Business Cycles and Macroeconomic Policy in China: Evidence from an Estimated DSGE Model

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Abstract

In a new Keynesian model with interest rate control, endogenous credit shocks and credit constraints, we study the sources of business cycles in China and the roles of credit policies. We find that credit shocks are the main driving force of economic fluctuations, while productivity shocks and inflation shocks are non-negligible impetus to business cycles. The countercyclical credit policy implemented by the central bank of China plays some role in stabilizing the economy.

1. Introduction

Since China launched the economic reform at the end of 1970s, China has experienced remarkable economic growth. Despite this growth, China's economy also exhibited non- negligible fluctuations. Figures 1(a)- 1(f) plot several time series of macroeconomic variables from 1998Q1-2010Q4[c]. Figure 1(a) shows the linear detrended logarithm of real GDP. Real GDP was above its trend by about 5

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[c] Data on GDP, investment, real estate prices and credits are transformed in real terms, deseasonalized, transformed in logarithm values and linear detrended. We use linear detrended data so that this is consistent with the data used in Bayesian estimation. There is a consensus that HP-filter data should not be used in Bayesian estimation in order not to loss a lot of information contained in the data.

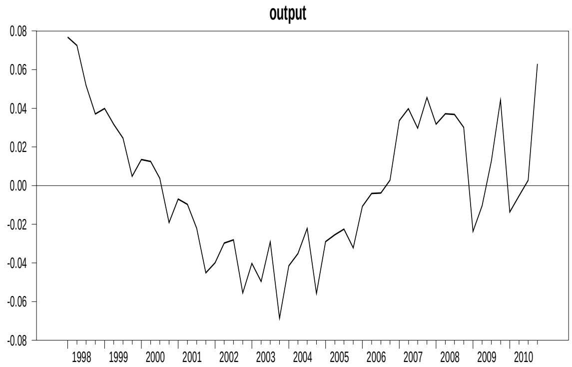
percentage points in the second quarter of 2007 and was below its trend by 7 percentage points in the fourth quarter of 2003. Figure 1(b) shows the inflation rate using 1997Q4 as the base period. Between 1998 and 2003, the Chinese economy experienced a period of deflation. The inflation reemerged since 2004. and continued to rise to more than 10% after 2007. Figure 2(c) shows the chained inflation rate at the quarterly frequency. Figures 2(d)-2(f) display the behavior of housing price, investment and credit, which were also volatile.

On the other hand, although the Chinese economy exhibited remarkable business cycles, the economic fluctuations were not as drastic as those in Latin American countries and other developing countries. In this paper, we attempt to identify the sources of business cycles and discuss the policies that the Chinese government implements to stabilize the economy. We show that credit shocks are the main driving force of business cycles and argue that the countercyclical credit policy employed by the central bank of China plays a role in alleviating economic fluctuations.

Since China started to establish the market economy system, the central bank of China -- the People's Bank of China -- has played a more and more important role. Besides regulating the supply of money through legal reserve requirement, open market operation and rediscounting, the central bank also use interest rate policy and credit policy to affect the behavior of the aggregate economy. In terms of interest rate policy, the central bank of China retains the power of regulating the deposite rates and the lending rates. The slow liberalization of interst rates is due to the concerns to avoid undesired market competition and the concern to maintain profitability for commercial banks within the Chinese financial system (Geiger, 2006). Although commercial banks have been permitted to use their own judgment in setting the lending rate since October 2004, most banks extend loans at the benchmark rates or at rates close to the benchmark rates due to strong competition in the credit market. Figure 1 shows the quarterly benchmark short

Figure 1

(a)



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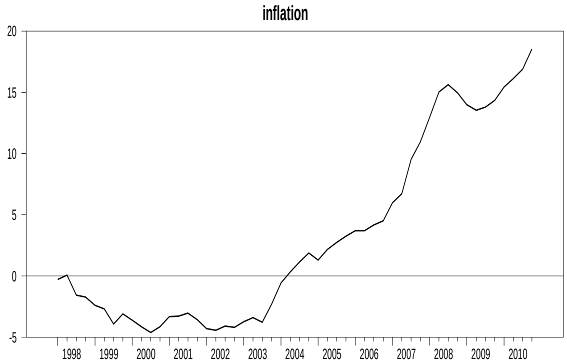

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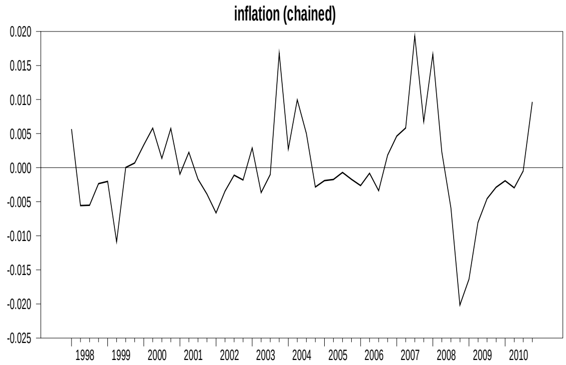

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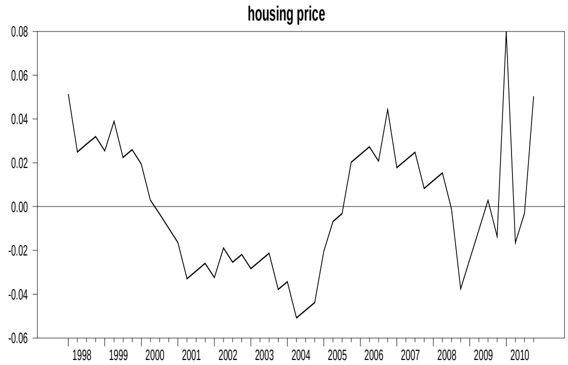

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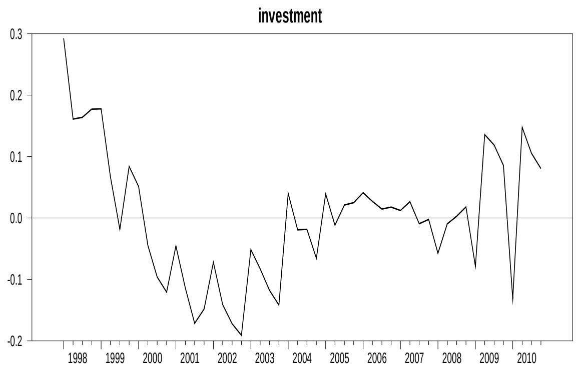


(f)

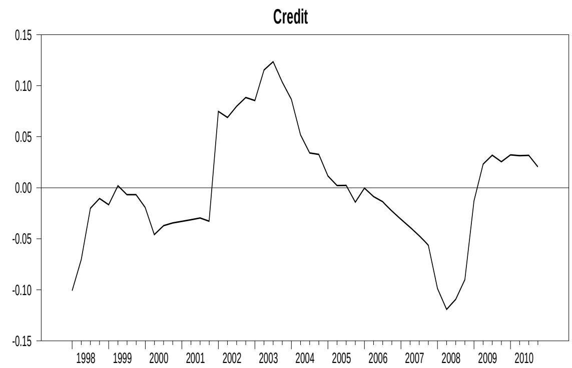
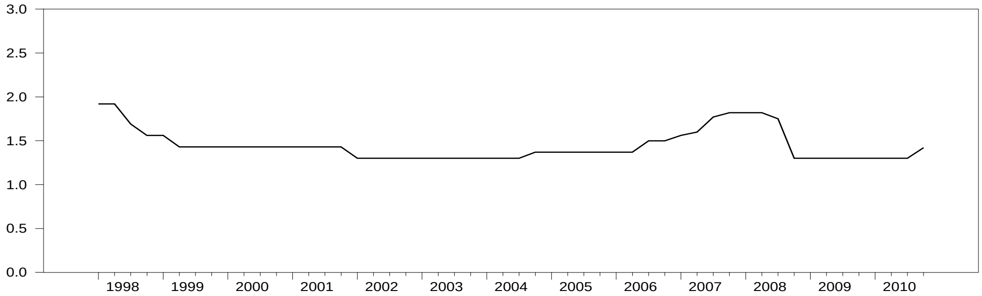


Figure 2



term lending rate set by the People's Bank of China from 1998Q1-2010Q4. A significant feature of the benchmark rates is that they were adjusted very slowly and did not respond to changes in macroeconomic conditions actively. For instance, between June 1999 and January 2002 (32 months), the benchmark lending rate was constant at 5.85 (annual rate) despite the economy experienced deflation and output fluctuations. Similarly, between December 2008 and October 2010 (22 months), the lending rate was kept at 5.31 despite the economy had high inflation and volatile output.

