series data of China's economy. Section 5 discusses the policy experiments and presents the empirical results. Section 6 concludes.

2. China's Monetary Policy and Financial Regulation System

The People's Bank of China (hereafter PBOC), China's central bank, did not operate as a central bank until September 1983. After ratification on 18 March 1995, the PBOC began to implement monetary policy legally as China's central bank. According to The Law of the People's Republic of China on the People's Bank of China (1995) "the PBOC shall, under the leadership of the State Council, formulate and implement monetary policies and exercise supervision and control over the banking industry". While China's monetary policy aims primarily to maintain the stability of the currency, its government lays down more specific targets, including annual GDP growth above 7%, a stable exchange rate, low unemployment, and, it appears, an annual inflation rate of 3%.

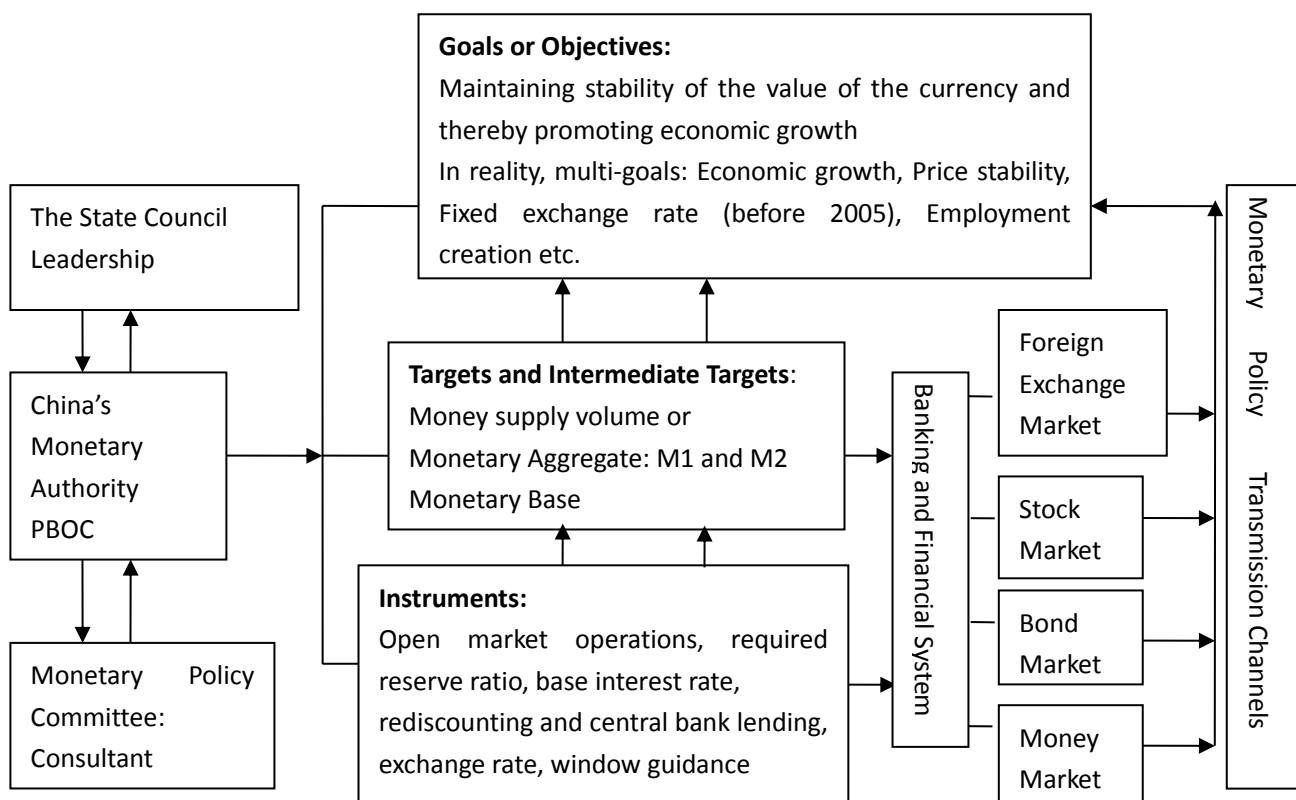
China started to anchor on an intermediate target in the late 1980s. Until 1986, the PBOC had no explicit intermediate monetary targets given a centrally-planned economic system in China. During the period 1986–1993, currency in circulation and banks' loan portfolio were adopted as intermediate targets. In September 1994, three

levels of money supply indicators, M0, M1, and M2 were defined and announced. Since 1996, the PBOC formally took money supply (monetary targeting) as an intermediary target.

China's monetary policy also differs from the conventional central banking in several other respects, which affect the construction of a DSGE model. First, the PBOC controls the retail deposit rate and loan rate besides the policy rate. But the marketization of interest rates still has some way to go. Second, the required reserve ratio is an important instrument of China's monetary policy. Third, the PBOC often employs non-market regulating orders, such as window guidance and loan quotas, to intervene business activities of commercial banks directly (Chen et al. 2012).

Figure 1 summarizes the general framework of China's monetary policy.

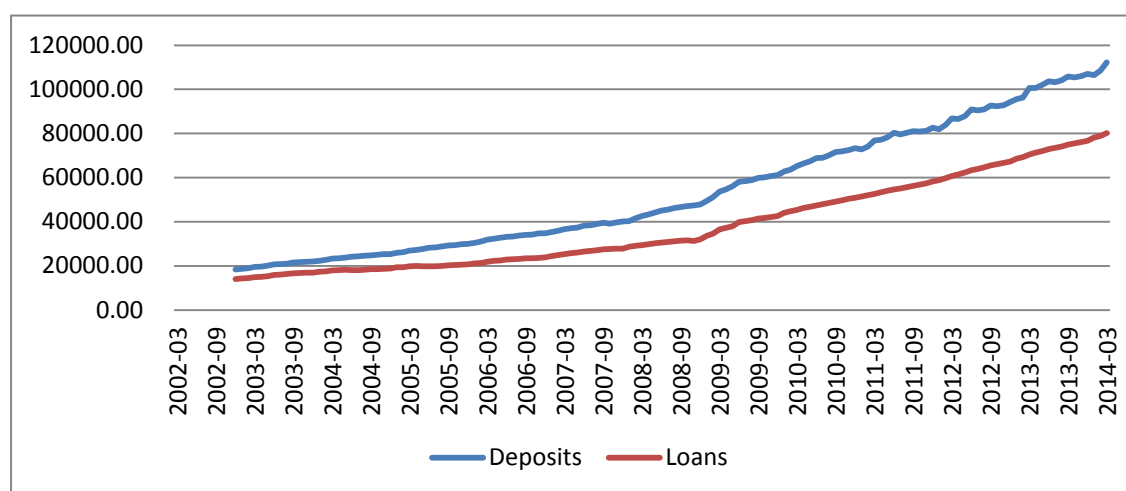
Figure 1 the Framework of Monetary Policy in China



Source: By Author

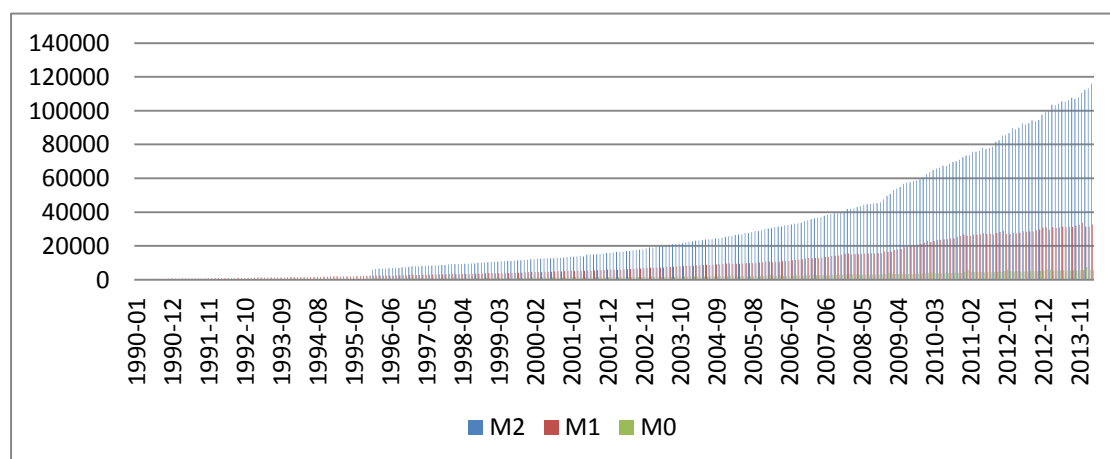
China's financial system (Figure 8) consists of a banking sector, financial markets, and a nonstandard financial sector. The large banking sector is dominated by the big-four state-owned commercial banks, despite the entry and growth of many domestic and foreign banks and financial institutions in recent years. China Banking Regulatory Commission (CBRC), is the state authorized supervisory body for the banking system. It was separated from the PBOC in 2004. Figure 2 shows the deposits and loans in the banking sector. Figure 3 shows broad and narrow money in China.

