In a new Keynesian DSGE model with interest rate control and credit constraints, we study the sources and transmission mechanism of business cycles in China. We find that inflation shocks are the main driving force of economic fluctuations, while investment shocks explain a non-negligible part of fluctuations. Interest rate control and credit constraints play a role in transmitting shocks. We compare our benchmark model with models with interest rate rules that are responsive to changes in economic conditions. We find that under certain parameter values, the alternative interest rate rules can reduce the macroeconomic volatility, suggesting that an active interest rate rule is preferable to a passive interest rate rule in making the Chinese economy less volatile.

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. Gong and Lin (2008) document that during the period 1980 to 2003, the growth rate of real GDP in China ranged from 3.8% to 14%, the growth rate of investment varied from -20% to 50%, and the inflation rate changed within 2% and 22%. Economists have provided several explanations for what caused these economic fluctuations. This paper attempts to contribute the literature by providing an additional explanation for the sources and transmission mechanism of business cycles in China.

Our model is built 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. The model contains the basic elements of the new Keynesian economy: monopolistic competition and sticky prices in the final goods sector. To capture the features of the Chinese economy, we modify the model in three 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 assume that entrepreneurs’ borrowing is constrained by the value of collateral assets (real estate or land) as well as the value of non-collateral assets (non-real estate capital). Third, we introduce investment shocks into the model.

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 inflation shocks are the main driving force of economic fluctuations, while investment shocks explain a non-negligible part of fluctuations. Under a constant interest rate rule, a positive inflation shock reduces the shadow price of capital (in terms of consumption goods) and the real estate price (in terms of consumption goods), which tightens the borrowing constraint. This effect together with a reduction in labor demand explains the drop in output. A positive investment shock boosts investment, but reduces the shadow price of capital and tightens the borrowing constraint. As a result, credit constraints dampens the effects of investment shocks.

We compare our benchmark model with a comparison model with active interest rate rules. We find that under certain parameter values, the alternative interest rate rules can reduce the macroeconomic volatility. This result leads naturally to the policy suggestion that to reduce the macroeconomic volatility in China, it is necessary to implement an interest rate rule that is actively responsive to macroeconomic conditions.

This paper closely relates to 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). Bernanke, Gertler and Gilchrist (1998) study a dynamic general equilibrium new Keynesian model in which the asymmetric information between borrowers and lenders generates a link between external finance premium and the net worth of borrowers that can amplify both real and nominal shocks to the economy. Kiyotaki and Moore (1997) analyze the dynamic interaction between a borrowing constraint and asset prices and how this interaction can transmit small shocks to large, persistent output fluctuations. 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.

A large body of literature has recently focused on the role of investment shocks in driving business cycles (Schmitt-Grohe and Uribe (2010), Justiniano, Primiceri and Tambalotti (2010), etc.). 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.

The rest of the paper is organized as follows. Section 2 documents the current interest rate policy and the facts about business cycles in China. 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. Macroeconomic Facts: Interest Rate Control and Business Cycles in China

2. 1. Interest Rate Control in China: Institutional Background

The economic reform in China centers on establishing the system of market economy. Many efforts had been made to set up a price system which can reflect the market forces of supply and demand. As a consequence, nowadays most prices of goods and labor are formed on the basis of market conditions. However, the reform on the prices in the financial market was rather slow compared to that in the goods and labor markets. The liberalization of interest rate did not start until 1996. Moreover, this reform was only confined to interest rates on interbank borrowing and lending and to the primary market of government bonds, while the major prices in the financial market, the lending rate to non-financial institutions and the deposit rate, are still set by the People’s Bank of China, the central bank of China. Although commercial banks have been allowed to adjust the lending rates within a certain bands since 1998, most banks extend loans at the benchmark rates set by the central bank due to strong competition in the credit market.

Figure 1 shows the quarterly interest rate from 1998Q1-2010Q4. The lending rate
was not completely flat during the period of our study. For example, the central bank reduced the lending rate 3 times in 1998 in response to deflation and to decreases in output growth. In 2007, the central bank increased the lending rate 6 times in response to inflation and to increases in output growth. However, there were periods that the lending rate did not react to changes in economic conditions. For instance, between June 1999 and January 2002 (32 months), the 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.

![Figure 1](image)

On the other hand, the role of interest rates has been found increasing in the real economy. In the past, loans to firms were allocated under the credit plans made by the central bank. The credit plans determine the amounts of credit the state banks could and should lend to firms. Under this institution, there is no role for the interest rate. Changes in economic environment in the mid-1990s altered this situation. Starting from 1994, state owned enterprises (SOEs) experienced profound reforms which resulted in profit-orientation of the SOEs. At the same time, the roles of private sector and foreign sector expanded rapidly in the economy. In 1998, the monetary authority abandoned the credit plan. Koivu (2009) finds that as a result of changes in the economic environment, the Chinese real economy became respond to interest rates. In particular, the credit demand by firms was found negatively affected by the real interest rate.