In terms of credit policy, the central bank abandoned the strict credit plan, which determined the amounts of credit the state bank could and should lend to firms, in 1998. However, credit policy, which directly affects the total amount of credit as well as the allocation of credit among different industries is still one of most important tools used by the central bank to regulate the economy. Compared to the interest rate policy, the credit policy reacts more actively to changes in economic conditions. Inspecting figure 1(a) and 1(f), we find that a significant feature of the behavior of credit is that it was countercyclical in some periods. For example, in the middle of 2003, when the output was significantly below its trend, credit was above its trend by about 13%. In the first quarter of 2008, when the economy was above its trend by about 4%, the credit was below its trend by 10%. When the Chinese economy was affected by the world financial crisis and earthquake in the middle and late 2008, output declined and credit rose. This negative relationship between (detrended) output and (detrended) credit suggests that the central bank of China conducted a countercyclical credit policy during some periods of our study.

In this paper we present a model based on Iacoviello (2005), which highlights the importance of financial factors for macroeconomic fluctuations on the one hand and can be used for monetary policy analysis on the other. To capture the features of the Chinese economy, we modify the model in several aspects. First, we impose a constant interest rate rule in the model to reflect the interest rate control policy currently implemented in China. Second, we introduce endogenous credit shocks into the model to examine the effects of credit policy. Third, we add more shocks into the model to explore the sources of business cycles.

We parameterize the model by calibration and Bayesian estimation using data on China's economy from the period 1998Q1 – 2010Q4. We select this period due to data availability. We find that credit shocks are the main driving force of economic fluctuations, while productivity shocks and inflation shocks are non-negligible impetus to business cycles. We model the interest rate policy in the Chinese economy as a constant interest rate rule and the credit policy as an active and countercyclical policy. We find that the countercyclical credit policy can reduce economic fluctuations.

The rest of the paper is organized as follows. Section 2 briefly reviews the literature. Section 3 sets up the model and characterizes the equilibrium. Section 4 parameterizes the model by calibration and Bayesian estimation. Section 5 presents the results and Section 6 concludes

2. Related Literature

An increasing body of literature has recently explored the sources of economic fluctuations in the U.S. and European economies using Bayesian Estimation. Smets and Wouters (2005) compare shocks and frictions for both the US and the euro area economy. Smets and Wouters (2007) estimated a new Keynesian model to address what the main driving forces of output developments in the United States. Jermann and Quadrini (2011) show that when debt and equity are not perfect substitutes, financial shocks will have significant effects on the firm's labor demand and thus on the production decision of firms. Justiniano, Primiceri and Tambalotti (2010) find that most of the variability of output and hours in the

U. S. economy is due to investment shocks and imperfect competition is the key to their transmission.

Our paper closely relates to the literature on the aggregate consequences of financial market imperfections. Two seminal papers in this field are Bernanke, Gertler and Gilchrist (1998) and Kiyotaki and Moore (1997). Iacoviello (2005) extends Bernanke, Gertler and Gilchrist (1998) by incorporating nominal debt as well as collateral constraints as in Kiyotaki and Moore (1997) to examine the different impacts of demand and supply shocks on the aggregate economy.

This paper also relates to literature on the effects of monetary policy on macroeconomic volatility. Ireland (2000) shows that, compared with a constant money growth rule, the U.S. Federal Reserves' interest rate policy, which is an active interest rate rule that responds to changes in inflation, successfully insulates aggregate output from money demand shocks and helps the economy adjust to technology shocks in the sense that the responses of the aggregate economy are resemble to those in an environment without nominal rigidities. Collard and Dellas (2005) examine the properties of two passive rules, i.e. a constant money growth rule and a constant interest rate rule and discuss under what conditions a constant money growth rule is better than a constant interest rate rule and vice versa.

3. The Model

In this section, we present a new Keynesian DSGE model with interest rate control, endogenous credit shocks and credit constraints in order to explain some features of the Chinese macroeconomy. Time is discrete and infinite. The economy consists of households, entrepreneurs, retailers, and the government. Households, entrepreneurs and retailers are of measure one, respectively. Households supply labor to entrepreneurs, demand real estate and money and consume the final goods. Entrepreneurs produce a homogenous intermediate good by combining labor, capital and real estate. Besides money, there is another financial asset, bonds, which can be traded between households and entrepreneurs. Retailers purchase intermediate goods from entrepreneurs in a competitive market, and transform them into composite final goods. The government conducts monetary and credit policies, collects taxes and makes government purchases.

3.1. Households

Households derive utility from consumption, housing, money and leisure. The representative household discounted lifetime utility is given by

$$E_0 \sum_{t=0}^{\infty} \beta^t (\ln c_t' + \varphi_t \ln h_t' - \frac{1}{\eta}(L_t')^\eta + \chi \ln(\frac{M_t'}{P})) \qquad (1)$$

where E_0 is the expectation formed at period 0, $\beta \in (0,1)$ is the subjective discount factor, c_t' is consumption, h_t' is the real estate (land) holdings by the household, L_t' is the labor input, M_t'/P_t are real money balances and η is the labor supply aversion, φ_t is the household's utility weight of real estate and we use it to represent housing demand shocks. The housing demand shocks capture social and institutional changes that shift preferences on housing or cyclical changes in resources needed to purchase housing relative to other goods (Iacoviello and Neri, 2010). The former is particular relevant to Chinese economy as the reform on housing institutions implemented in China in recent two decades has significant effects on Chinese households' demand for housing. Following the literature, we assume that the housing demand shocks follow an AR(1) process

$$\ln \varphi_t = (1-\rho_\varphi)\ln \overline{\varphi} + \rho_\varphi \ln \varphi_{t-1} + \varepsilon_{\varphi t} \qquad (2)$$

where $\overline{\varphi} > 0$ is a constant, $0 < \rho_\varphi < 1$, and ε_{φ_t} is i.i.d.N$(0, \sigma_\varphi^{\ 2})$.

Assume that households lend (borrow) in real terms b_t' ($-b_t'$) to (from) entrepreneurs. The household period budget constraint is

$$c_t'+q_{h,t}(h_t'-h_{t-1}')+b_t+\frac{M_t'-M_{t-1}'}{P_t}+T_t=w_tL_t'+\frac{R_{t-1}b_{t-1}'}{\pi_t}+F_t \qquad (3)$$

where $q_{h,t}\equiv Q_t/P_t$ is the real housing price, T_t is lump-sum taxes, $w_t'\equiv W_t'/P_t$ is the real wage, $\pi_t\equiv P_t/P_{t-1}$ denotes the gross inflation rate and F_t are lump-sum profits received from retailers. The right hand side of equation (3) is the inflow of funds for the household, which includes wage income, gross returns from lending in real terms and lump-sum profits. The left hand side of equation (3) is the outflow of funds for the household, which consists of consumption, housing investment, lending, changes in real money balances and tax payments.