Figure 2 Deposits and Loans in the Banking Sector (Unit: Billion RMB)



Source: CEIN (China Economic Information Networks)

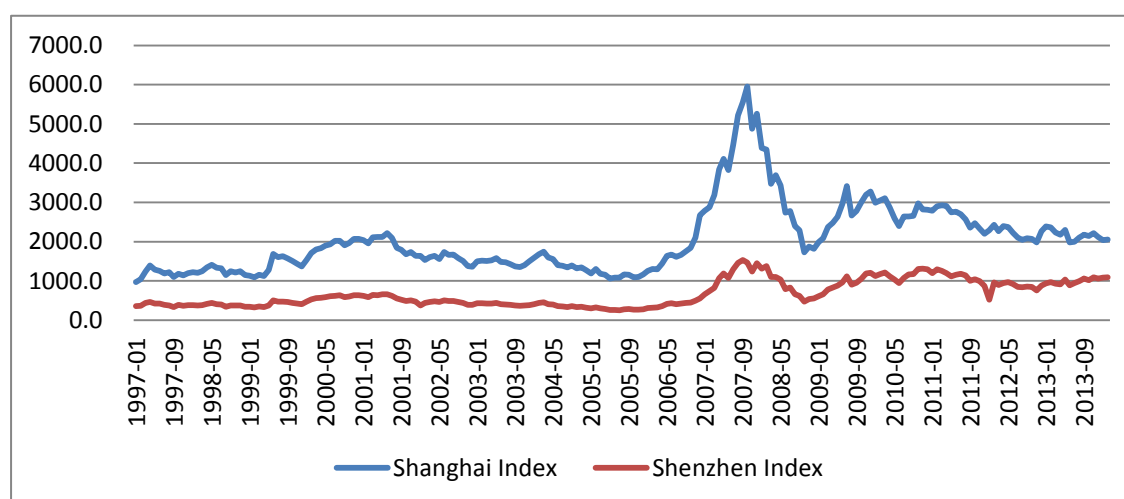
Figure 3 Broad and Narrow Money in China (Unit: Billion RMB)



Source: CEIN

Two stock markets, the Shanghai Stock Exchange and Shenzhen Stock Exchange, were established in 1990. After two decades' development, they are still underdevelopment and inefficiency in allocating the financial resources because of highly speculations and more inside trading, but they are growing in important for China's development. China's Securities Regulatory Commission (CSRC), established in October 1992, is responsible for regulating the stock markets and the still embryonic futures markets. Figure 5 presents the indices of stocks in two stock markets.

Figure 5 Indices of Stocks in Two Stock Markets

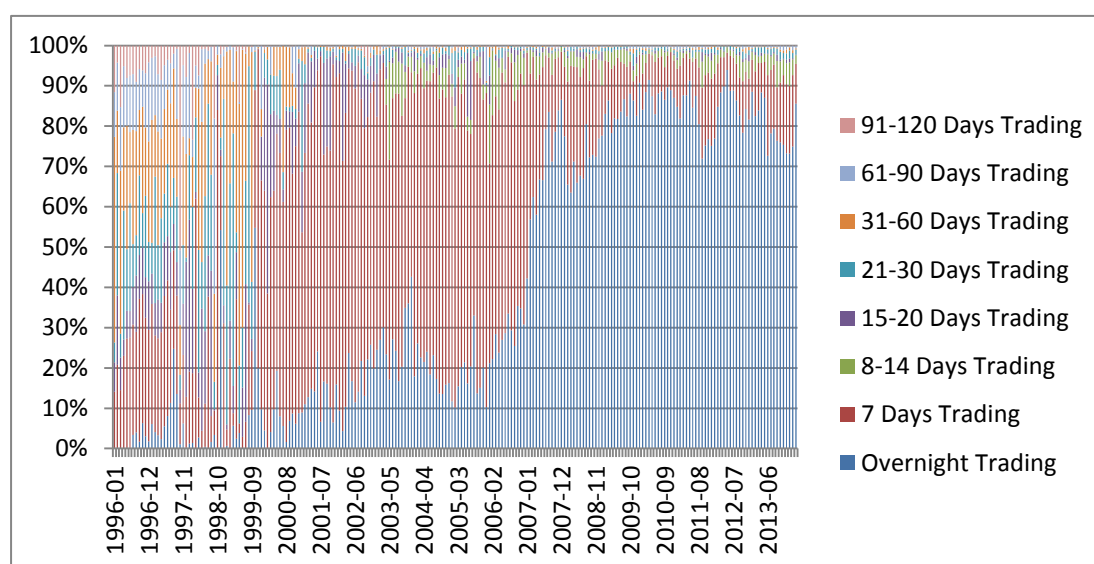


Source: CEIN

There are three bond markets in China: the inter-bank bonds market, the stock market and the commercial bank over-the-counter market. Wholesale transactions of booked bonds and policy banks bonds are conducted in the Inter-bank bonds market by institutional investors, while bonds are traded at the Stock Exchange by institutions and individuals. In the over-the-counter market, treasury bonds are issued to individuals and corporations where they are traded by investors. Among these three

markets the stock exchange trade dominates according to turnover. The whole bond market is organized by 2-level custody arrangements. As China's central Securities depository (CSD) for the bond Market, China Government Securities Depository Trust & Clearing Co. Ltd, (CGSDTC) takes the responsibility of the General Custodian, which is under supervision of the PBOC. Figure 6 presents the proportions of the bonds trading in the interbank market.

Figure 6 Proportions of the Bonds Trading in Interbank Market



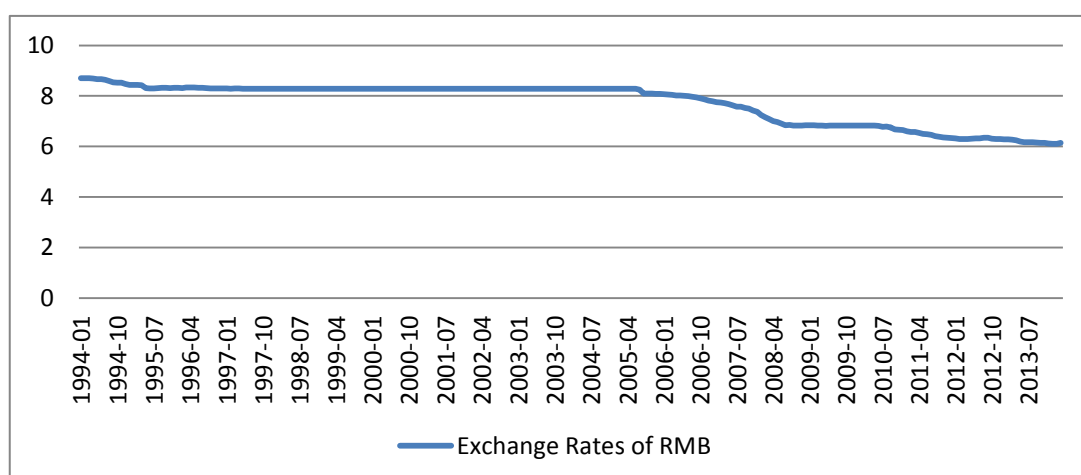
Source: CEIN

For many years, China had a fixed exchange rate system. Foreign exchange transactions have been strictly controlled by the government up to now, although some deregulation is under way. With the capital flows controlled, China can have an independent monetary policy under a fixed exchange rate regime. The participants in foreign exchange markets are composed primarily of institutional investors in China. On July 21 2005, the Chinese government reformed the exchange rate regime by moving to a managed floating exchange rate system with reference to a basket of

currencies. On May 18 2005, foreign currency trading was formerly launched in the inter-bank foreign exchange market where spot transactions of eight currency pairs were conducted³. On August 2 2005, the PBOC released a Notice on Expanding Designated Banks Forward Purchases and Sales Business and Launching RMB and Foreign Currencies Swaps which permits qualified commercial banks to undertake RMB and foreign currency swaps. Further, on January 4 2006, the PBOC issued the Public Announcement on Further Improving the Inter-Bank Spot Foreign Exchange Market (Public Announcement of the PBOC No. 1[2006]), introducing the market-maker system and over the counter transactions (OTC transactions) into the inter-bank spot foreign exchange market. The foreign exchange markets are regulated by the State Administration of Foreign Exchange, which is directed by the PBOC (generally, the head of the SAOEF is one of the deputy presidents of the PBOC).