### 2.2. Stylized Facts: Business Cycles in China

Figures 2 (a)-(f) plot several time series of the key macroeconomic variables we are interested in. Figure 1(a) shows the detrended log of real GDP. Although the period we study was not the most unstable period after the economic reform, the degree of macroeconomic fluctuations was still remarkable. Real GDP was above its trend by 3.5 percentage points in the third quarter of 2007 and below its trend.

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2 Data on GDP, investment, real estate prices and consumption are transformed in real terms, deseasonalized, transformed in logarithm values and HP-filtered.
by 4 percentage points in the fourth quarter of 2008.

Figure 2(b) shows the inflation rate using 1997Q4 as the base period. A feature of the Chinese economy during the period of our study was that inflation was pretty volatile. Between 1998 and 2003, the Chinese economy experienced a period of deflation. The inflation reemerged since 2004. The inflation rate reached 10% in the middle of 2007 and continued to be above 10% in the following three years. Figure 2(c) shows the chained inflation rate at the quarterly frequency (i.e. inflation in period $t$ / inflation in period $t-1$).

Figure 2(d) illustrates the behavior of housing prices. Comparing figure 2(a) and figure 2(c), we find that housing price was procyclical and lead the cycle. This pattern tends to be more significant after 2007, indicating that the real estate price has become an important indicator in the aggregate economy.

Figure 2(e) plots the time series of investment. Investment was much more volatile compared to output and closely positively related to output. This is a significant characteristic of China’s business cycles. Figure 2(f) depicts the time series of consumption per capita. Due to data availability, the plot shows consumption per capital during the period 2003Q1—2010Q3. According to our data, consumption in this period was somewhat less volatile than output3.

### 3. The Model

In this section, we present a new Keynesian DSGE model with 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 central bank. 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. In this section, we present the benchmark model in which the central bank implements a constant interest rate rule. In section 5 we will assume that the central bank can adopt alternative interest rate rules which respond to changes in economic conditions.

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3 Hu and Liu (2007) document that as in many other emerging economies, the volatility of consumption in China is higher than that of output. We find different results potentially due to lack of data. In addition, in Hu and Liu (2007), the volatility of rural consumption is much higher than that of output, while the volatility of urban consumption is actually lower than that of output.
3.1. Households

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

\[ E_0 \sum_{t=0}^{\infty} \beta^t (\ln c_t + \phi_t \ln h_t - \frac{1}{\eta} (L_t)^{\eta} + \chi \ln \left( \frac{M_t}{P} \right)) \]  

(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 \( \eta \) is the labor supply aversion. The household’s housing demand shock \( \varphi_t \) follows the autoregressive process

\[
\ln \varphi_t = (1 - \rho_\varphi) \ln \varphi_0 + \rho_\varphi \ln \varphi_{t-1} + \xi_{\varphi_t} \tag{2}
\]

where \( \varphi > 0 \) is a constant, \( 0 < \rho_\varphi < 1 \), and \( \xi_{\varphi_t} \) 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

\[
c_t' + q_{h,t} (h_t' - h_{t-1}') + b_t + \frac{M_{t-1}' - M_{t-1}'}{P_t} = w_t L_t' + \frac{R_t b_{t-1}'}{\pi_t} + F_t \tag{3}
\]

where \( q_{h,t} = Q_t / P_t \) is the real housing price, \( w_t' = W_t' / P_t \) is the real wage, \( \pi_t = P_t / P_{t-1} \) 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 and changes in real money balances.

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

\[
\frac{1}{c_t} = E_t (\frac{\beta R_t}{\pi_{t+1} c_{t+1}}) \tag{4}
\]

\[
\frac{q_{h,t}}{c_t} = \frac{\varphi_t}{h_t'} + \frac{\beta}{c_{t+1}} q_{h,t+1} \tag{5}
\]

\[
( L_t' )^{\eta-1} = \frac{1}{c_t} w_t \tag{6}
\]

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,

\[ Y_t = A_t k_{t-1}^\mu h_{t-1}^\nu L_t^{1-\mu-\nu} \]  

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

\[ \ln A_t = \rho A \ln(A_{t-1}) + \varepsilon_{At} \]  

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

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

\[ E \sum_{t=0}^{\infty} \gamma^t \ln c_t \]  