The household's problem is choosing consumption, the holdings of real estate, money and bonds to maximize its lifetime utility subject to (3). The first order conditions are

$$\frac{1}{c_t'}=E_t\left(\frac{\beta R_t}{\pi_{t+1}c'_{t+1}}\right) \qquad (4)$$

$$\frac{q_{h,t}}{c_t}=\frac{\varphi_t}{h_t'}+\frac{\beta}{c_{t+1}'}q_{h,t+1} \qquad (5)$$

$$(L_t')^{\eta-1}=\frac{1}{c_t'}w_t \qquad (6)$$

Equation (4) is the household's Euler condition for consumption. Equations (5) is the necessary condition for choosing real estate holdings optimally. It states that in equilibrium, the marginal utility loss of holding real estate should be equal to the marginal utility gain of holding real estate. The marginal utility gain consists of the utility gain from consuming the real estate services and the utility gain from changes in the value of one unit of real estate. Equation (6) is the optimal condition for labor supply. The first-order condition for money demand is standard and can be ignored because we focus on the interest rate rule and the utility is separable in money balances.

3.2. Entrepreneurs

Entrepreneurs produce intermediate goods according to a Cobb-Douglas production function,

$$Y_t = A_t k_{t-1}^{\mu} h_{t-1}^{\nu} L_t^{1-\mu-\nu} \tag{7}$$

where Y_t is output, A_t is technology, k_{t-1} is capital, h_{t-1} is real estate and L_t is labor input. The aggregate technology shock A_t follows the autoregressive process

$$\ln A_t = \rho_A \ln(A_{t-1}) + \varepsilon_{At} \tag{8}$$

where $0 < \rho_A < 1$ and ε_{At} is i.i.d. $N(0, \sigma^2{}_A)$.

The representative entrepreneur derives utility from consumption. His expected lifetime utility is given by

$$E \sum_{t=0}^{\infty} \gamma^t \ln c_t \tag{9}$$

and his period budget constraint is given by

$$\frac{Y_t}{X_t} + b_t = c_t + q_{h,t}(h_t - h_{t-1}) + \frac{R_{t-1} b_{t-1}}{\pi_t} + w_t L_t + I_t \tag{10}$$

where $X \equiv P / P^w$ denotes the markup of final over intermediate goods, b_t $(-b_t)$ is the entrepreneur's borrowing (lending) from (to) the household, h_t is the entrepreneur's holdings of real estate and I_t is investment. The left hand side of equation (9) is the inflow of funds to the entrepreneur, which includes output and borrowed funds. The right hand side of equation (10) is the outflow of funds to the entrepreneur, which consists of consumption, real estate investment, debt repayment, wage payment and capital investment.

The law of motion for capital is given by

$$k_t = (1-\delta) k_{t-1} + \phi_t (1 - S(\frac{I_t}{I_{t-1}})) I_t \tag{11}$$

where δ is the depreciation rate. The function $S(\frac{I_t}{I_{t-1}})$ represents the adjustment costs in investment. We assume $S(\frac{I_t}{I_{t-1}}) = \frac{1}{2}\psi(\frac{I_t}{I_{t-1}} - 1)^2$, which satisfies the conditions that in steady state $S = S' = 0$, and $S'' = \psi > 0$.

The investment shock, ϕ_t, which represents shocks to the marginal productivity of investment, follows the process

$$\ln \phi_t = \rho_\phi \ln(\phi_{t-1}) + \varepsilon_{\phi,t} \tag{12}$$

where $0 < \rho_\phi < 1$ and $\varepsilon_{\phi,t}$ is i.i.d. $N(0, \sigma^2{}_\phi)$.

When entrepreneurs borrow from households, we assume that they face a borrowing constraint. We introduce a borrowing constraint into the model to capture the fact that in China, financial resources are limited. Thus, the entrepreneur's borrowing constraint is modeled as:

$$b_t \le \xi_t E_t [\frac{1}{R_t} q_{h,t+1} h_t \pi_{t+1} + q_{k,t} k_{t\text{-}1}] \tag{13}$$

where $q_{k,t}$ is the shadow price of capital in terms of consumption goods, ξ_t is the credit shock which reflects the disturbances to the tightness of the credit market. We consider two ways of modeling the credit shocks. One is that we assume that the credit shocks are exogenous stochastic processes and depend on (unspecified) market conditions, i.e.

$$\log \xi_t = (1 - \rho_\xi) \log \bar{\xi} + \rho_\xi \log \xi_{t-1} + \varepsilon_{\xi,t}$$

where $0 < \rho_\xi < 1$, $\varepsilon_\xi \sim i.i..d.N(0.\sigma_\xi)$. This is the commonly used approach in the literature (Jermann and Quadrini, 2011, Liu, Wang and Zha, 2010). Another way to model the credit shocks is that we assume that they are related to the central bank's credit policy, which will be presented in section 3.4.

The borrowing constraint states that the amount of loans the entrepreneur obtains cannot exceed a fraction of the expected discounted value of collateral assets (including real estate and non-real estate capital).

To make our analysis interesting, we assume that $\beta > \gamma$, that is, the household's subjective discount factor is bigger than the entrepreneur's subjective discount factor. This assumption ensures that the entrepreneur will borrow from the household in equilibrium. This assumption also ensures that in steady state, the borrowing constraint is binding. In non-steady state equilibrium, the borrowing constraint might not be binding if there exists large uncertainty in the economy. In this case, the entrepreneur's precautionary saving motive might outweigh impatience and the borrowing limit will not be hit. To rule out this possibility, we following Iacoviello (2005) to assume that uncertainty is "small enough" relative to degree of impatience so that the borrowing constraint is binding in any equilibrium.

The entrepreneur's problem is choosing the amount of labor, capital stock, capital investment, real estate investment, the amount of borrowing (lending) and consumption to maximize his expected lifetime utility subject to the constraints (7), (8), (10), (11), (12) and (13). Let χ_t be the Lagrangian multiplier associated with the budget constraint. Let λ_t be the Lagrangian multiplier associated with the borrowing constraint. Let Q_t be the Lagrangian multiplier associated with the law of motion of capital. The first order conditions are

$$[c_t]: \qquad \frac{1}{c_t} = \lambda_t + \frac{\gamma}{c_{t+1}} \frac{R_t}{\pi_{t+1}} \tag{14}$$

$$[k_t]: \qquad \frac{q_{k,t}}{c_t} = \frac{\gamma}{c_{t+1}} \frac{\mu Y_{t+1}}{X_{t+1} k_t} + \frac{q_{k,t+1}}{c_{t+1}} \gamma (1-\delta) + \gamma \lambda_{t+1} \xi_{t+1} q_{t+1,k} \tag{15}$$

$$[I_t]: \qquad \frac{1}{c_t} = \frac{q_{k,t}}{c_t} \phi_t (1 - \frac{1}{2} \psi (\frac{I_t}{I_{t-1}} - 1)^2) - \frac{q_{k,t}}{c_t} \phi_t \psi (\frac{I_t}{I_{t-1}} - 1) \frac{I_t}{I_{t-1}} + \gamma \frac{q_{k,t+1}}{c_{t+1}} \phi_{t+1} \psi (\frac{I_{t+1}}{I_t} - 1)(\frac{I_{t+1}}{I_t})^2 \tag{16}$$

$$[h_t]: \qquad \frac{1}{c_t}q_{h,t} = \frac{\lambda_t \xi_t q_{h,t+1}\pi_{t+1}}{R_t} + \gamma \frac{1}{c_{t+1}}\left(\frac{\nu Y_{t+1}}{X_{t+1}h_t} + q_{h,t+1}\right) \tag{17}$$

$$[L_t]: \qquad \frac{(1-\mu-\nu)Y_t}{X_t L_t} = w_t \tag{18}$$

where $q_{k,t} = \frac{Q_t}{\chi_t}$ implying $Q_t = \frac{q_{k,t}}{c_t}$. Equation (14) is the Euler condition for consumption. Equations (15) and (16) are the necessary conditions for optimal capital stock and optimal investment, respectively. Equation (17) is the first order condition for entrepreneur's real estate holdings. It states that in equilibrium, the marginal utility loss of holding real estate, $q_{h,t}/c_t$ should be equal to the marginal gain from holding real estate. The latter consists of the discounted future marginal product of real estate, the discounted resale price, and the shadow value of real estate as a collateral asset. Equation (18) is the optimal condition for labor demand. The first order conditions (14)-(18), together with the constraints (7), (10),(11),and a binding borrowing constraint (13) solve the entrepreneur's problem.