Figure 7 presents the Evolution of the Exchange Rate of RMB (Chinese Currency) vs. US\$

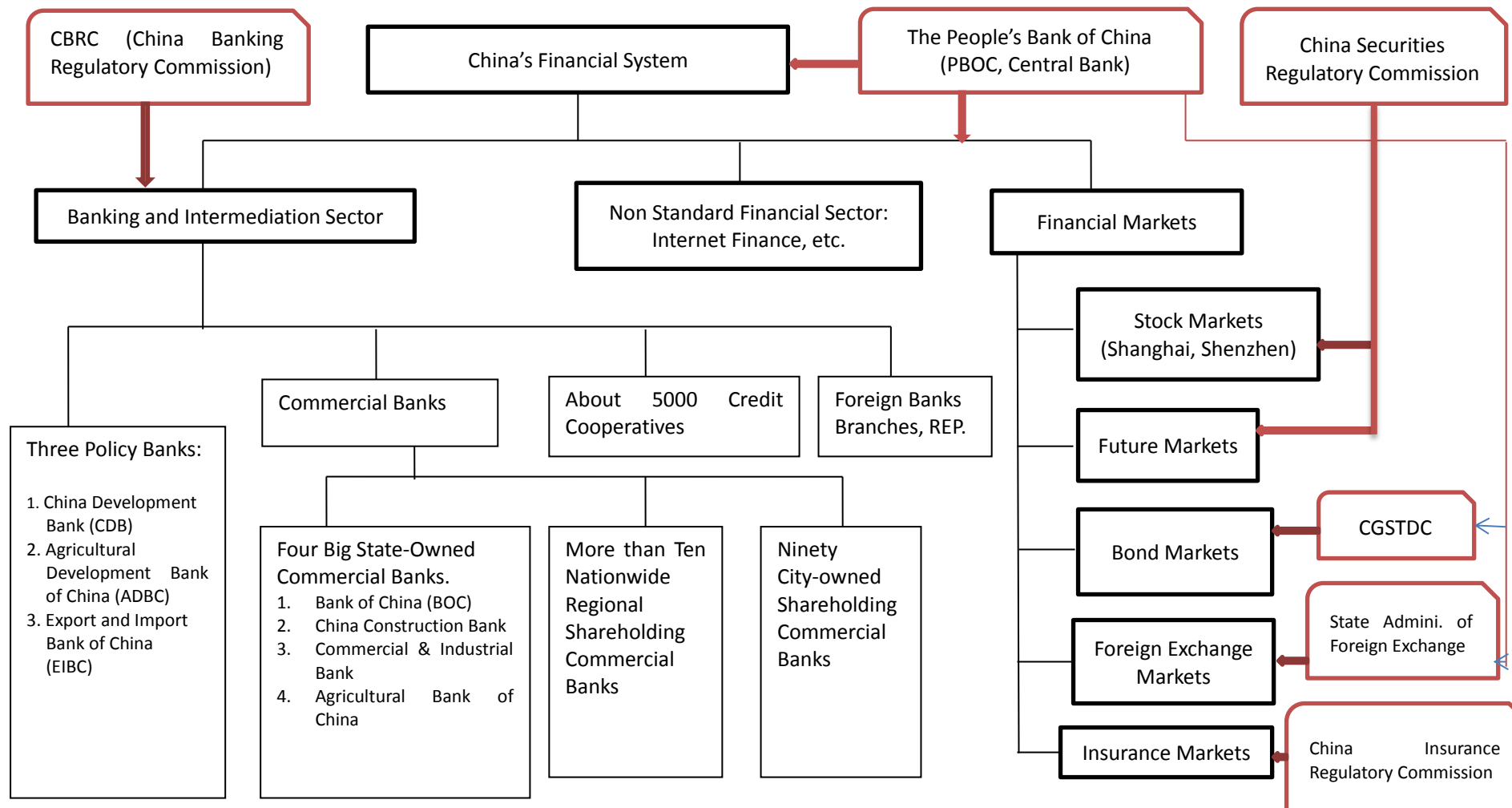
Figure 7 Exchange Rates of Chines RMB against US\$



Source: CEIN

³ These were the US dollar against the Australian, Canadian and Hong Kong dollars, the euro, the Japanese yen, sterling and the Swiss franc, and for euro-yen transactions.

Figure 8 China's Monetary and Financial Regulating System



China's insurance markets are also dominated by big state-owned insurance corporations, which are regulated by China Insurance Regulatory Commission (CIRC).

The PBOC, CRBC, CSRC, and CIRC are parallel regulators under the State Council, China's central government, although the PBOC is authorized to oversight the monetary and financial stabilities.

3. The Model

Following Iacoviello (2005) and Chen et al. (2012), our model economy consists of heterogeneous households including savers (patient households) and borrowers (impatient households), entrepreneurs, firms, a banking sector, a central bank and government. Monetary authority (central bank, PBOC) is responsible for conducting the monetary policy and the macroprudential policy. Government (fiscal authority) implements a balance budget policy (Ricardian equivalence is assumed to hold.)

3.1 Households

3.1.1 Savers

The agent of the saving (patient) households maximizes the present value of the stream of utilities in an infinite horizon:

$$Max.E_0 \sum_{t=0}^{\infty} \beta_s^t (\ln c_t^s + A_N \ln N_t^s - \frac{(H_t^s)^{1+\eta}}{1+\eta}), \quad (1)$$

where c_t^s denotes the real consumption of the savers at time t , β_s denotes the subjective discount factor of savers, N_t^s denotes the services of the accumulated net property mainly comprising durable goods and real estate., with its coefficient A_N ; H_t^s denotes the labour hours provided by the savers, η is labour supply aversion coefficient.

The budget constraint faced by the savers is

$$c_t^s + q_t \Delta N_t^s + d_t = w_t^s H_t^s + (R_{t-1}^d / \pi_t) d_{t-1} - T_t^s + Div_t^s, \quad (2)$$

where q_t represents the real price of the services from the net property; d_t represents the deposits of the savers in the commercial banks, R_t^d is the gross interest rate of deposit; $w_t^s = W_t^s / P_t$ is real wage; T_t^s is the lump sum tax paid to the government by the savers; Div_t^s is the dividend from the commercial banks and retailers.

The first order conditions are

$$\frac{1}{c_t^s} = \beta_s E_t \left(\frac{R_t^d}{\pi_{t+1} c_{t+1}^s} \right) \quad (3)$$

$$w_t^s = (H_t^s)^{\eta} / \epsilon, \quad (4)$$

$$\frac{q_t}{c_t^s} = \frac{A_N}{N_t^s} + \beta_s E_t \left(\frac{q_{t+1}}{c_{t+1}^s} \right) \quad (5)$$

Equation (3) is Euler equation, equation (4) is a labour supply equation, and equation (5) shows the dynamic evolution of the asset price.

3.1.2 Borrowers

Borrowers (impatient households) borrow money from commercial banks to smooth their consumption. Their problem is given by

$$Max. E_0 \sum_{t=0}^{\infty} \beta_t^b (\ln c_t^b + \psi_t \ln N_t^b - \frac{(H_t^b)^{1+\eta}}{1+\eta}), \quad (6)$$

where the terms for borrowers with superscript b have similar meaning as for savers. ψ_t represents a shock to net property following an AR(1) process.

The budget constraints satisfies

$$c_t^b + q_t \Delta N_t^b + R_{t-1}^l b_t^b / \pi_t = w_t^b H_t^b + b_t^b - T_t^b + Div_t^b + \phi_b (\Delta N_t^b / N_{t-1}^b)^2 q_t N_t^b / 2, \quad (7)$$

with a borrowing constraint:

$$R_t^l b_t^b \leq V_t^b E_t [q_{t+1} N_{t+1}^b \pi_{t+1}] \quad (8)$$

where b_t^b denotes the loans obtained by the borrowers from the commercial banks; R_t^l

denotes the lending interest rate; the last term ϕ_b on the right hand of equation (7) denotes the property adjustment costs. v_t^b is a time-varying loan-to-value ratio, which is a key instrument for China's macroprudential policy.

The FOCs are:

$$\frac{1}{c_t^b} = \beta_b E_t \left(\frac{R_t^l}{\pi_{t+1} c_{t+1}^b} \right) + \lambda_t^b R_t^l \quad (9)$$

$$w_t^b = (H_t^b)^\gamma / \alpha, \quad (10)$$

$$\frac{q_t}{c_t^b} (1 + \phi_b \frac{\Delta N_t^b}{N_{t-1}^b}) = \frac{\psi_t}{N_t^b} + \beta_b E_t \left(\frac{q_{t+1}}{c_{t+1}^b} (1 + \phi_b \frac{\Delta N_{t+1}^b}{N_t^b}) \right) + \lambda_t^b v_t^b q_{t+1} \pi_{t+1}, \quad (11)$$

where λ_t^b denotes the multiplier on the borrowing constraint (8).

3.1.3 Entrepreneurs

The entrepreneurs produce intermediate goods by using a Cobb-Douglas production function. Following Iacoviello (2005), the problem of the entrepreneur is given by

$$\max E_0 \sum_{t=0}^{\infty} \beta_E^t c_t^E \quad (12)$$

Subject to the following budget constraints:

Production function:

$$Y_t = A_t K_t^\alpha (N_t)^\gamma (H_t)^{\alpha(1-\alpha)\gamma} (H_t^s)^{1-\mu(1-\alpha)} \quad (13)$$

Capital accumulation:

$$I_t = K_t - (1 - \delta) K_t \quad (14)$$

Flow of Funds:

$$Y_t / X_t + b_t^E = c_t^E + q_t \Delta N_t^E + R_{t-1}^l b_{t-1}^E / \pi_t + w_t^s H_t^s + w_t^b H_t^b + I_t + \phi_E (\Delta N_t^E / N_{t-1}^E)^2 q_t N_t^E / 2 + \varphi (I_t / K_{t-1} - \delta)^2 K_{t-1} (2\delta), \quad (15)$$

where the last term in the right hand of equation (15) denotes the capital installation costs; b_t^E represents the loans borrowed by the entrepreneurs, δ represents the depreciation rate of the capital; N_t^E denotes the net property owned by the entrepreneurs, which could be collateral when they borrow money from the commercial banks.

The borrowing constraint for the entrepreneurs satisfies

$$R_t^l b_t^E \leq V_t^E E_t [q_{t+1} \pi_{t+1} N_t^E] \quad (16)$$

where V_t^E is a time-varying loan-to-value ratio for borrowing of the entrepreneurs.

3.2 Retailers

Retailers produce the *final goods* by differentiating the intermediate goods.