And his period budget constraint is given by

\[ \frac{Y_t}{X_t} + b_t = c_t + q_{h_t}(h_t - h_{t-1}) + \frac{R_{t-1}b_{t-1}}{\pi_t} + w_t L_t + I_t \]  

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

\[ k_t = (1-\delta)k_{t-1} + \phi_1(1-S(\frac{I_t}{I_{t-1}}))I_t \]  

where

\[ S(\frac{I_t}{I_{t-1}}) = \frac{1}{1+\alpha(I_t - \Pi)} \]  

where \( I_t \) is investment, \( \Pi \) is the price of real estate, \( \alpha \) is a parameter, and \( S \) is a function of the capital stock to investment ratio. The parameter \( \phi_1 \) is the elasticity of capital with respect to investment, and \( \delta \) is the depreciation rate.
where $\delta$ 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, $\phi_t$, follows the process

$$\ln \phi_t = \rho_\phi \ln(\phi_{t-1}) + \varepsilon_{\phi,t}$$ (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 reflect the fact that in China, financial resources are limited as well as the increasing importance of mortgage loans. Before the economic reform, almost all loans to firms were credit loans. This situation has changed gradually since the economic reform started. Today, loans to firms are classified as five categories: credit loans, secured loans, mortgage loans, pledge loans and discounted note. Among them, secured loans and mortgage loans are the primary types of loans. For example, in 2000, secured loans consist of about 35% of total loans and mortgage loans consist of about 15% of total loans. In addition, the fraction of mortgage loans has become larger and the fraction of secured loans has become smaller. For instance, at the end of 2005, the ratio of mortgage loans to total loans rose to about 25%, while the ratio of secured loans to total loans fell to about 20% (Yang and Qian, 2008).

Motivated by the above facts, we assume that the entrepreneur’s borrowing consists of two parts: non-mortgage loans and mortgage loans. The mortgage loans are attached to the value of a fraction of the entrepreneur’s real estate. The non-mortgage loans are not collateralized, but we assume that they are associated with $k_{t-1}$, the current value of the entrepreneur’s capital stock. This aims to capture the fact that financial resources are limited and usually loans are extended based on firm size. Thus, the entrepreneur’s borrowing constraint is modeled as:

$$b_t \leq \frac{1}{R_t} m_h q_{h,t+1}(\alpha h_t)\pi_{t+1} + m_k q_{k,t}\pi_t k_{t-1}$$ (13)

where $0 \leq m_h \leq 1$ represents the ratio of mortgage loan to the value of real estate,
\( \alpha \) is the fraction of real estate the entrepreneur used as collateral, \( m_k \geq 0 \) is the ratio of non-mortgage loan to the value of capital stock, \( q_{k,t} \) is the shadow price of capital in terms of consumption goods. The borrowing constraint states that the amount of loans the entrepreneur obtains cannot exceed a fraction of the expected discounted value of his real estate holdings and a fraction of his present capital stock.

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 \( \lambda_t \) be the Lagrangian multiplier associated with the budget constraint. Let \( \lambda_t \) 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

\[
[c_t]: \quad \frac{1}{c_t} = \lambda_t + \frac{\gamma}{c_{t+1}} \frac{R_t}{\pi_{t+1}}
\]

\[
[k_t]: \quad \frac{q_{k,t}}{c_t} = \frac{\gamma}{c_{t+1}} \frac{\mu Y_{t+1}}{X_{t+1} k_t} + \frac{q_{k,t+1}}{c_{t+1}} \gamma (1 - \delta) + \gamma m_t \lambda_{t+1} \pi_{t+1} q_{k,t+1}
\]

\[
[I_t]: \quad \frac{1}{c_t} = \frac{q_{k,t}}{c_t} \phi_t \left( \frac{I_t}{I_{t-1}} - 1 \right)^2 - \frac{q_{k,t}}{c_t} \phi_t \psi \left( \frac{I_t}{I_{t-1}} - 1 \right) I_t I_{t-1} + \gamma \frac{q_{k,t+1}}{c_{t+1}} \phi_{t+1} \psi \left( \frac{I_{t+1}}{I_t} - 1 \right) \left( \frac{I_{t+1}}{I_t} \right)^2 \gamma
\]
\[ [h_i]: \quad \frac{1}{c_i} q_{h,i} = \frac{\alpha^t}{R^t} m_k q_{h,t+1} \pi_{t+1} + \frac{1}{c_{t+1}} \left( \frac{v^r_{t+1}}{X_{t+1}^t} h_i + q_{h,t+1} \right) \]  

(17)

\[ [L_i]: \quad \frac{(1 - \mu - \nu) Y^r}{X_i L_i} = w_i \]  