3.3. Retailers

A continuum of retailers of mass 1, indexed by j, purchase intermediate goods Y_t from entrepreneurs at P_t^w in a competitive market, differentiating the goods at no cost into $Y_t(j)$ and sell $Y_t(j)$ at the price $P_t(j)$. Final goods are composites of the differentiated goods according to the constant-returns-to-scale technology described by

$$Y_t^f = \left[\int_0^1 (Y_t(j))^{\frac{1}{1+\theta_t}} dj\right]^{1+\theta_t}$$

where θ_t is a stochastic parameter which will introduce time-varying mark-up in the retail goods market. We assume it following the autoregressive process

$$\log\theta_t = (1-\rho_\theta)\overline{\theta} + \rho_\theta \log\theta_{t-1} + \varepsilon_{\theta,t} \tag{17}$$

Where $\overline{\theta} > 0$, $0 < \rho_\theta < 1$ and $\varepsilon_{\theta,t} \sim i.i.d.N(0,\sigma_\theta)$.

Consumers minimize the cost of the bundle of differentiated goods for a given level of composite consumption. This gives us the demand for good j as $Y_t(j) = (\frac{P_t(j)}{P_t})^{-\frac{1+\theta_t}{\theta_t}} Y_t^f$ and the aggregate price index $P_t = (\int_0^1 P_t(j)^{-1/\theta_t} dj)^{-\theta_t}$

Following Calvo (1983), we assume that each period a fraction $1-\omega$ of all retailers resets prices optimally while the remaining ω fraction does not. As in Smets and Wouters (2003), we augmented the Calvo model by assuming that retailers who cannot reset prices optimally adjust their prices according to an indexation rule

$$P_{t+k}(j) = P_t(j)(\frac{P_{t+k-1}}{P_{t-1}})^{\delta_p} \qquad k = 0,1,2..... \qquad (18)$$

where the coefficient $\delta_p \in [0,1]$ indicates the degree of indexation to past prices. If $\delta_p = 1$, we get a full price indexation. If $\delta_p = 0$, we get the original Calvo price setting.

The retailers that adjust their prices at time t choose optimal price $P_t*(j)$ to maximize the expected discounted value of current and future profits. Since profits at some future date $t+k$ are affected by the choice of price at time t only if the retailer has not received another opportunity to optimally adjust his price between t and $t+k$, the probability of this is ω^k. The problem of the retailer who resets his price optimally is

$$\max_{P_t(j)} E_t \sum_{k=0}^{\infty} (\omega\beta)^k \Lambda_{t,t+k} [\frac{P_t(j)}{P_{t+k}}(\frac{P_{t+k-1}}{P_{t-1}})^{\delta_p} Y_{t+k}(j) - \frac{1}{X_{t+k}} Y_{t+k}(j)]$$

$$s.t. \qquad Y_{t+k}(j) = (\frac{P_t(j)}{P_{t+k}}(\frac{P_{t+k-1}}{P_{t-1}})^{\delta_p})^{-\frac{1+\theta_t}{\theta_t}} Y_{t+k}^f$$

where $\Lambda_{t,t+k} = c_t'/c_{t+k}', \beta^k \Lambda_{t,t+k}$ is the stochastic discount factor. The first order condition with respect to $P_t(j)$ is

$$E_t \sum_{k=0}^{\infty} (\omega\beta)^k \Lambda_{t,t+k} Y_{t+k}(j)[\frac{P_t*(j)}{P_{t+k}}(\frac{P_{t+k-1}}{P_{t-1}})^{\delta_p} - (1+\theta_t)\frac{P_{t+k}^w}{P_{t+k}}] = 0 \quad (19)$$

The aggregate price index is an average of the price charged by the fraction $1-\omega$ of retailers setting their prices optimally in period t and the average of the average of the remaining fraction ω of all retailers that do not reset their prices optimally in period t. Since we assume that adjusting retailers were selected randomly, the average price of the non-adjusters is just the average price of all retailers that prevail in period $t-1$, augmented by partial price indexation. Thus the average aggregate price index in period t satisfies

$$P_t^{1-\theta_t} = (1-\omega)(P_t*)^{1-\theta_t} + \omega(P_{t-1}(\frac{P_{t-1}}{P_{t-2}})^{\delta_p})^{1-\theta_t} \quad (20)$$

Log-linearizing equations (19) and (20) leads to the Phillips curve

$$\hat{\pi}_t = \frac{\beta}{1+\beta\delta_p} E\pi_{t+1} + \frac{\delta_p}{1+\beta\delta_p}\hat{\pi}_{t-1} + \frac{(1-\omega)(1-\omega\beta)}{\omega}\frac{1}{1+\beta\delta_p}(-\hat{X}_t + \hat{\theta}_t) \quad (21)$$

A hat stands for log-deviations from the deterministic steady state. As in the traditional Phillips curve, inflation depends positively on expected inflation and negatively on the markup $\hat{X}_t$ of final over intermediate goods. Unlike the traditional Phillips curve, inflation also depends positively on past inflation. This is due to the presence of partial price indexation. Inflation is also positively affected by inflation shocks, which is captured by $\hat{\theta}_t$.

3.4. The government

The central bank implements a (an almost) constant nominal interest rate rule. In order to avoid the indeterminacy problems, we follow Collard and Dellas (2005) to specify the rule as follows

$$\hat{R}_t = r_R \hat{R}_{t-1} + (1-r_R) r_\pi \hat{\pi}_{t-1} \quad (22)$$

with $r_R = 0.999$ and $r_\pi = 1.01$. This way, the nominal interest rate will hardly respond to any change in economic conditions.

The central bank also implements credit policy to influence the economy. Inspecting the time series of credit and output we find that during some periods of our study, credit and output are significantly negatively related. This is because the central bank used credit policy to stabilize the economy. We incorporate this feature into the model by assuming that the central bank can affect the tightness of the credit market. In other words, the credit shocks are endogenously determined as follows

$$\hat{\xi}_t = \rho_\xi \hat{\xi}_{t-1} + (1-\rho_\xi)\rho_y \hat{y}_{t-1} + \varepsilon_{\xi,t}$$

where $r_y < 0$ means that the central bank conducts a contractionary credit policy when the economy is in boom, and $\varepsilon_{\xi,t} \sim i.i.d.N(0,\sigma_\xi)$. We regard this credit shock modeling as our benchmark case.