The production function of the final good producer is

$$Y_t^f = \left[\int_0^1 Y_{i,t}^{\frac{\lambda_f - 1}{\lambda_f}} di \right]^{\lambda_f / (\lambda_f - 1)}, 1 \leq \lambda_f < \infty, \quad (17)$$

where $Y_{i,t}$ denotes the intermediate good provided by the i^{th} intermediate producer (Entrepreneur). λ_f is a coefficient governing the mark-up of the costs of the final good producer.

Assuming that the final good producer operates in a perfectly competitive market, so the price of its output, P_t , and the prices of its inputs, $P_{i,t}$, are given exogenously. The relationship between these two prices satisfies

$$P_t = \left[\int_0^1 P_{i,t}^{1 - \lambda_f} di \right]^{1 / (1 - \lambda_f)}, \quad (18)$$

Profit maximization produces a demand function for the output of the i^{th} intermediate producer

$$\frac{Y_{i,t}}{Y_t^f} = \left(\frac{P_{i,t}}{P_t} \right)^{-\lambda_f}, \quad (19)$$

Following Iacoviello (2005), assuming that $1 - \theta$ fraction of retailers can change their prices optimally, the optimal price level is denoted by P_t^* , other prices keep unchanged, then the aggregate price level can be calculated by

$$P_t = [\theta P_{t+1}^* + (1 - \theta) P_t^*]^{1 - \lambda_f} \quad (20)$$

The above pricing behaviours imply a following Phillips curve:

$$\hat{\pi}_t = \beta_s E_t \hat{\pi}_{t+1} - \frac{(1 - \theta)(1 - \beta_s \theta)}{\theta} \hat{X}_t, \quad (21)$$

3.3 Commercial Banks

Following Chen et al. (2012), a representative commercial banks manages its loans (L_t), deposits (D_t), excess reserves (E_t), and borrowings from the interbank market (IB_t).

Therefore its balance sheet is:

$$IB_t + (1 - RRR_t) D_t = L_t + E_t \quad (22)$$

where RRR_t denotes the required reserve ratio.

The profits of the commercial bank are given by

$$\begin{aligned} \Phi_t^B = & (1 + r_t^l)L_t - L_{t+1} + (1 + r_t^e)E_t - E_{t+1} - [(1 + r_t^d) - RRR_t(1 + r_t^r)]D_t \\ & + (1 - RRR_t)D_{t+1} - (1 + r_t^{ib})IB_t + IB_{t+1} - C_t(E) - C_t(L) \end{aligned} \quad (23)$$

where r_t^e is the interest rate for excess reserves; r_t^r denotes the interest rate for required reserves, r_t^{ib} denotes the interest rate for interbank borrowing; $C_t(E) = \frac{1}{2}(c_d[(1 - RRR_t)D_t]^2 + c_l L_t^2 + c_e E_t^2)$ represents the costs of managing loans, deposits and reserves; $C_t(L) = \frac{\kappa}{2}(L_t - L_t^{cb})^2$ represents the costs of managing the loans to meet the loan target L_t^{cb} set by the central bank.

Substituting (22) into (23) produces

$$\Phi_t^B = (r_t^l - r_t^{ib})L_t + (r_t^e - r_t^{ib})E_t - [r_t^d - RRR_t r_t^r - (1 - RRR_t)r_t^{ib}]D_t - C_t(E) - C_t(L) \quad (24)$$

The problem of the commercial bank is given by

$$\max_{\{L_t, D_t, E_t, IB_t\}} \sum_{t=0}^{\infty} \beta^t \Phi_t^B \quad (25)$$

yielding the following FOCs:

$$r_t^l = r_t^{ib} + c_l L_t - \lambda_t^l \quad (26)$$

$$r_t^e = r_t^{ib} + c_e E_t \quad (27)$$

$$r_t^d = RRR_t r_t^r + (1 - RRR_t)r_t^{ib} - \lambda_t^d \quad (28)$$

The market interest rate of loans, r_t^l , and the market interest rate of deposits, r_t^d , are connected with the exogenous interest rate of loans and deposits ($r_t^{d,cb}$, $r_t^{l,cb}$, which are

set by the PBOC) by two positive time-varying parameters:

$$r_t^l = \nu r_t^{l,cb}, \nu > 0 \text{ for any } t, \quad (29)$$

$$r_t^d = \vartheta r_t^{d,cb}, \vartheta > 0 \text{ for any } t. \quad (30)$$

3.4 Monetary Authority

In China, the PBOC is authorized to conduct monetary policy and macroprudential policy to ensure monetary stability and financial stability.

3.4.1 Monetary Policy

China differs sharply from advanced economies in the way monetary policy works. The PBOC not only control the policy rate, it also set deposit and lending rates (Chen et al. 2012). Moreover, the nonmarket instruments, such as window guidance and loan targets, are often employed by the PBOC. Finally, the PBOC's favoured instrument is the required reserve ratio less used, if at all, in advanced economies.

Following Chen et al. (2012), we suggest following rules to simulate the implementation of China's monetary policy:

First, a kind of Taylor rule for the interest rate:

$$r_t = \rho_\pi \pi_t + \rho_y y_t + \rho_r r_{t-1} + \varepsilon_t^r \quad (31)$$

where ε_t^r denotes a shock from the policy rate.

The second rule relates to the deposit rates set by the PBOC:

$$r_t^{d,cb} = (1 - \rho_r^d) r_t + \rho_r^d r_{t-1}^{d,cb}, \quad (32)$$

Similarly, the PBOC sets the lending rate according to:

$$r_t^{l,cb} = (1 - \rho_r^l) r_t + \rho_r^l r_{t-1}^{l,cb},$$

The fourth rule is the credit target rule, which is given by

$$l_t^{c,b} = -(1 - \rho_l^{c,b}) \beta_l \pi_t + \rho_l^y y_t + \rho_l^b l_{t-1}^{c,b} \quad (33)$$

The final rule is for the required reserve ratio, which satisfies

$$R_{RR} = (1 - \rho_{RR}^R) \beta_{RR} \pi_t + \rho_{RR}^y y_t + \rho_{RR}^B R_{RR} \quad (34)$$

3.4.2 Macroprudential Policy

We follow other authors⁴ by specifying two macroprudential policy instruments: loan-to-value (LTV) ratio and required reserve ratio (RRR).

Let the loan-to-value ratio, V_t^b , response to the loan target and asset price⁵, yielding:

$$\hat{V}_t^b = \rho_v \hat{V}_{t-1}^b + (1 - \rho_v) \rho_q \hat{q}_{t+1} + (1 - \rho_v) \rho_l \hat{l}_t + \varepsilon_t^v, \quad (35)$$

When the required reserve ratio is used as an instrument of macroprudential policy, it responses to the loan target as well as to the rate of inflation, equation (34) is replaced by

$$RRR_t = (1 - \rho_{RRR}^R) (\rho_{RRR}^\pi \pi_t + \rho_{RRR}^y y_t) + (1 - \rho_{RRR}^m) \rho_{RRR}^l (\hat{l}_t - \hat{l}_t^{cb}) + \rho_{RRR}^m RRR_{t-1}, \quad (36)$$

3.5 Government and Fiscal Policy

China's government is assumed to adhere to a continuously balanced budget, its budget constraint is

$$G_t = T_t \quad (37)$$

Fiscal policy is implemented by controlling the tax and the government spending.

3.6 General Equilibriums

The Aggregate Resources Equilibrium satisfies

$$c_t^s + c_t^b + c_t^E + i_t + G_t = y_t \quad (38)$$

The government spending is assumed to be given exogenously.

Because the interbank borrowings cancel out in the whole market, equation (22) implies that the loan market equilibrium satisfies

$$(1 - RRR_t) D_t = L_t + RR_t + E_t \quad (39)$$

where RR_t denoted the required reserves.

3.7 The Process of Shocks

We simulate the effects of six structural economic shocks. These are shocks to technology, net property, cost, R, RRR and LTV. The fourth is a monetary policy

⁴ See, for example, Glocker and Towbin (2012).

⁵ This is because that, housing prices contain significant useful information about aggregate price movements, response of the monetary policy to the asset prices help stabilise macroeconomic stability (Bernanke and Gertler, 1999; Cecchetti et al., 2000;), and the volatility in asset prices is a key indicator for the financial stability (Bernanke and Gertler, 1999; Borio and Lowe, 2002; and so on).

innovation, and the last two are macroprudential instrument shocks. Most shocks (excluding the fourth one) follow AR (1) processes:

$$\hat{Y}_t = \rho_Y \hat{Y}_t + \varepsilon_{Y,t}, \varepsilon_{Y,t} \stackrel{iid}{\sim} N(0, \sigma_Y^2) \quad (40)$$

Where $Y_t = \{\psi_t, a_t, RRR_t, u_t\}$

4. Parameters Calibration

Following Chen et al. (2012), Iacoviello (2005), Glocker and Towbin (2012), Quint and Rabanal (2013), Sun and Sen (2011), Sun (2012), and other regarding Chinese literature, we calibrate all the parameters in Table 1.