(18)

where \( q_{k,t} = \frac{Q_t}{X_t} \) implying \( Q_j = \frac{q_{k,t}}{c_i} \). 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, \( q_{h,t} / c_i \), 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 \( j \), buy intermediate good \( Y_i \) from entrepreneurs at \( P^w_i \) in a competitive market, differentiating the goods at no cost into \( Y_i(j) \) and sell \( Y_i(j) \) at the price \( P_i(j) \). 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 \( Y_i(j) = \left( \frac{P_i(j)}{P_i} \right)^{-\theta} Y_i \) and the aggregate price index \( P_i = \left( \int P_i(j)^{-\theta} d j \right)^{\frac{1}{1-\theta}} \), where \( \theta > 1 \) is the elasticity of demand. The retailer chooses a sales price \( P_i(j) \) taking \( P^w_i \) and the demand for \( Y_i(j) \) as given.

Following Calvo (1983), we assume that each period a fraction \( 1 - \omega \) of all retailers adjust prices while the remaining \( \omega \) fraction do not adjust. Those retailers that adjust their prices at time \( t \) choose optimal price \( P_i^* \) to maximize the expected discounted value of current and future profits. Since profits at some future date \( t + s \) are affected by the choice of price at time \( t \) only if the retailer has not received another opportunity to adjust between \( t \) and \( t + s \). The probability of this is \( \omega \).
The problem of the retailer who adjusts his price is

$$\max \sum_{i=0}^{\infty} \omega^i \Lambda_{t,i} \left[ \frac{P_j(j)}{P_{t+i}} Y_{t+i}(j) - \frac{Y_{t+i}(j)}{X_{t+k}} \right]$$

(19)

where \( \Lambda_{t,i} = \beta^i c_t^i / c_{t+i}^i \) is the household relevant discount factor.

Using the relation \( Y_j(j) = \frac{P_j(j)}{P_t} \), the objective function can be written as

$$\max \sum_{i=0}^{\infty} \omega^i \Lambda_{t,i+1} \left[ \left( \frac{P_j(j)}{P_{t+i+1}} \right)^{1-\theta} - \frac{1}{X_{t+k}} \left( \frac{P_j(j)}{P_{t+i+1}} \right)^{1-\theta} \right] Y_{t+i}$$

The first-order condition for the optimal choice of \( P_t^* \) is

$$E \sum_{i=0}^{\infty} \omega^i \Lambda_{t,i+1} \left[ (1-\theta) \frac{P_j(j)}{P_{t+i+1}} - \frac{\theta}{X_{t+k}} \right] Y_{t+i} = 0$$

(20)

The aggregate price index is an average of the price charged by the fraction \( 1-\omega \) of retailers setting their price in period \( t \) and the average of the remaining fraction \( \omega \) of all firms that do not charge their price 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 \( t-1 \). Thus the average aggregate price index in period \( t \) satisfies

$$P_t^{1-\theta} = (1-\omega)(P_t^{*})^{1-\theta} + \omega P_{t-1}^{1-\theta}$$

(21)

Combining equations (20) and (21) and linearizing lead to the Phillips curve,

$$\hat{\pi}_t = \beta E \hat{\pi}_{t+1} - \kappa \hat{X}_t$$

(22)

Where \( \kappa = (1-\omega)(1-\omega\beta) / \omega \). A hat stands for log-deviations from the deterministic steady state. Since we are interested in the effects of inflation shocks on the economy, we augment a disturbance term to the above equation. Equation (22) then becomes

$$\hat{\pi}_t = \beta E \hat{\pi}_{t+1} - \kappa \hat{X}_t + \hat{u}_t$$

(23)

The inflation shock \( \hat{u}_t \) follows the autoregressive process

$$\hat{u}_t = \rho_u \hat{u}_{t-1} + \hat{\epsilon}_{u,t}$$

(24)

where \( \rho_u \in (0,1) \) is the autocorrelation coefficient and \( \hat{\epsilon}_{u,t} \) is serially uncorrelated with mean zero and standard deviation \( \sigma_u \). Equation (23) states that inflation depends positively on expected inflation and inflation shocks and
negatively on the markup \( X_t \).

3.4. The central bank

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

\[
\hat{R}_t = r_n \hat{R}_{t-1} + (1 - r_n) r_x \hat{R}_{t-1}
\]

with \( r_n = 0.999 \) and \( r_x = 1.01 \). This way, the nominal interest rate will hardly respond to any change in economic conditions.