The government expenditures are financed by lump-sum taxes and money creation:

$$G_t = T_t + \frac{M_t - M_{t-1}}{P_t} \tag{23}$$

We assume that government purchases follow the stochastic process

$$\ln G_t = (1-\rho_G)\ln \overline{G} + \rho_G \ln G_{t-1} + \varepsilon_{G,t} \tag{24}$$

where $\overline{G} > 0$, $0 < \rho_G < 1$, $\varepsilon_{G,t} \sim i.i.d.N(0,\sigma_G)$

3.5. Equilibrium

Given $\{k_{t-1}, h_{t-1}, R_{t-1}, b_{t-1}, P_{t-1}\}$ and the sequences of productivity, housing demand, credit, inflation, and government expenditure shocks $\{A_t, \varphi_t, \xi_{t,} \phi_t, \theta_t, G_t\}_{t=0}^{\infty}$, the equilibrium of the economy is characterized by allocations for households $\{c_t', h_t', L_t', b_t'\}_{t=0}^{\infty}$, allocations for entrepreneurs $\{c_t, h_t, L_t, b_t, I_t', k_t'\}_{t=0}^{\infty}$ and the sequence of values $\{w_t, R_t, P_t, P_t^*, X_t, q_t, \lambda_t\}_{t=0}^{\infty}$ such that households and entrepreneurs solve their optimization problem, and the labor market clears ($L_t = L_t'$), the real estate market clears ($h_t + h_t' = 1$), the goods market clears ($c_t + c_t' + I_t + G_t = Y_t$), the credit market clears ($b_t = b_t'$), the government budget is balanced ($G_t = T_t + \frac{M_t - M_{t-1}}{P_t}$) and the relevant transversality conditions.

4. Calibration and Estimation

To quantitatively analyze the model, we parameterize the model by calibration and Bayesian estimation using date during the period 1998 Q1 – 2010 Q4. We need to pin down 26 parameter values: the discount factors β and γ; the technology parameters μ, ν and δ; the household's preference parameters $\overline{\varphi}$ and η; the markup X, the degree of price rigidity ε, the degree of partial indexation δ^p, the steady state the parameter determining the investment adjustment cost ψ, the steady state loan to value ratio ξ, the steady state ratio of government expenditures over output $\overline{G}/\overline{Y}$, and the parameters characterizing the shock processes $\rho_{A,}\rho_u, \rho_\varphi, \rho_\phi, \rho_\xi$, ρ_y, ρ_G $\sigma_A, \sigma_u, \sigma_\varphi, \sigma_\phi, \sigma_\xi, \sigma_G$.

Following the monetary business cycle literature we set $X = 1.15$. We assign $\varepsilon = 0.67$, meaning that in each period two thirds of entrepreneurs adjust their prices. This value is within the range of the degree of price rigidity in the monetary and business cycle literature.

In the steady state $R\beta = 1$. During the period of our study, the average annual lending rate is 5.93%, which implies a quarterly rate of 1.014%. This gives us $\beta = 0.99$. Following Iacoviello (2005), we use the reciprocal of γ to proxy for the firm's internal rate of return. We assume that this is twice as big as the equilibrium interest rate, which leads to $\gamma = 0.98$. We set $\delta = 0.025$ implying an annual depreciation rate of 10%.

Following the business cycle literature in the Chinese economy, we set the capital share $\mu = 0.4$. The elasticity of output to entrepreneurial land is set to 0.06. This number implies that the average value of land is about 70% over annual output. The steady state ξ is set at 0.4 to match that the steady state ratio of debt over quarterly output is about 4.14. The steady state ratio of government spending to output is 0.18 over the range of our data set. Table 1 presents the calibration results.

It remains to pin down the parameters that characterize the shock processes and the structural parameters $\bar{\varphi}, \eta, \psi, \bar{\theta}$, δ^p. We estimate these parameters using Bayesian method. The Bayesian method takes the parameters as random variables and computes the relevant statistics based on the posterior distribution. The posterior distribution is obtained by coupling the likelihood function (associated with the state-space representation of the model) with a prior distribution using Bayes' Rule. The data we use are $(\log y_t, \log \pi_t, \log b_t, \log q_{h,t}, \log I_t, \log G_t)$.The data are quarterly and cover the period from 1998Q1 to 2010Q4. All the data are seasonally adjusted and linearly detrended. We impose beta prior distribution with mean 0.08 and standard deviation 0.01 on $\bar{\varphi}$. Following Justiniano, Primiceri and Tambalotti (2010), the prior distribution of ψ is gamma with mean 4 and standard deviation 1. Following Smets and Wouters (2005) and Jermann and Quadrini (2011), the prior distributions of $\bar{\theta}$, δ^p and η are normal (0.5, 0.1), beta (0.7, 0.1) and normal (1.6, 0.1), respectively. We assume that the prior distribution of ρ_y is normal with mean -1.5 and standard deviation 0.01. As commonly applied in the literature, the prior distributions of persistence parameters is beta with mean 0.90 and standard deviation 0.01. The prior distribution of all shocks is inverse gamma with standard deviation of infinity. The reported posterior statistics are computed from a 20,000 MCMC chain from which the first 10,000 draws were discarded. Table 2 presents key statistics of the prior and posterior distributions.

Table 1. Calibrated Parameters

Description	Parameter	Value
Household's discount factor	β	0.99
Entrepreneur's discount factor	γ	0.98
Capital share	μ	0.4
Real estate share	ν	0.06
Depreciation rate	δ	0.025
Steady-state gross markup	X	1.15
Degree of price rigidity	ω	0.67
Steady state loan to value ratio	ξ	0.4
Steady state ratio of government expenditure over output	$\overline{G}/\overline{Y}$	0.18

Table 2. Prior distributions and Posterior Estimates

Parameters	prior distribution	prior mean	std	posterior mean	confidence interval
η	normal	1.6	0.1	1.50	[1.38 1.59]
$\overline{\varphi}$	beta	0.08	0.01	0.10	[0.09 0.11]
ψ	gamma	4	1	1.18	[0.80 1.64]
$\overline{\theta}$	normal	0.5	0.1	0.52	[0.34 0.67]
δ^p	beta	0.7	0.1	0.80	[0.76 0.85]
ρ_A	beta	0.90	0.01	0.89	[0.88 0.90]
ρ_θ	beta	0.90	0.01	0.91	[0.91 0.92]
ρ_φ	beta	0.90	0.01	0.91	[0.89 0.92]
ρ_ϕ	beta	0.90	0.01	0.89	[0.88 0.90]
ρ_ξ	beta	0.90	0.01	0.90	[0.89 0.91]
ρ_g	beta	0.90	0.01	0.90	[0.89 0.91]
ρ_y	normal	−1.5	0.01	−1.11	[−1.21 −0.99]
σ_A	inverse gamma	0.2	inf	0.56	[0.47 0.66]
σ_θ	inverse gamma	0.02	inf	0.041	[0.035 0.048]
σ_φ	inverse gamma	0.2	inf	0.329	[0.243 0.394]
σ_ϕ	inverse gamma	0.2	inf	0.182	[0.152 0.215]
σ_ξ	inverse gamma	0.2	inf	2.310	[1.910 2.667]
σ_g	inverse gamma	0.2	inf	0.101	[0.086 0.117]

5. Results

In this section we examine the relative importance of different shocks, report the impulse response functions and discuss the role of the central bank's policies.

5.1. The relative importance of shocks

Table 3 reports the variance decomposition results, which shows the contribution of each shock to the variance of key macroeconomic variables at different frequencies. In the very short run (one-quarter horizon), output fluctuations are dominantly driven by credit shocks. At the one-year horizon, credit shocks account for around 70% of output movements, while technology shocks account for about 25% of output developments. Over the medium to the long run, these two shocks are still important, but the contribution of inflation shocks increases. In the long run, credit, technology and inflation shocks explain 45%, 27% and 27% of output fluctuations, respectively.