Table 1 Calibration of Parameters

Identification	Value	Description
β_s	0.99	Discount factor of savers (Patient households)
β_b	0.95	Discount factor of borrowers (Impatient Households)
β_E	0.98	Discount factor of entrepreneurs
δ	0.03	Depreciation rate of capital
A_N	0.1	Coefficient of net property service
η	2.20	Labour supply aversion
α	0.42	Capital share in production
γ	0.03	Net property share in production
μ	0.70	Patient households wage share
ϕ_E	1.0	Coefficient of entrepreneurs' property adjustment cost
ϕ_b	1.0	Coefficient of borrowers' property adjustment cost
φ	2.0	Coefficient of capital adjustment cost
X	1.15	Steady-state gross mark up
θ	0.75	Probability fixed price
V^E	0.85	Steady-state loan-to-value entrepreneurs
V^b	0.60	Steady-state loan-to-value borrowers

c_d	2.0	cost coefficient for deposits
c_l	1.0	cost coefficient for loans
c_e	1.0	cost coefficient for excess reserves
κ	50	coefficient determining the window guidance for loans
ρ_π	1.01	Inflation coefficient in Taylor rule
ρ_y	0.01	Output gap coefficient in Taylor rule
ρ_r	0.75	Persistence coefficient of policy rate in Taylor rule
ρ_r^d	0.7	Persistence coefficient for deposit rule
ρ_r^l	0.7	Persistence coefficient for loans rule
ρ_l^{cb}	0.2	Persistence coefficient for loan target rule
ρ_l^π	50	Inflation coefficient in loan target rule
ρ_l^y	5.0	Output gap coefficient in loan target rule
ρ_{RR}^R	0.90	Persistence coefficient of interest rate of required reserves
ρ_{RRR}^R	0.6	Persistence coefficient of required reserve ratio rule
ρ_{RRR}^l	10.0	Loan coefficient in required reserves ratio rule
ρ_{RRR}^π	5.0	Inflation coefficient in required reserves ratio rule
ρ_{RRR}^y	2.0	Output coefficient in required reserves ratio rule
ρ_v	0.90	Persistence coefficient for loan-to-value ratio
ρ_q	0.75	Asset price coefficient in the loan-to-value rule
ρ_l	0.87	Loan target coefficient in the loan-to-value rule
ρ_J	0.85	Persistence coefficient for net property service shocks
ρ_u	0.75	Persistence coefficient for cost-push shocks

ρ_a	0.5	Persistence coefficient for technology shocks
ρ_{RRR}	0.85	Persistence coefficient for required reserve ratio shocks
σ_J	24.89	Standard error of net property service shock
σ_u	0.17	S.E of cost-push shock
σ_a	1.30	S.E. of technology shock
σ_{RRR}	1	S.E. of required reserve ratio shock
σ_R	0.27	S.E. of policy rate shock

According to equation (3), the steady-state value of deposit rate is calculated by $r^d = 1/\beta_s$; we set steady-state interest rate on require reserves at 1.009, same as the steady-state interest rate on excess reserves. The steady-state for the require reserves ratio is set at 10% to match its average level in the Chinese data. The steady-state ratio for deposits to output is 0.50; other steady-state values are calculated following Iacoviello (2005) and Chen et al. (2012).

The discount factor of savers β_s is set to 0.99, implying that the annual rate of interest in China is 4% (the gross rate is 1.04); so the discount factors of borrowers and entrepreneurs are set at 0.95 and 0.98 respectively; China's annual rate of depreciation is about 12%, so the quarterly value of the depreciation δ is set to 0.030. Following the estimation of Sun Lixin et al. (2011), the labour supply aversion and capital share in production take 2.20 and 0.42 respectively. The coefficients of capital adjustment costs follow Iacoviello (2005), and the coefficients of managing deposits and loans are set following Chen et al. (2012). The persistence parameters are mainly calibrated following the estimation in Sun et al. (2011), and most persistent coefficients of shocks are also calibrated following Sun et al. (2011). The standard variances of the shocks and the parameters of China's monetary policy follow Chen et al. (2012) and Sun et al. (2011).

5. Policy Experiments and Empirical Analysis

5.1 The Policy Experiments

Following Glocker and Towbin (2012), we assume that the central bank's objective is to minimize an exogenously given loss function. The traditional price stability loss function⁶ is defined as

$$\Phi^{PS} = E[\pi_t^2 + \zeta_y \hat{y}_t^2] \quad (41)$$

where ζ_y denotes the policymakers' subjective weight of output stability, relative to price stability. \hat{y}_t denotes the output gap, which is a very important variable to the objectives of China's monetary policy.

When the financial stability is added to the objectives of the central bank, the loss function is given by

$$\Phi^{PS+FS} = E[\pi_t^2 + \zeta_y \hat{y}_t^2 + \zeta_L \hat{L}_t^2 + \zeta_q \hat{q}_t^2] \quad (42)$$

where \hat{L}_t, \hat{q}_t denote the deviations of loans and asset prices from their steady state respectively.

We design the following 4 policy experiments to assess the effects of monetary policy and macroprudential policy and their interdependencies⁷.

Policy Experiment I: Only Monetary Policy: Interest Rate and Required Reserve Ratio are Policy Instruments Respectively

In which we keep the equation (31)-(34), screening out the effects of macroprudential policy.

⁶ The reason for choosing this type of loss functions by the central bank can refer to the discussions by Glocker and Towbin (2012).

⁷ In designing our policy experiments, we do follow the Tinbergen rule-one instrument for one objective-in monetary policy, yet not in macroprudential policy, as stressed by Lim et al. (2011): multiple instruments should be used for financial stability.

Policy Experiment II: Monetary Policy and Macroprudential Policy: Interest Rate and Required Reserve Ratio are Monetary Policy Instruments Respectively; Loan-to-value ratio is taken as the instrument of Macroprudential Policy.

In this experiment, besides the monetary policy rules including equation (31)-(34), we add a macroprudential policy operation: Loan-to-value rule (equation (35)).

Policy Experiment III: Monetary Policy and Macroprudential Policy: Interest Rate is Monetary Policy Instrument, and Required Reserve Ratio Is Macroprudential Policy Instrument.

In this test, we include equations (31)-(33) for monetary policy, and equation (34) is replaced by equation (36) for macroprudential policy.

Policy Experiment IV: Monetary Policy and Macroprudential Policy: Interest Rate Is the Instrument of Monetary Policy, and LTV and RRR Are the Instruments of Macroprudential Policy.

In this experiment, we test the combination effects of monetary policy with equations (31)-(33), and of macroprudential policy with equations (35)-(36).

All the empirical results are presented and discussed in section 5.2.

5.2 Empirical Analysis

5.2.1 The Effects of Monetary Policy Shocks

If the PBOC's monetary policy is concerned with price stability, its two instruments are the policy rate and required reserve ratio. Figure 9 presents the effects of shocks from policy rate. When policy rate increases 27 base points by a positive shock, inflation falls 0.05%,

the price of assets falls about 2.5% immediately, deposits fall about 10%, output declines 2.5% after 3 quarters, consumption of households decreases about 0.8%, investment doesn't decrease, so the fall in the output comes from the decrease in households' consumption.

Figure 9 The Effects of Policy Rate Shocks (Policy rate increases 27 base points)