3.5. Equilibrium

Given \( \{k_{t-1}, h_{t-1}, R_{t-1}, b_{t-1}, P_{t-1}\} \) and the sequences of productivity, inflation, and housing demand shocks \( \{A_i, u_i, \varphi_i\}_{i=0}^\infty \), the equilibrium of the economy is characterized by allocations for households \( \{c_i', h_i', L_i', b_i'\}_{i=0}^\infty \), allocations for entrepreneurs \( \{c_i, h_i, L_i, b_i, I_i', k_i'\}_{i=0}^\infty \) and the sequence of values \( \{w_i, R_i, P_i, P^*, X_i, q_i, \lambda_i\}_{i=0}^\infty \) 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 (\( c_t + c_t' + I = Y \)), the credit market clears (\( b_t = b_t' \)), 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 21 parameter values: the discount factors \( \beta \) and \( \gamma \); the technology parameters \( \mu, \nu \) and \( \delta \); the household's preference parameters \( \varphi \) and \( \eta \); the markup \( X \), the degree of price rigidity \( \varepsilon \); the parameters attached to the borrowing constraint, \( m_h, m_k \) and \( \alpha \), the parameter determining the
investment adjustment cost $\psi$, and the parameters characterizing the shock processes $\rho_A, \rho_u, \rho_\phi, \sigma_A, \sigma_u, \sigma_\phi$.

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 $\gamma$ 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%. The parameter $\eta$ is calibrated at 1.6, which implies a labor-supply elasticity of 1.7. This value is commonly used in the literature on emerging economies.

Yang and Qian (2008) document that during the period 2000Q1 – 2005Q4, the ratio of collateral loans to total loans had increased from about 17% to 25%, that the maximum loan to value ratio for collateral loans extended by commercial banks was between 70% and 80%. We choose $m_h = 0.7$ and assume that that the fraction of collateral loans in the total loans is 20%. Statistical records show that the total loan to output ratio is about 20%. We choose $m_k = 0.016$ and $\alpha = 0.02$ to match that the non-collateral loan – output ratio and collateral loan –output ratio are 16% and 4%, respectively. Following the business cycle literature in Chinese economy, we set the capital share $\mu = 0.5$. 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.

It remains to pin down the parameters that characterize the shock processes and
the parameters $\varphi$ and $\psi$. We estimate these parameters using Bayesian method. The data we use are $(\log y_t, \log \pi_t, \log q_{h,t}, \log i_t)$. The data are quarterly and cover the period from 1994Q1 to 2006Q4. All the data are seasonally adjusted and linearly detrended. We impose beta prior distribution with mean 0.06 and standard deviation 0.001 on $\varphi$. Following Justiniano, Primiceri and Tambalotti (2010), the prior distribution of $\psi$ is gamma with mean 4 and standard deviation 1. 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 two-million MCMC chain from which the first one million draws were discarded.

The estimated $\varphi$ is 0.059. This value implies that the ratio of the value of the household's real estate to output is about 2 at the annual frequency, which is plausible. All the estimated exogenous processes are persistent. Table 1 presents key statistics of the prior and posterior distributions.

Table 1. Calibrated Parameters

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household's discount factor</td>
<td>$\beta$</td>
<td>0.99</td>
</tr>
<tr>
<td>Entrepreneur's discount factor</td>
<td>$\gamma$</td>
<td>0.98</td>
</tr>
<tr>
<td>Labor supply aversion</td>
<td>$\eta$</td>
<td>1.6</td>
</tr>
<tr>
<td>Capital share</td>
<td>$\mu$</td>
<td>0.5</td>
</tr>
<tr>
<td>Real estate share</td>
<td>$\nu$</td>
<td>0.06</td>
</tr>
<tr>
<td>Depreciation rate</td>
<td>$\delta$</td>
<td>0.025</td>
</tr>
<tr>
<td>Mortgage loan to real estate value ratio</td>
<td>$m_{hf}$</td>
<td>0.7</td>
</tr>
<tr>
<td>Non-mortgage loan to capital value ratio</td>
<td>$m_{k}$</td>
<td>0.016</td>
</tr>
<tr>
<td>Fraction of real estate as collateral</td>
<td>$\alpha$</td>
<td>0.02</td>
</tr>
<tr>
<td>Steady-state gross markup</td>
<td>$X$</td>
<td>1.15</td>
</tr>
<tr>
<td>Degree of price rigidity</td>
<td>$\varepsilon$</td>
<td>0.67</td>
</tr>
</tbody>
</table>
Table 2. Prior distributions and Posterior Estimates