Regarding other variables, credit shocks contribute dominantly to the volatility of investment both in the short run and in the long run. At one-year horizon, credit shocks explain around 90% of investment fluctuations. Credit shocks contribute significantly to the movements of real estate prices in the short run but not in the long run.

Productivity shocks are the most important determinants of employment and real wages, both in the short run and in the long run. Given that the supply of labor is almost perfectly elastic in China, these results are reasonable. Productivity shocks are also the main driving forces of consumption fluctuation. A puzzling result is that productivity shocks explain most of the movements in inflation, which is expected to be influenced primarily by the inflation or markup shocks.

Inflation shocks become important in the long run. This may be because partial indexation makes inflation inertia and thus the inflation shock has a long run effects on the economy.

Housing demand shocks, investment shocks and government spending shocks turn out to be relatively not important in determining economic fluctuations under our estimation.

It is natural to question that the significant contribution of credit shocks to business cycles stemming from the larger standard error of credit shocks in our estimation results. Indeed, the size of standard error matters. The relatively large standard error of credit shocks is due to our specification of countercyclical credit policy. However, the size of standard error is not the only element that influences the contribution of shocks. For instance, the standard error of housing demand shocks is much larger than that of inflation shocks, but the contribution of inflation to economic fluctuations is much bigger. The impact of an economic shock on the economy depends not only on the size and persistence of the shock but also on the mechanism which relates economic variables.

Table 3. Variance decomposition of aggregate variables

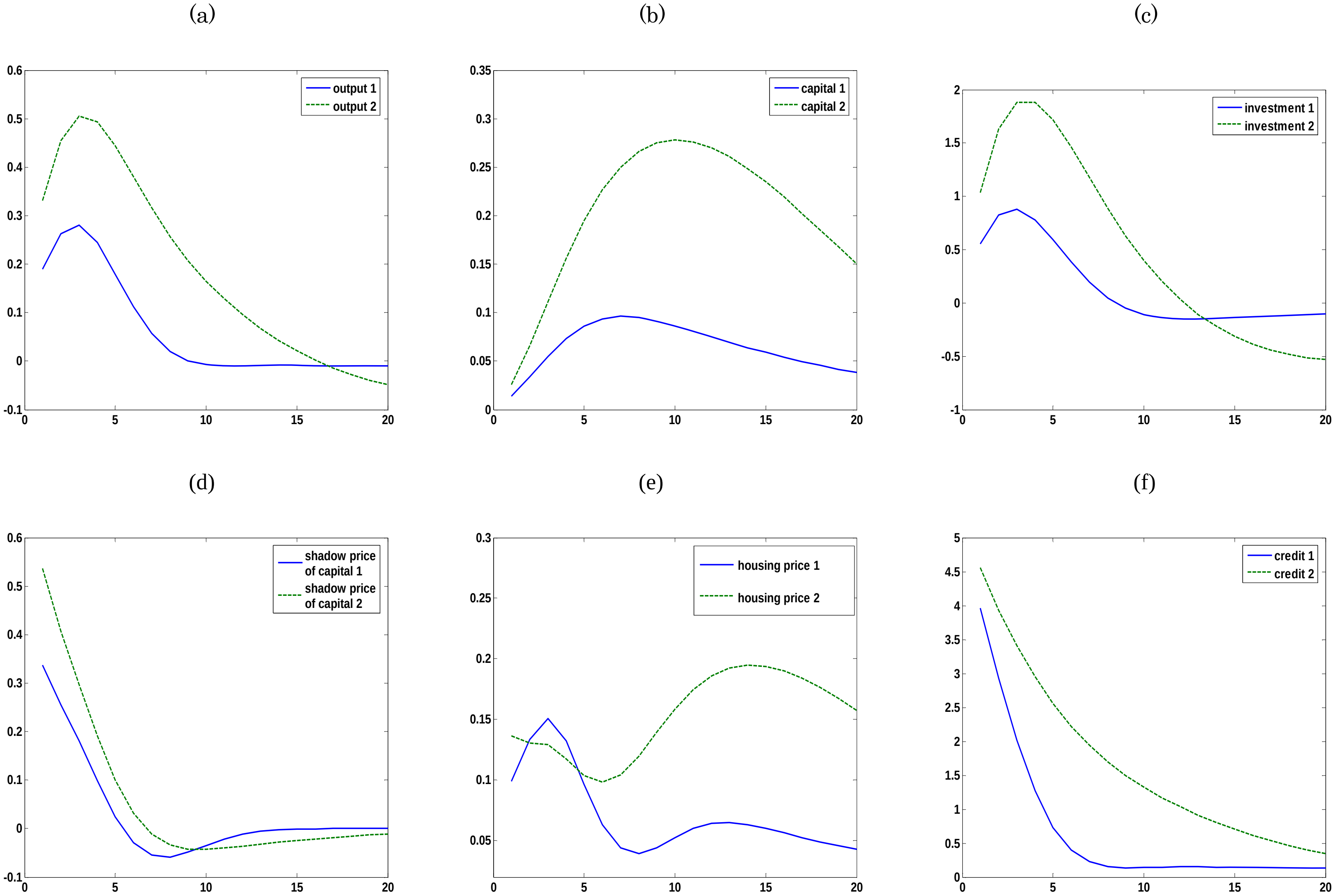
	Shocks					
	Technology	inflation	housing	investment	credit	government
Period 1						
Output	2.09	2.16	0.19	0.03	94.94	0.59
Investment	13.50	0.50	0.13	3.17	82.68	0.02
Credit	1.79	0.06	0.00	0.14	98.01	0.00
Real estate price	22.83	0.04	4.39	8.07	64.56	0.12
Inflation	95.33	4.48	0.01	0.04	0.10	0.03
Consumption(E)	66.86	0.26	0.20	3.30	29.37	0.01
Consumption (H)	95.34	4.47	0.01	0.04	0.10	0.03
Labor	90.32	0.21	0.02	0.00	9.39	0.06
Wages	70.41	4.49	0.02	0.00	25.00	0.06
Period 4						
Output	25.26	6.36	0.05	0.06	68.19	0.09
Investment	4.01	1.89	0.10	3.12	90.80	0.08
Credit	6.23	0.87	0.00	0.34	92.55	0.02
Real estate price	81.05	2.31	0.31	1.66	14.60	0.07
Inflation	89.21	4.02	0.01	0.12	6.59	0.04
Consumption(E)	63.15	1.70	0.24	7.81	27.09	0.01
Consumption (H)	91.22	3.91	0.02	0.12	4.69	0.04
Labor	83.63	6.37	0.03	0.14	9.76	0.07
Wages	69.20	18.30	0.01	0.03	12.44	0.03
Period 10						
Output	28.58	8.98	0.04	0.08	62.24	0.07
Investment	11.08	2.18	0.09	3.36	83.14	0.14
Credit	23.41	4.73	0.01	0.49	71.33	0.02
Real estate price	83.89	1.94	0.26	1.63	12.17	0.10
Inflation	89.11	4.13	0.01	0.22	6.49	0.03
Consumption(E)	51.78	12.57	0.21	8.73	26.68	0.04
Consumption (H)	90.99	3.49	0.02	0.12	5.32	0.06
Labor	76.74	13.29	0.03	0.14	9.74	0.07
Wages	69.54	19.27	0.01	0.05	11.10	0.03
Period ∞						
Output	26.99	26.64	0.03	0.50	45.77	0.07
Investment	14.32	2.92	0.09	3.65	78.89	0.14
Credit	28.34	26.75	0.01	0.79	44.07	0.05
Real estate price	76.40	5.64	0.28	1.84	15.66	0.18
Inflation	89.06	4.16	0.02	0.24	6.49	0.03
Consumption(E)	24.02	68.10	0.02	2.14	5.65	0.08
Consumption (H)	82.78	7.86	0.02	0.62	8.61	0.12
Labor	67.04	22.72	0.02	0.25	9.88	0.09
Wages	66.94	20.48	0.01	0.40	12.11	0.06