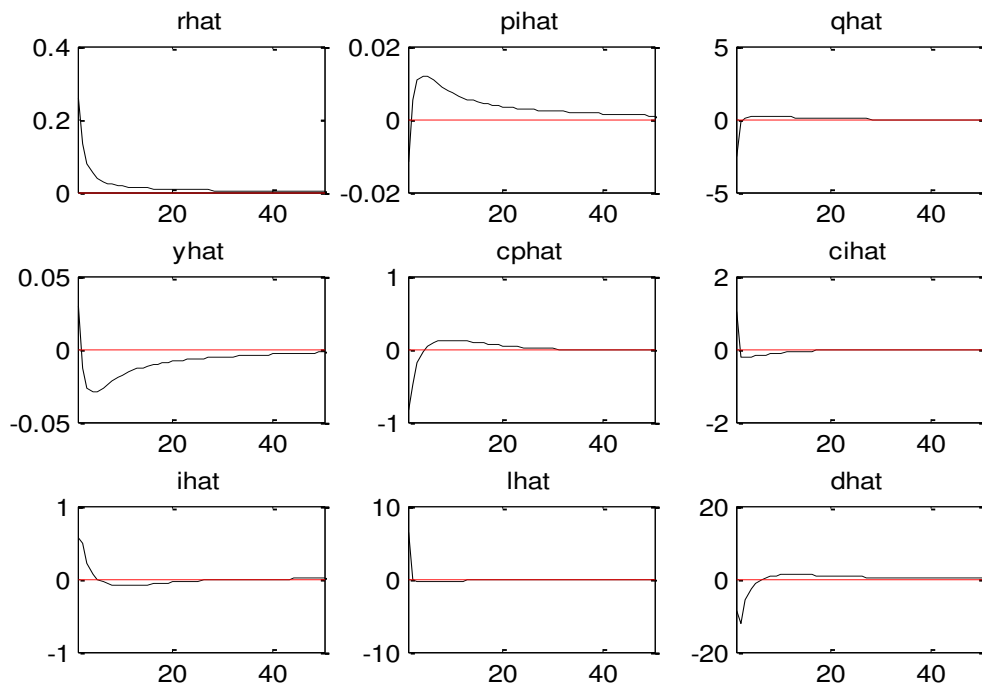
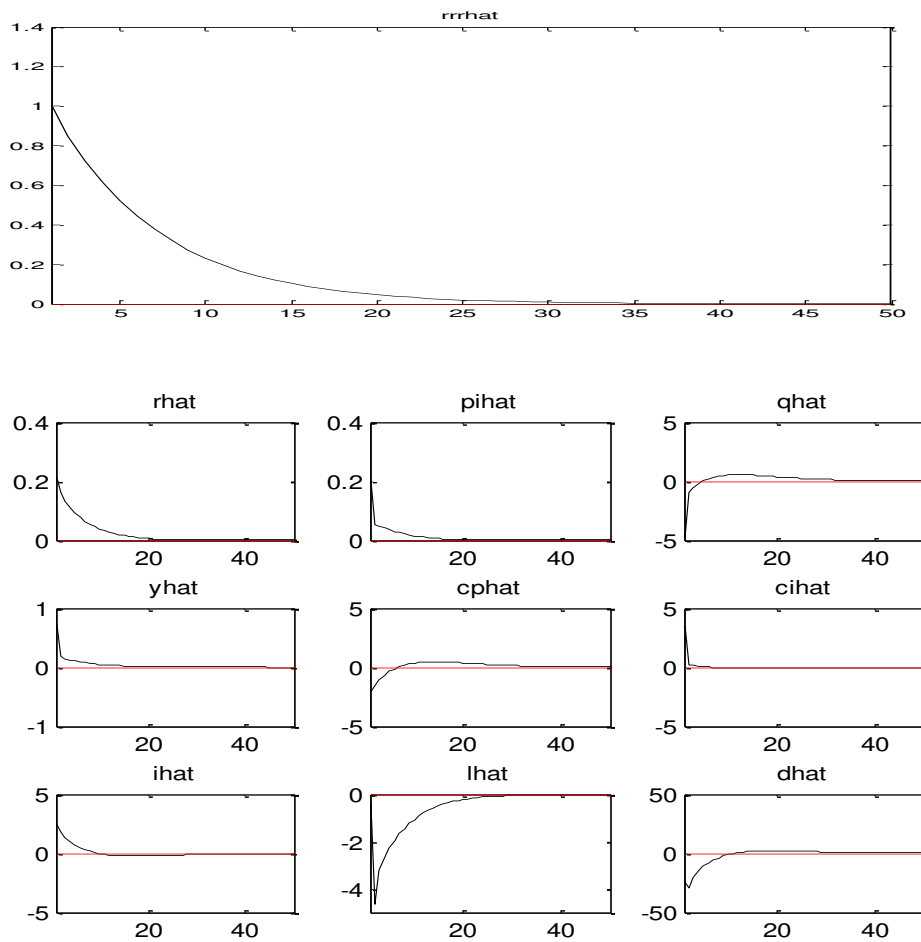


Figure 10 shows the effects of required reserve ratio shocks. A shock to the required reserve ratio raises it about 1%. This causes asset prices to fall by about 4.8%, and loans by 4%, but neither CPI inflation, investment nor output go down. Only household consumption drops. This implies that the required reserve ratio is a poor instrument for stabilizing output or the price level, but a good one for stabilizing asset prices and loans, and hence has an absolute advantage as a financial stability instrument.

Figure 10 The Effects of Required Reserves Ratio (1% increase)



5.2.2 The Effects of Macroprudential Policy Shocks

The two macroprudential instruments we consider are the required reserve ratio, and the loan-to-value ratio (LTV). The effects of these two types of shocks are shown in Figure 11 and Figure 12 respectively.

In Figure 11, a positive LTV shock cuts asset prices and loans sharply, implying that LTV is a powerful financial stability instrument. Furthermore, from Fig 12, we may infer that including a required reserve ratio shock enhances monetary stability in our experiment suggesting that this macroprudential device can enhance monetary policy. So macroprudential policy complements to the monetary policy.

Figure 11 the Effects of Loan-to-Value Ratio Shocks

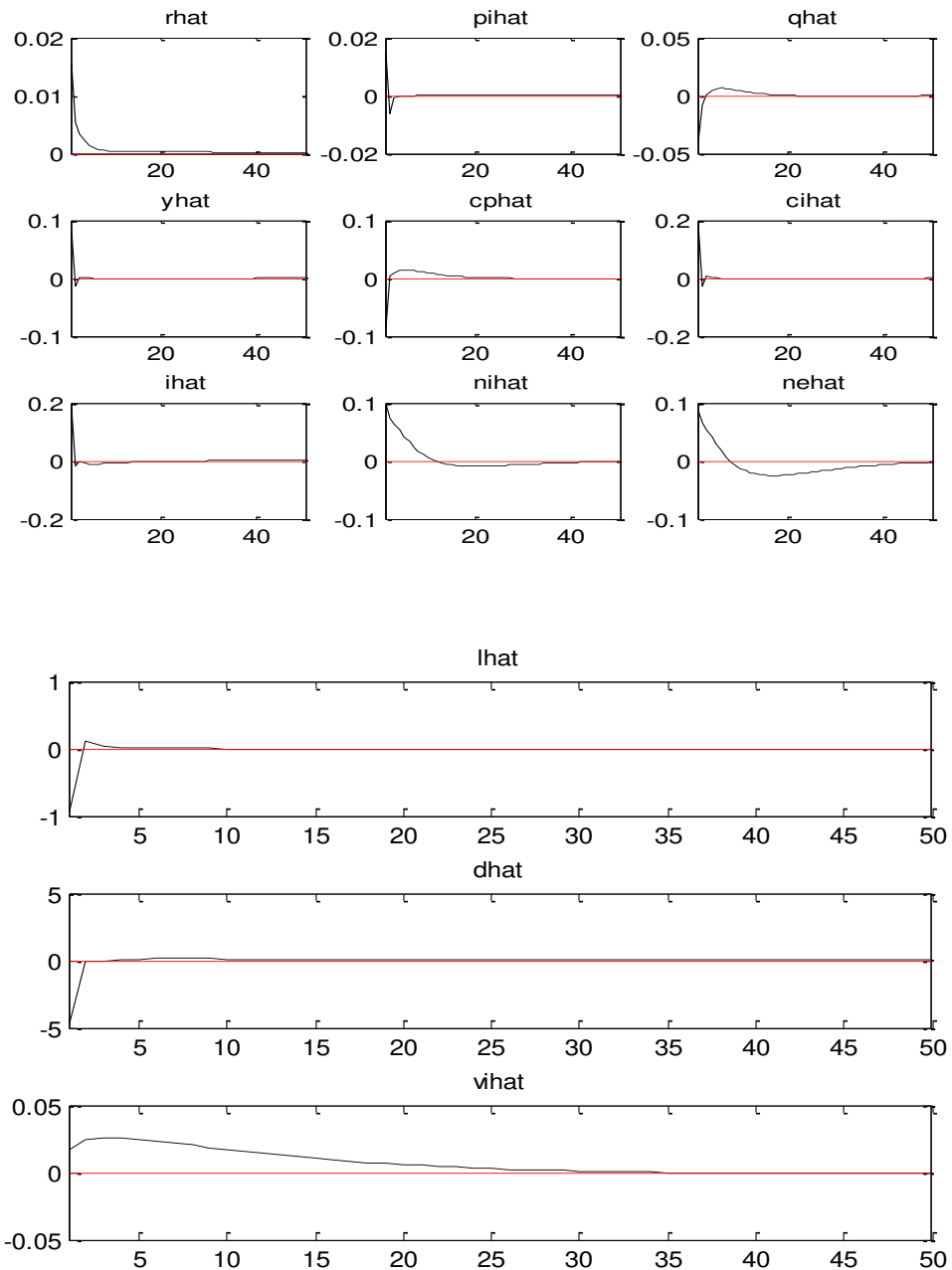
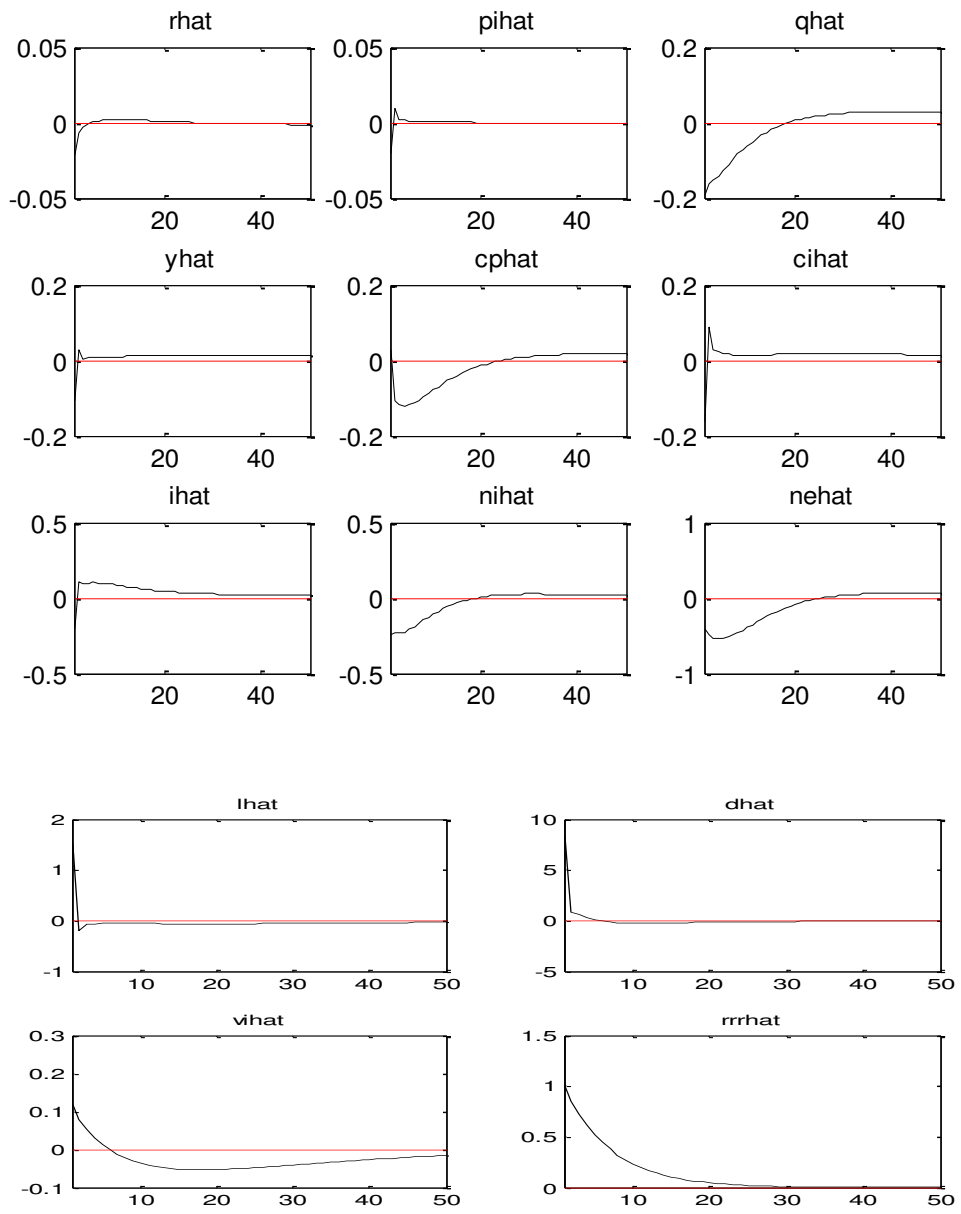