<table>
<thead>
<tr>
<th>Parameters</th>
<th>prior distribution</th>
<th>prior mean</th>
<th>std</th>
<th>posterior mean</th>
<th>confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\phi$</td>
<td>beta</td>
<td>0.06</td>
<td>0.001</td>
<td>0.0618</td>
<td>[0.0605, 0.0632]</td>
</tr>
<tr>
<td>$\psi$</td>
<td>gamma</td>
<td>4</td>
<td>1</td>
<td>10.79</td>
<td>[8.4276, 13.3906]</td>
</tr>
<tr>
<td>$\rho_A$</td>
<td>beta</td>
<td>0.90</td>
<td>0.01</td>
<td>0.9319</td>
<td>[0.9189, 0.9445]</td>
</tr>
<tr>
<td>$\rho_u$</td>
<td>beta</td>
<td>0.90</td>
<td>0.01</td>
<td>0.8817</td>
<td>[0.8654, 0.8947]</td>
</tr>
<tr>
<td>$\rho_\phi$</td>
<td>beta</td>
<td>0.90</td>
<td>0.01</td>
<td>0.9051</td>
<td>[0.8888, 0.9206]</td>
</tr>
<tr>
<td>$\rho_\phi$</td>
<td>beta</td>
<td>0.90</td>
<td>0.01</td>
<td>0.9207</td>
<td>[0.907, 0.9348]</td>
</tr>
<tr>
<td>$\sigma_A$</td>
<td>inverse gamma</td>
<td>0.2</td>
<td>inf</td>
<td>1.8274</td>
<td>[1.5164, 2.138]</td>
</tr>
<tr>
<td>$\sigma_u$</td>
<td>inverse gamma</td>
<td>0.02</td>
<td>inf</td>
<td>0.576</td>
<td>[0.4784, 0.6731]</td>
</tr>
<tr>
<td>$\sigma_\phi$</td>
<td>inverse gamma</td>
<td>0.2</td>
<td>inf</td>
<td>0.7816</td>
<td>[0.6052, 0.9578]</td>
</tr>
<tr>
<td>$\sigma_\phi$</td>
<td>inverse gamma</td>
<td>0.2</td>
<td>inf</td>
<td>1.7282</td>
<td>[1.4313, 2.023]</td>
</tr>
</tbody>
</table>

5. Results

In this section we first examine the relative importance of different shocks. We then explore the transmission mechanism and introduce alternative interest rate rules to see whether they can play a role to stabilize the aggregate economy.

5.1. The relative importance of shocks

Table 2 reports the variance decomposition results, which shows the contribution of each shock to the variance of the logarithm level of the observable variables at business cycle frequencies. The third column of the table illustrates that inflation shocks are the main driving force of business cycles. Inflation shocks account for 54 percent of fluctuations in output and 70 percent, 80 percent, 39 percent of fluctuations in investment, credit and real estate prices, respectively. The fifth column of the table shows that investment shocks are non-negligible impetus to fluctuations. They explain 6.5 percent of output fluctuations, and about 10 percent of fluctuations in investment, credit and real estate prices. In addition, about 45 percent of fluctuations in the shadow price of capital are driven by investment shocks.

In our model, technology shocks remain important driving forces. They account
for 40 percent of fluctuations in output, 51 percent of those in real estate prices, 44 percent of those in real wages, and almost 71 percent of those in households’ consumption. The result that 90 percent of fluctuation of inflation is caused by technology shocks might be surprising. This may be because changes in inflations are mainly caused by changes in markup, which in our model responds strongly to technology shocks. However, the unusually high fraction of technology shocks in inflation fluctuations could be an anomaly of this model. Finally, housing demand shocks do not play any role in driving business fluctuations. One possible reason is that collateral loans have not been the most important type of loans. When we increase $\alpha$, the fraction of real estate the entrepreneur uses as collateral, we find that the role of housing demand shocks increases, although it does not increase much.

