

# The Driving Forces of China's Business Cycles: Evidence from an Estimated DSGE Model with Housing and Banking\*

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## Abstract

We study the sources of China's business cycles in an estimated dynamic stochastic general equilibrium (DSGE) model with housing and banking. The model replicates well the volatility and cyclicity of key macroeconomic variables observed in the past two decades in China. A host of shock decomposition exercises demonstrate that, in addition to the non-housing technology shock, both financial and housing shocks are the main driving forces of China's business cycles, accounting for nearly 90 percent of the variations in most macroeconomic variables at the business cycle frequencies. In particular, the capital quality, housing demand, and loan-to-value shocks display prominent contributions to the business cycle fluctuations. Moreover, there exists substantial interactions between the banking and housing sectors in China, where the collateral constraint and the financial constraint amplify with each other. The results shed new light in the understanding of China's business cycles, and provide guidelines to DSGE modeling on China's macroeconomy.

**JEL Codes:** E32, E44, G01, G21, R31

**Keywords:** China's Business Cycles; Housing; Banking; DSGE Model; Shocks

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# 1 Introduction

China has experienced an unprecedentedly rapid economic growth in forty years since the economic reform was launched in 1978. Yet, the economic growth tended to slow down in the near decade. The annual growth rate rose to 14.23 percent in 2007, and then gradually fell to 6.6 percent in 2018. As shown in the data, the economic growth slows down quickly, accompanied by a rapid growth in house prices and credit expansion. There is a consensus, perhaps among most economists, that the rapid economic growth of China in the previous decades is attributed to technological advances and high capital accumulation. However, the driving forces of China's business cycles, especially in the recent decade, are far from being understood. Using an estimated dynamic stochastic general equilibrium (DSGE) model, we address a number of key issues about China's business cycles: What are the main driving forces of China's business cycles? Are there any disturbances other than technology shocks and/or investment shocks serving as the main sources of business cycle fluctuations? What is the role of other disturbances, like financial and housing shocks, in affecting business cycle fluctuations in China? Can the model explain the volatility in financial, housing, and other macroeconomic variables being concerned?

To address these issues, we develop and estimate a DSGE model with housing and banking, using Bayesian methods. In particular, we extend a version of the New Keynesian DSGE model developed by [Iacoviello and Neri \(2010\)](#) on housing to encompass financial frictions along the lines of [Gertler and Kiyotaki \(2010\)](#). In doing so, it allows us to study the interactions between banking, housing, and the broader economy. The experience of the Great Recession forcefully demonstrates that business cycle fluctuations can not be understood properly without considering financial disturbances. The objectives of this paper are threefold. First, we want to examine the extent to which a DSGE model with widely accepted elements can reproduce the second moments of key variables observed in the Chinese data. Due to differences in economic structures and institutions between China and the more advanced countries, the off-the-shelf leading business cycle models, such as [Smets and Wouters \(2007\)](#), may not well suited *a priori* to account for business cycle fluctuations in China. Second, we want to investigate the contributions of frictions and disturbances in both the housing and banking sectors to the business cycle fluctuations in China. To this end, we combine key modeling elements from the literatures in housing and macro finance in the past decade, so to create a unified quantitative framework for both estimations and simulations. Last, we use the estimated model to identify the main driving forces of business cycles in China over the past two decades. The outcome from the quantitative evaluations not only deepens our understanding of China's business cycles, but also provides useful guidance to the modeling of China's macroeconomy.

We confront the model with quarterly data of China over the period of 2000Q1–2018Q4, including key variables in both financial and housing sectors. Our estimated model explains the business cycle properties of the data well. In particular, it replicates the volatility and cyclicity in consumption, nonresidential investment, house prices, bank net worth, nonresidential loans, deposits, bank leverage, inflation, and

hours, as observed in the data over the past two decades. Furthermore, we find that the capital quality, non-housing technology, housing demand and supply, loan-to-value (LTV), and labor supply shocks are the main driving forces of the China's business cycles, accounting for nearly 90 percent of the variance in most variables of interest. Of them, the contributions of the financial and housing shocks, such as capital quality shocks, LTV shocks, housing supply shocks, and housing demand shocks, play the most prominent roles in the fluctuations of Chinese macroeconomy at the business cycle frequencies. Moreover, there are substantial interactions between the banking and housing sectors in China. Housing shocks exert a significant influence on the operation of the banking sector via financial frictions.

Our baseline model consists of six main features: (i) two production sectors of consumption goods and housing; (ii) two types of households, savers and borrowers; (iii) nominal rigidities; (iv) collateral constraints in household loans; (v) financial frictions in the banking sector; and (vi) a rich set of shocks. These features are mostly drawn from two strands of current literature which study the housing and financial cycles. The business cycle models with housing study the behavior of the housing market over the business cycle by dealing with some combination of (i)–(iv).<sup>1</sup> Business cycle models with banking study the role of financial intermediaries in the transmission of financial shocks by dealing with (v).<sup>2</sup> While many papers in the literature focus on housing and banking separately, we stress that a combination of the two is crucial to understand the business cycles in China.

Among the literature considering the interaction between housing and banking over the business cycles, [Iacoviello \(2015\)](#), [Ferrante \(2019\)](#), and [Ge et al. \(2020\)](#) are the closest to this paper. [Iacoviello \(2015\)](#) finds that repayment shocks, housing demand shocks and LTV shocks account for about two-thirds of the decline in output and investment during the Great Recession. In addition to frictions tied to households and banks, [Ferrante \(2019\)](#) introduces endogenous default to a DSGE model in accounting for the comovements in consumption, house prices, business investment and output, and finds that housing risk shocks and MBS collateral shocks are able to explain the pattern of comovements among these variables during the Great Recession. [Ge et al. \(2020\)](#) also develop a DSGE model with housing and banking to explore the transmission of various financial shocks, and find that capital quality shocks, bank liquidity shocks and housing preference shocks play an important role in the housing and financial cycles. None of these studies, however, addresses the issues we raise in this paper about China's business cycles, since all papers focus on the US experience. The novel elements of this paper are goodness-of-fit of the model, and the quantification of the sources of the business cycle fluctuations in China.