Figure 12 shows that the increase in RRR by a positive shock decreases the price of assets significantly, reduces the volume of loans a little, and reduces output and CPI inflation. So the RRR could be used as either a macroprudential policy instrument or a monetary policy instrument.

Figure 12 The Effects of Required Reserve Ratio (RRR) Shocks (RRR as a macroprudential instrument)



5.2.3 The Comparisons of Price Stability Objective and Financial Stability Objective

To compare, we set $\zeta_y = \zeta_l = \zeta_q = 0.5$. We conduct the following four policy experiments:

Experiment I: No LTV Rule. Here we suppress equations (35) and (36), and freeze the LTV instrument at the steady state values. The RRR is attuned to the monetary policy target only.

Experiment II: As I, but with LTV introduced, and attuned to macroprudential objectives. Only equation (36) is suppressed; (35) now applies.

Experiment III: As I, but with (36) replacing (34), so the RRR responds to macroprudential aims only, and no longer to monetary aims; and the LTV instrument is idle.

Experiment IV: As III, but with LTV reintroduced, and directed to macroprudential objective.

When the PBOC's monetary policy is concerned solely with price stability, the loss results are given in Table 2.

Table 2 the Results under Price Stability Objective (Experiment I)

	Policy Rate Rule	Required Reserve Ratio Rule
Φ^{PS}	0.000591	0.3141

Table 2 indicates that the policy rate (interest rate) is a better instrument for price stability than the required reserve ratio in our Experiment I.

Table 3 presents the results for Experiment II, III, and IV.

Table 3 the Results under both Price Stability and Financial Stability Objectives

	Experiment II		Experiment III		Experiment IV			
	Monetary Policy		Macropru. Policy	Monetary Policy	Macropru. Policy	Monetary Policy	Macropru. Policy	
	R*	RRR	(LTV)	R	RRR	R	LTV	RRR
$\Phi^{PS/FS} \bullet$	0.00333	0.0451		0.5582		0.1666		0.00615
Φ^{FS}	45.77	60.37	0.07166	13.73	0.0578	37	0.439	1.17
$\Phi^{PS/FS} /$ Φ^{PS}	5.63	0.1435		944		281.9		0.0196

*R denotes policy rate rule, RRR: required reserve ratio rule, LTV: loan-to-value rule.

- $\Phi^{PS/FS}$ denotes the loss by price stability policy given financial stability is concerned.

The results of Experiment II show that when the PBOC chooses required reserve ratio as its monetary policy instrument and LTV as its macroprudential policy instrument, macroprudential and monetary policies are complementary. Otherwise, if the interest rate is taken as the instrument of monetary policy, the implementation of macroprudential policy increases the wealth loss of price stability, so may conflict with the effects of monetary policy. So, as row (6) reveals, pursuing financial stability destabilizes the price level.

In Experiment III, the policy rate is attuned to price stability (monetary policy) and the required reserve ratio is chosen for financial stability (macroprudential policy). The loss results show that the required reserve ratio is a better choice of the macroprudential policy

instruments, but the macroprudential policy operation enhances the loss in price stability.

This portrays macroprudential and monetary policy in conflict.

In Experiment IV, monetary policy relies on the interest rate, and macroprudential the LTV. RRR is deployed for both purposes; and conflict again appears

On the basis of the above results, our suggestions for policy combination are:

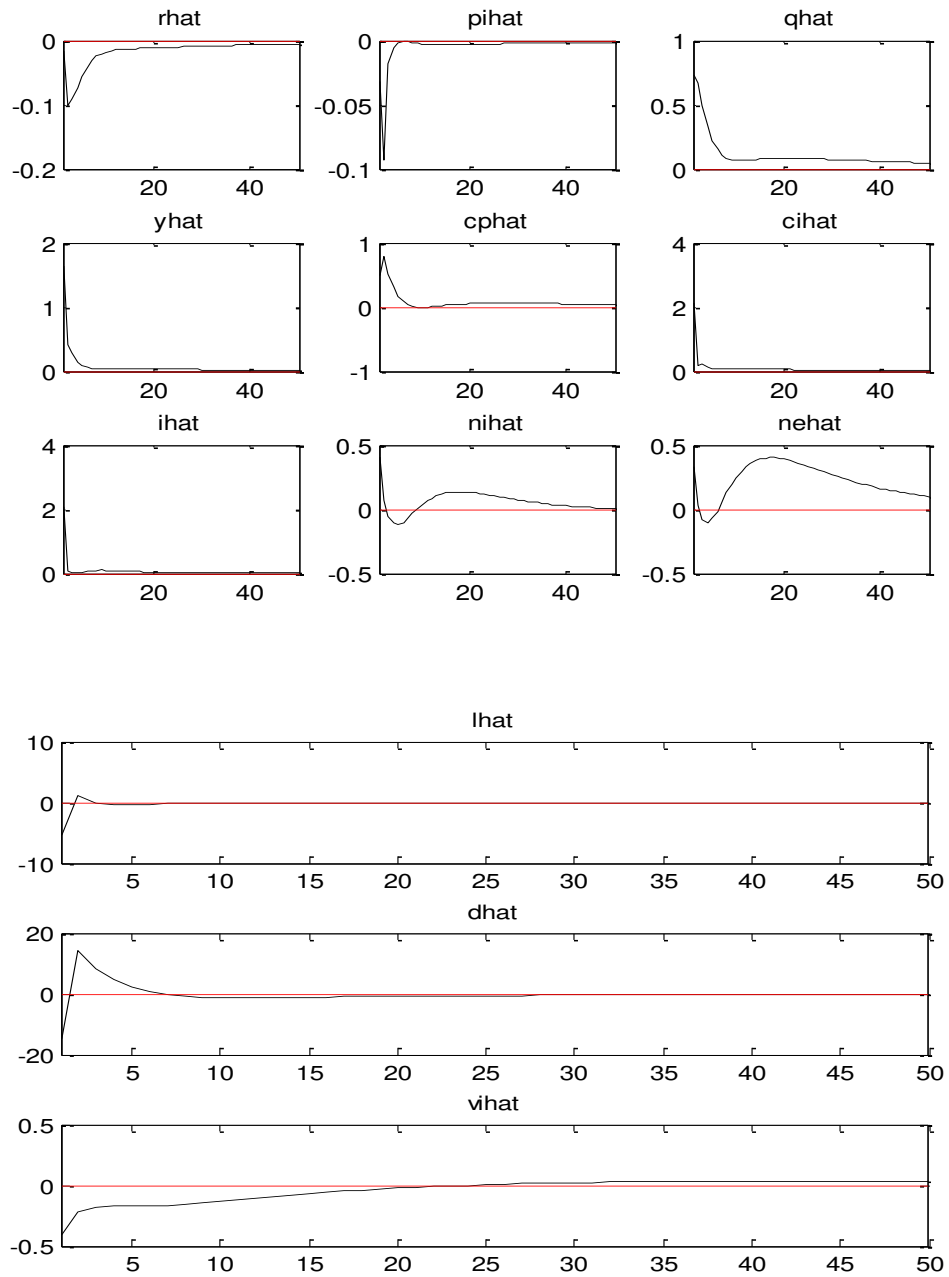
- When the PBOC aims solely at price stability, the interest rate is a better choice for the implementation of monetary policy than the required reserve ratio.
- If the PBOC is responsible for both the price stability and financial stability, the better combination of policy instruments is: required reserve ratio for monetary policy and the loan-to-value ratio for macroprudential policy. Or
- The required reserve ratio is taken as the tool for both monetary and macroprudential policies, while the loan-to-value ratio is chosen as the instrument for the macroprudential policy.