<table>
<thead>
<tr>
<th>Shocks</th>
<th>Output</th>
<th>Investment</th>
<th>Credit</th>
<th>Real estate price</th>
<th>Capital price</th>
<th>Inflation</th>
<th>Entrepreneur’s consumption</th>
<th>Household's consumption</th>
<th>Labor</th>
<th>Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>39.54</td>
<td>53.96</td>
<td>0.00</td>
<td>6.51</td>
<td>12.49</td>
<td>9.19</td>
<td>7.68</td>
<td>10.18</td>
<td>19.19</td>
<td>44.43</td>
</tr>
<tr>
<td>Inflation</td>
<td>19.31</td>
<td>70.42</td>
<td>0.01</td>
<td>10.26</td>
<td>79.88</td>
<td>8.36</td>
<td>9.24</td>
<td>19.04</td>
<td>80.22</td>
<td>48.48</td>
</tr>
<tr>
<td>Housing demand</td>
<td>10.86</td>
<td>79.48</td>
<td>0.01</td>
<td>9.24</td>
<td>42.45</td>
<td>8.36</td>
<td>0.77</td>
<td>0.00</td>
<td>0.01</td>
<td>0.00</td>
</tr>
<tr>
<td>Investment</td>
<td>19.31</td>
<td>70.42</td>
<td>0.01</td>
<td>10.26</td>
<td>79.88</td>
<td>8.36</td>
<td>9.24</td>
<td>19.04</td>
<td>80.22</td>
<td>48.48</td>
</tr>
<tr>
<td>Credit</td>
<td>10.86</td>
<td>79.48</td>
<td>0.01</td>
<td>9.24</td>
<td>42.45</td>
<td>8.36</td>
<td>0.77</td>
<td>0.00</td>
<td>0.01</td>
<td>0.00</td>
</tr>
<tr>
<td>Real estate price</td>
<td>51.40</td>
<td>39.26</td>
<td>0.04</td>
<td>9.30</td>
<td>12.49</td>
<td>9.19</td>
<td>7.68</td>
<td>10.18</td>
<td>19.19</td>
<td>44.43</td>
</tr>
<tr>
<td>Capital price</td>
<td>12.49</td>
<td>42.45</td>
<td>0.02</td>
<td>45.03</td>
<td>70.78</td>
<td>19.04</td>
<td>0.00</td>
<td>10.18</td>
<td>19.19</td>
<td>44.43</td>
</tr>
<tr>
<td>Inflation</td>
<td>90.87</td>
<td>8.36</td>
<td>0.01</td>
<td>0.77</td>
<td>83.12</td>
<td>0.00</td>
<td>7.09</td>
<td>0.00</td>
<td>0.01</td>
<td>0.00</td>
</tr>
<tr>
<td>Entrepreneur’s</td>
<td>9.19</td>
<td>83.12</td>
<td>0.01</td>
<td>7.68</td>
<td>19.04</td>
<td>0.00</td>
<td>10.18</td>
<td>10.18</td>
<td>19.19</td>
<td>44.43</td>
</tr>
<tr>
<td>consumption</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Household’s consumption</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.2. The transmission mechanism of shocks

Having identified which shocks are the important sources of business cycles, we now explore the transmission mechanism of shocks implied in our model. We start from inflation shocks. Figure 3 displays the impulse responses of main variables to a positive inflation shock. A positive inflation shock may affect our economy in various ways. Under a constant interest rate rule, a positive inflation shock will transfer wealth from lenders (households) to borrowers (entrepreneurs). This may induce entrepreneurs to borrow more and increase production. However, our results show that a positive inflation shock leads to a fall in output. In particular, a 1 percent increase in inflation causes about 1.25 percent decrease in output on impact of the shock. Output continues to fall for 5 periods and then gradually approaches its steady state. The behavior of output in
response to an inflation shock is due to the credit constraint. In our model, under a constant interest rate rule, households respond to a positive inflation shock by accumulating more real estate. Given that the amount of real estate is fixed, the entrepreneurs’ real estate holdings have to decrease. In addition, in the case of inflation, both the real price of real estate and the real shadow price of capital have to fall. This means that the entrepreneurs’ borrowing constraint is tightened in response to the inflation shock. An inflation shock also causes an increase in price makeup, which reduces the entrepreneur’s labor demand (not shown). All in all, output falls in response to a positive inflation shock.

Figures 4 shows the impulse response functions of main variables to a positive investment shock. A positive investment shock means a positive shock to the marginal productivity of investment. An increase in marginal productivity increases the rate of return of investment, giving entrepreneurs an incentive to reduce consumption and real estate holdings. The decrease in real estate demand by entrepreneurs reduces real estate price on impact of the shock. A positive investment shock also causes a reduction in the share price of capital. The combined effects are the tightening of the borrowing constraint. However, since investment increases, capital rises and output starts to rise in the first period. The gradual increase in output induces the subsequent increase in entrepreneurs’ consumption and the behavior of real estate prices and credit. In short, due to the presence of the borrowing constraint, the impact of investment shocks are dampened. This may partly explain why the contribution of investment shocks is not big in our model economy.

The impacts of the technology shocks are quite standard. To save place, we do not present the impulse response functions. In general, a positive productivity shock increases output, entrepreneurs’ and households’ consumption, real estate price and the shadow value of capital, credit and capital. Due to the competition of real estate between households and entrepreneurs in the real estate market, the entrepreneur’s real estate holdings reduce 0.5% for a 1% increase in productivity. However, since the real estate – output share ($\nu$) is small, the reduction in real estate holdings will not lead to a fall in output.