5.2. Impulse Response Functions

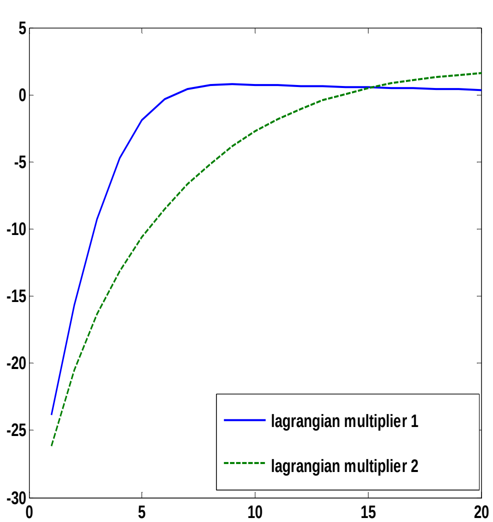
Given that credit shocks are the main driving force of business cycle in China's economy, we focus on the propagation mechanism of credit shocks to the economy implied in our model. The solid lines of Figures 3(a) – 3(i) display the impulse response functions of several key macroeconomic variables to a positive credit shock in our benchmark model. A positive credit shock increases output (panel a). This is mainly due to the increased responses of investment to credit shocks (panel c). A positive credit shock reduces inflation in the very short run (panel i). Because nominal interest rate almost does not respond to the shock (panel h), the cost of debt actually increases, which will not contribute to the expansion of production. However, the positive credit shock relaxes the borrowing constraint, which can be seen from a decrease in the Lagrangian multiplier for the borrowing constraint (panel g) and an increase in credit (panel f). The relaxation of the borrowing constraint enables the entrepreneur to expand production by increase factors of production. Since there are investment adjustment costs in the model economy, the shadow price of capital is not equal to the price of consumption goods. A positive credit shock raises the shadow price of capital (panel d), which raises the marginal benefit of investment (see equation (16)). Thus, it pays entrepreneurs to increase investment to a large extent. Consequently, output rises.

The solid lines of Figures 4(a) – 4(e) display output responses to a positive technology shock, a positive inflation shock, a positive housing demand shock, a positive investment shock and a positive government spending shock. Generally speaking, the results are reasonable. A positive inflation shock can lead to an increase or decrease in output, depending on whether the inflation shock arises from the supply side or the demand side. Since in our model, the inflation shock affects cost, they negatively affect the output.

Figure 3 Impulse responses to a positive credit shock

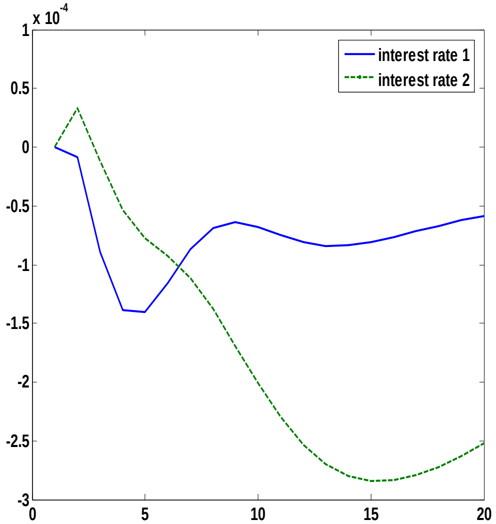


(g)



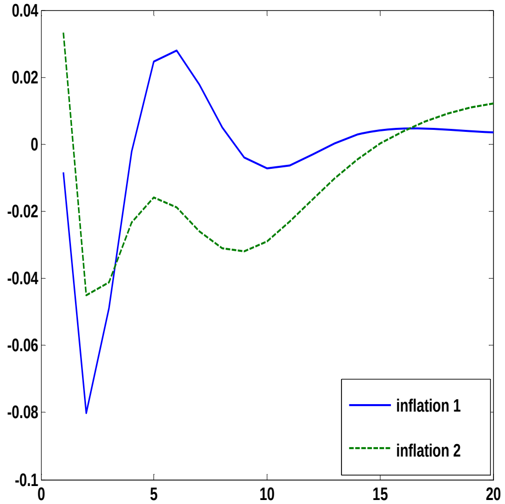
lagrangian multiplier 1
lagrangian multiplier 2

(h)



x 10^-4
interest rate 1
interest rate 2

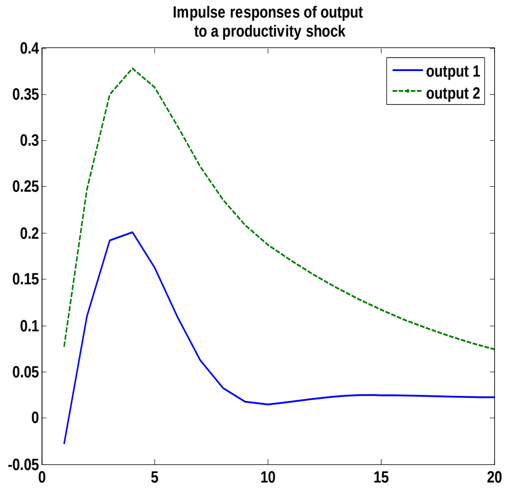
(i)



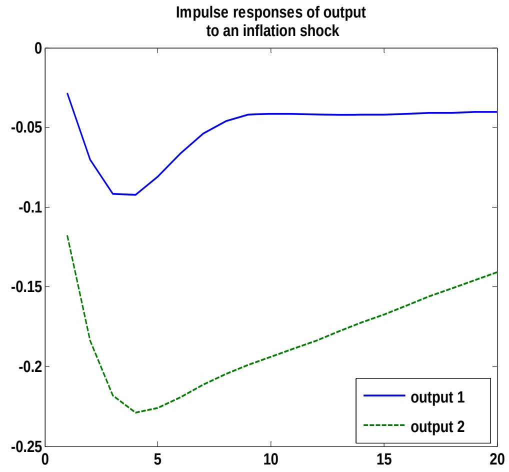
inflation 1
inflation 2

Figure 4

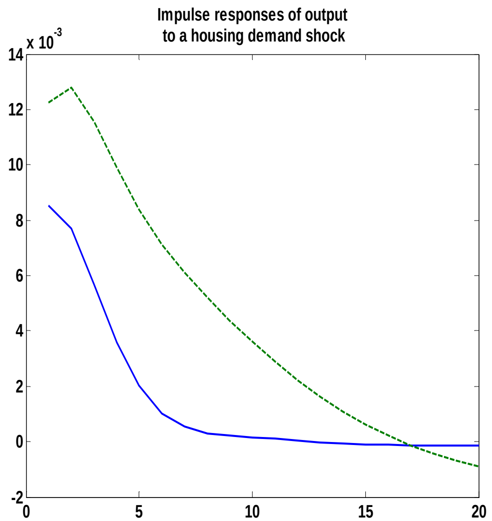
(a)



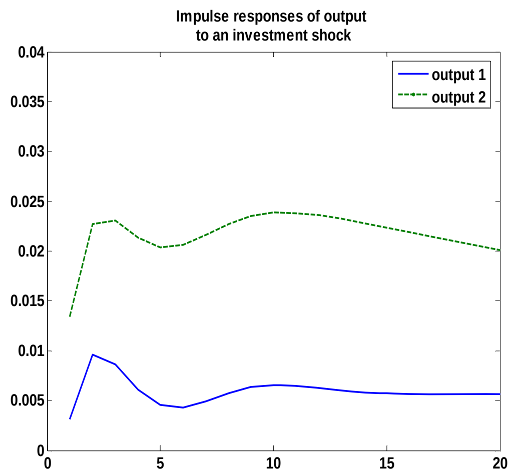
(b)