The latter two suggestions ensure that the macroprudential policy complements the monetary policy.

5.2.4 The Effects of Other Shocks

We now consider the other three disturbances: a technology shock, a cost-push shock and a net asset shock. The effects of these shocks are presented in Figure 13, 14, and 15 respectively.

Figure 13 the Effects of Technology Shocks



A positive shock to technology increases consumption, investment and thereby increasing output and property; the jump in technology reduces rates of interest rate and inflation, and stimulates the output. (Figure 13)

Figure 14 the Effects of Cost-Push Shocks

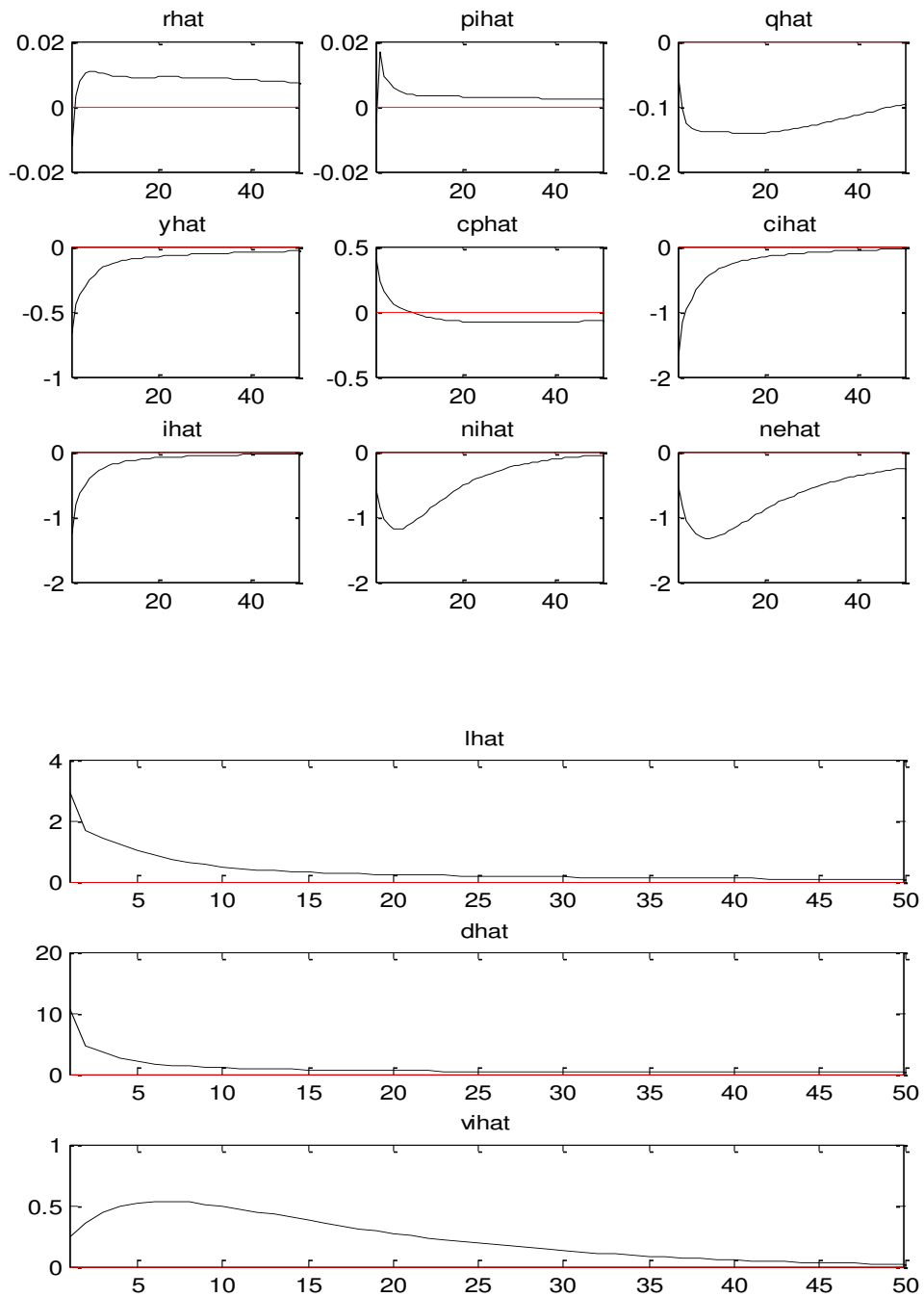
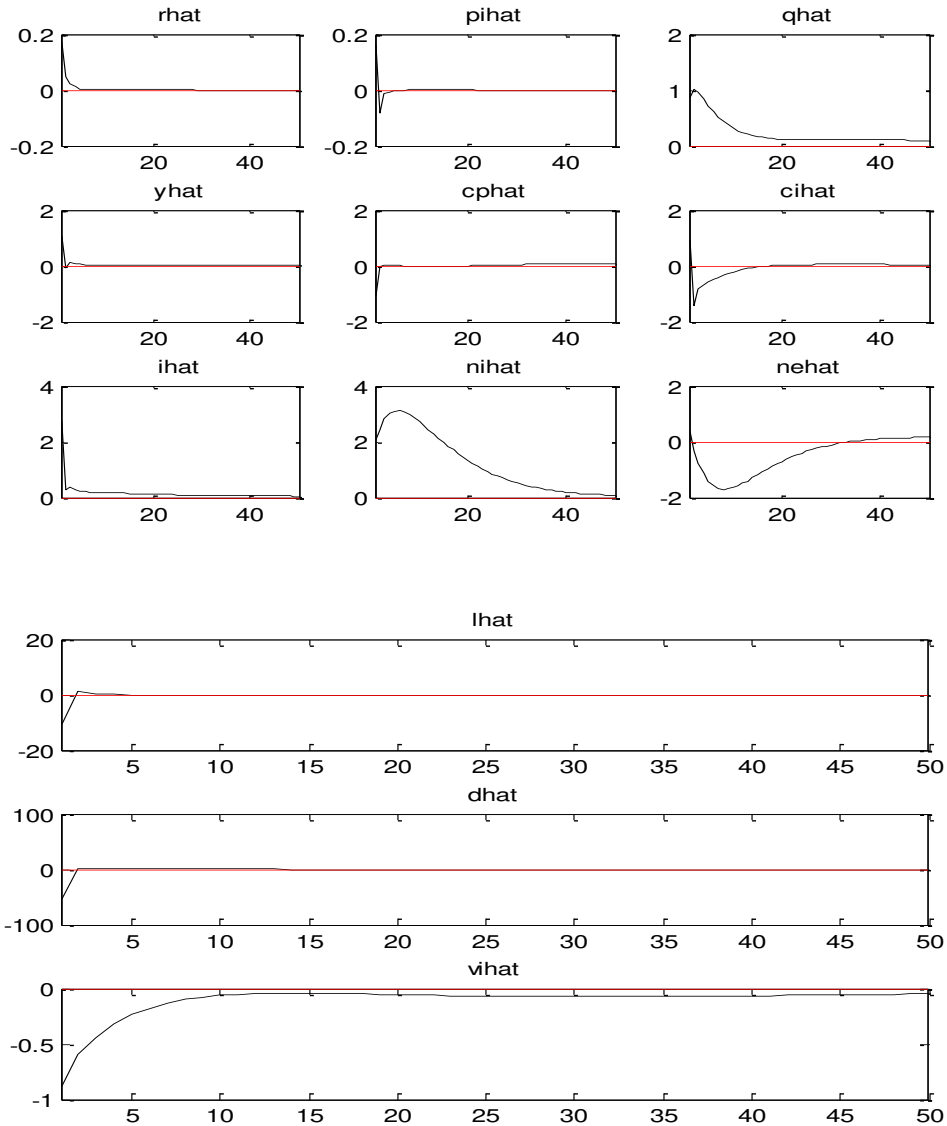


Figure 14 shows that a positive cost-push raises rates of inflation and interest, and thus lowers the investment and output.

Figure 15 the Effects of Net Asset Shocks



In Figure 15, a property service shock causes a rise in the price of asset, reducing consumption; the rise in the price of assets increases investment and hence output.

6. Concluding Remarks

Using a DSGE model featuring China's unique monetary policy and financial regulations, we analyse the interactions between monetary and macroprudential policies in China. Our policy experiments show that monetary policy and macroprudential policy could be either

complements or substitutes in China, which depends on the choices of instruments for two policies.

If price stability is the sole objective of the PBOC, our analysis suggests that policy rate is a better tool than the required reserve ratio. If the PBOC are required to target both price stability and financial stability, our empirical results suggest that the PBOC should prefer RRR as its monetary instrument and LTV as its macroprudential instrument. Alternatively, it should employ the RRR for both aims, with LTV as solely macroprudential tool. These policy combinations can achieve the two objectives of price stability and financial stability simultaneously.

Globally, the framework of macroprudential policy is still under exploration, a sound policy combination for price stability and financial stability in China also need more study and empirical examinations.

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