Figure 3     Impulse responses to inflation shocks
Figure 4  Impulse responses to investment shocks
5.3. Macroeconomic volatility and alternative interest rate rules

Given that inflation is the major source of business cycles in China, the natural question is whether the People’s Bank of China should adopt an active interest rate rule to respond changes in inflation and other key macroeconomic variables. To answer this question, we need to embed an active monetary policy reaction function into the benchmark model. Since data on lending rate can not be used to estimate the policy function, one option is to use other interest rates which are formed on the market basis to proxy for the lending rate. Xie and Luo (2002) use interbank interest rates in Shanghai as a proxy for the lending rate and estimate the policy function. They find that the reaction coefficient of expected inflation is less than 1, implying that a positive inflation shock brings about a negative real interest rate. In other words, the Taylor principle is not satisfied. We use data on interbank interest rate during period 2002Q1—2010Q4 published by the People’s Bank of China to estimate the policy reaction function and get the same result. Thus, it is not possible to use that policy function as an alternative interest rate rule.

Given this limitation, we simply propose an active interest rate rule and compare the results with those in our benchmark model. Consider the following interest rate rule:

\[
\hat{R}_t = r_R \hat{R}_{t-1} + (1 - r_R)(1 + r_y)\hat{\pi}_t^e + (1 - r_R)r_y \hat{Y}_t
\]

where \( \hat{\pi}_t^e \) is the average of inflation rate in the current and previous three periods. We find that under certain parameter values, the active interest rate rule can reduce macroeconomic volatility. Table 4 reports the standard deviations of main macroeconomic variables under our proposed interest rate rule with \( r_R = 0.999, \ r_y = 40, \ r_R = 1 \) and those of our benchmark model with \( r_R = 0.999, \ r_y = 0.01 \). The results show that by adopting the active interest rate rule instead of the constant interest rate rule, the volatility of all key macroeconomic variables reduces. In particular, the standard deviation of output drops from 7.71 to 7.68, the standard deviation of inflation falls from 1.19 to 1.09, the standard deviations of investment and credits reduce from 14.0 and 9.3 to 13.8 and 9.05, respectively. This experiment suggests that by increasing the volatility of interest rate appropriately, the central bank can make the macroeconomy less volatile.
Table 4. Standard deviations of key macroeconomic variables

<table>
<thead>
<tr>
<th></th>
<th>The model with an active Interest rate rule</th>
<th>The benchmark model with a constant interest rate rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td>7.68</td>
<td>7.71</td>
</tr>
<tr>
<td>Inflation</td>
<td>1.09</td>
<td>1.19</td>
</tr>
<tr>
<td>Real estate price</td>
<td>6.576</td>
<td>6.577</td>
</tr>
<tr>
<td>Investment</td>
<td>13.84</td>
<td>14.00</td>
</tr>
<tr>
<td>Credit</td>
<td>9.05</td>
<td>9.31</td>
</tr>
<tr>
<td>Consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Entrepreneur</td>
<td>9.12</td>
<td>9.35</td>
</tr>
<tr>
<td>· Household</td>
<td>6.61</td>
<td>6.60</td>
</tr>
<tr>
<td>Interest rate</td>
<td>0.19</td>
<td>0.0067</td>
</tr>
</tbody>
</table>

6. Conclusion

In this paper, we study the sources and transmission of business cycles in China in a model economy with a constant interest rule and credit constraints. Inflation shocks and technology shocks are important driving forces of economic fluctuations, while investment shocks also play a role. The constant interest rule together with credit constraints can partly explain the transmission of shocks, demonstrating the limitations of the interest rate control policy. We find that appropriate active interest rules can reduce the macroeconomic volatility of the Chinese economy.
References


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. Data Description

<table>
<thead>
<tr>
<th>Variables</th>
<th>Data Source</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment</td>
<td>China Economic Information Network</td>
<td>1998Q1 – 2010Q4</td>
</tr>
<tr>
<td>Consumption</td>
<td>China Economic Information Network</td>
<td>2003Q1 – 2010Q3</td>
</tr>
<tr>
<td>CPI</td>
<td>China Economic Information Network</td>
<td>1998Q1 – 2010Q4</td>
</tr>
<tr>
<td>Lending rate</td>
<td>The People’s Bank of China</td>
<td>1998Q1 – 2010Q4</td>
</tr>
</tbody>
</table>

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 are calculated based on data on sales on housing, sale volume on housing and the house price index.
4. Annual lending rate is adjusted to have a quarterly frequency.