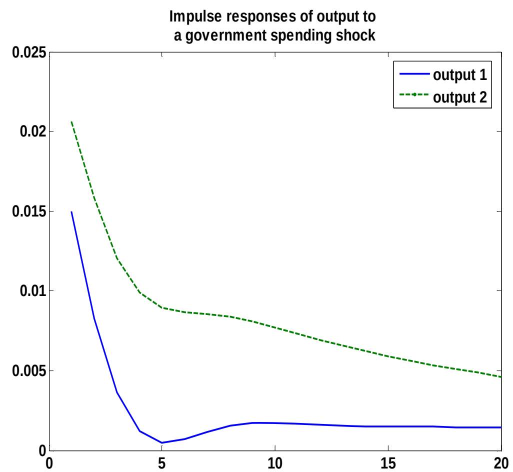
(c)



(d)



(e)



The dashed lines of Figures 3(a)-3(i) and Figures 4(a)-4(e) show the impulse responses of macroeconomic variables to shocks when we shut down the countercyclical response of credit policy, i.e. when $\rho_y = 0$. In this case, the responses of macroeconomic variables to credit shocks and other types of shocks are larger than those in the benchmark case, which implies that the volatility of these variables are bigger in the later case. Thus, countercyclical credit policy can reduce macroeconomic volatility. Of course, in reality, the People's Bank of China does not implement a countercyclical credit policy constantly, as specified in our model. In some periods, the central bank applies a procyclical credit policy to meet the demand for credits in the economy. However, our model shows that the central bank's credit policy does play a role in alleviating the economic fluctuations.

A drawback of credit policy is that it directly affects the availability of loans for all firms in the aggregate economy and this may results in resource misallocation. Koivu (2009) finds that changes in the economic environment, including the profound reforms of the state owned entrepreneurs (SOEs), and the expansion of the private sector and the foreign sector, have made the Chinese real economy became responding to interest rates. In particular, the credit demand by firms was found negatively affected by the real interest rate. Thus, an active interest rate rule, which responds to changes in macroeconomic conditions, instead of an active credit policy, may be a more effective policy to stabilize the aggregate economy.

6. Conclusion

In this paper, we study the sources of business cycles in the Chinese economy in a model economy with a constant interest rule, endogenous credit shocks and credit constraints. We find that credit shocks are the main driving forces of economic fluctuations. The countercyclical credit policy is effective in reducing macroeconomic volatility to some extent, but this can be achieved by using appropriate interest rate policy as well.

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Notes:

[1] When we analyze the role of monetary policy in China's real economy, a natural question is how to model the monetary policy. Strictly speaking, the current Chinese monetary policy cannot be modeled exactly in the standard new Keynesian framework. In the standard new Keynesian model, monetary policy is usually characterized either by an interest rate rule or by a money supply rule. When the behavior of the central bank is modeled as an interest rate rule, the money supply is endogenously determined to support the rule and clear the money market. By the same token, when the behavior of the central bank is modeled as a money supply rule, the nominal interest rate is endogenously determined. In China, money supply is the primary focus of monetary policy; however, the nominal interest rate is not flexible. The sluggish lending and deposit rates can be regarded as that the central bank employs a constant interest rate rule. Since we are interested in the impact of interest rates on macroeconomic volatility, we model the monetary policy as a rule on interest rate and assume that the money supply is endogenously determined.

Appendix A: Derivation of the Phillips Curve

The first order condition of the retailers' optimization problem is

$$E_t \sum_{k=0}^{\infty} (\omega\beta)^k \Lambda_{t,t+k} Y_{t+k}(j) \frac{P_t*(j)}{P_{t+k}} \left(\frac{P_{t+k-1}}{P_{t-1}}\right)^{\delta_p} = E_t \sum_{k=0}^{\infty} (\omega\beta)^k \Lambda_{t,t+k} Y_{t+k}(j)(1+\theta_t) \frac{P^w_{t+k}}{P_{t+k}} \tag{A.1}$$

Log-linearize equation (A.1) we have

$$\hat{P}_t*(j) + (1-\omega\beta)\sum_{k=0}^{\infty}(\omega\beta)^k (\hat{Y}_{t+k}(j) - \hat{P}_{t+k} + \delta(\hat{P}_{t+k-1} - \hat{P}_{t-1}) + \hat{\Lambda}_{t,t+k})$$

$$= (1-\omega\beta)\sum_{k=0}^{\infty}(\omega\beta)^k (\hat{Y}_{t+k}(j) + \hat{p}^w_{t+k} - \hat{P}_{t+k} + \hat{\theta}_t + \hat{\Lambda}_{t,t+k}) \tag{A.2}$$

(A.2) can be simplified as

$$\hat{P}_t*(j) = (1-\beta\omega)\sum_{k=0}^{\infty}(\omega\beta)^k [\hat{P}^w_{t+k} + \hat{\theta}_t - \delta_p(\hat{P}_{t+k-1} - \hat{P}_{t-1})] \tag{A.3}$$

(A.3) can be rewritten as

$$\hat{P}_t*(j) - \delta_p \hat{P}_{t-1} = (1-\beta\omega)(\hat{P}^w_t + \hat{\theta}_t - \delta_p \hat{P}_{t-1}) + \omega\beta(\hat{P}_{t+1}*(j) - \delta_p \hat{P}_t) \tag{A.4}$$

Log-linearize the equation

$$P_t^{1-\theta_t} = (1-\omega)(P_t*(j))^{1-\theta_t} + \omega\left(P_{t-1}\left(\frac{P_{t-1}}{P_{t-2}}\right)^{\delta_p}\right)^{1-\theta_t}$$

we obtain

$$\hat{P}_t^*(j) = \frac{1}{1-\omega}(\hat{P}_t - \omega\hat{P}_{t-1} - \omega\delta_p\hat{\pi}_{t-1}) \quad \text{(A.5)}$$

Substituting (A.5) into (A.4) and after some manipulations (e.g. collecting terms), we have the Phillips curve given by

$$\hat{\pi}_t = \frac{\beta}{1+\beta\delta_p} E\pi_{t+1} + \frac{\delta_p}{1+\beta\delta_p}\hat{\pi}_{t-1} + \frac{(1-\omega)(1-\omega\beta)}{\omega}\frac{1}{1+\beta\delta_p}(-\hat{X}_t + \hat{\theta}_t)$$

Appendix B. Data Description

Variables	Data Source	Period
Output	National Bureau of Statistics of China	1998Q1 – 2010Q4
Investment	China Economic Information Network	1998Q1 – 2010Q4
Housing price	National Bureau of Statistics of China	1998Q1 – 2010Q4
CPI	China Economic Information Network	1998Q1 – 2010Q4
Lending rate	The People's Bank of China	1998Q1 – 2010Q4
Credit	The People's Bank of China	1998Q1 – 2010Q4

Notes

1. Investment refers to fix capital investment.
2. Consumption per capita is the average of urban consumption per capita and rural consumption per capita.
3. Housing prices refers to national average housing price$/m^2$. Data on housing prices during the period of our study are not directly available. We calculated housing prices in the following way: First, we calculate one year's housing prices by dividing the value of sales on housing by sale volume on housing. Then we back out the remaining housing prices by using the house price index.
4. Annual lending rate is adjusted to have a quarterly frequency.
5. credit means the total loans extended to non-financial institutions.