As in [Smets and Wouters \(2007\)](#), [Iacoviello and Neri \(2010\)](#), and [Justiniano et al. \(2010\)](#), our model considers a rich set of shocks: the technology shocks in both housing and consumption goods sector, the

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<sup>1</sup>The main references include [Greenwood and Hercowitz \(1991\)](#), [Benhabib et al. \(1991\)](#), [Gervais \(2002\)](#), [Davis and Heathcote \(2005\)](#), [Iacoviello \(2005\)](#), [Fisher \(2006\)](#), [Christensen et al. \(2016\)](#), [Iacoviello and Neri \(2010\)](#), [Iacoviello and Pavan \(2013\)](#), and [Kiyotaki et al. \(2011\)](#).

<sup>2</sup>The main references include [Meh and Moran \(2010\)](#), [Gertler and Karadi \(2011\)](#), [Gerali et al. \(2010\)](#), [Angeloni and Faia \(2013\)](#), [Gertler and Kiyotaki \(2010\)](#), [Gertler et al. \(2012\)](#) and [Gertler and Kiyotaki \(2015\)](#).

housing preference shock, the intertemporal preference shock, the LTV shock, the capital quality shock, the cost-push shock, the labor supply shock, and the monetary policy shock. Among these shocks, the capital quality shock could be one of the most important driving forces in China's business cycles, given the significant role played by the non-residential investment in China's economy. The estimated model indeed shows that, at the business cycle frequencies, the capital quality shock accounts for more than 10 percent of the variance in consumption, more than one-quarter of the variance in nonresidential investment, and a large fraction of variance in nonresidential loans, net worth, leverage and inflation, between 16 and 32 percent. More broadly, this result is in line with the recent business cycle literature. While the seminal paper of [Chari et al. \(2007\)](#) finds the investment wedge to play a minor role in the US business cycles, the more recent works applying the methodology to emerging countries and Asian economies find that the investment wedge to be a dominant factor in business cycle fluctuations.<sup>3</sup>

There are a few recent papers studying the Chinese housing market using the DSGE framework. [Ng \(2015\)](#) represents an early attempt to understand China's housing market from a macro perspective based on NK DSGE approach, however, due to data limitation, the author relies on annual data to estimate the model. Abstracting from the nominal side, [Minetti et al. \(2019\)](#) focus on the real house price dynamics in China by incorporating an external habits in housing consumption into the preference specification. The recent paper by [Gai et al. \(2020\)](#), which is also based on the NK DSGE framework, focuses on the implications of the housing collateral constraint on China's business cycles. Contrary to the typical findings in the literature, the statistical test of this paper favors the benchmark model without the collateral constraint on house financing. The crucial distinction of our paper from these three papers lies in both the modeling part and the empirical implementation. All the three papers do not incorporate banking and financial friction into their model frameworks. As showed by our quantitative evaluations, shocks and frictions in the housing sector have significant impacts on the dynamics of the financial sector. Intuitively, Chinese economy features a tight link in the banking sector and housing sector, since housing related loans claim a substantial portion on the bank's balance sheet in China. Moreover, the quarterly data sample we construct for the calibration and estimation spans for nearly two decades and covers all the key variables in both financial and housing sector, the most comprehensive one in the related literature on China's business cycle, as far as we know. This enables us to uncover a more accurate picture of the sources of business cycle fluctuations in China.

The rest of the paper is organized as follows. Section 2 develops the baseline model. Section 3 describes the data, parameter calibration, and Bayesian estimation. Section 4 presents the quantitative results of the baseline model. Section 5 inspects the mechanisms of China's macroeconomic dynamics through the impulse responses of estimated shocks. Section 6 conducts a series of sensitivity analyses by shutting down

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<sup>3</sup>See, for example, [He et al. \(2009\)](#), [Otsu \(2010\)](#), [Lu \(2012\)](#), [Chakraborty and Otsu \(2013\)](#), [Cho and Doblus-Madrid \(2013\)](#). In contrast, [Brinca \(2014\)](#) reports that for OECD countries, the investment wedge is much less important than the efficiency and labor wedge, confirming the original results by [Chari et al. \(2007\)](#) for the US. For the equivalence of the investment specific shock and the investment wedge, see [Brinca et al. \(2016\)](#) for a formal proof. As pointed out below at the end of the model section, the capital quality shock in our setting is closely related to the investment specific shock as investigated by [Fisher \(2006\)](#) and [Justiniano et al. \(2010\)](#).

key channels of the model economy one by one. Section 7 concludes. Details about the data sources and a complete list of model equations are relegated to the appendix.

## 2 The Model

We consider an infinite discrete-time economy. The economy features three sectors: households, financial intermediaries, and firms. The household sector includes two types of households, patient and impatient, and each type of households is of unit measure. Households do not hold physical capital directly. They work, consume final goods, buy housing, and either deposit funds into or borrow from banks. In equilibrium, patient households turn out to be net savers and lend funds to impatient households, and eventually to non-financial firms through financial intermediaries. Impatient households turn out to be net borrowers, and they borrow funds from financial intermediaries against their collateral which is tied to their housing values.

In the economy, there are four types of producers in the production sector, retail and wholesale producers in the consumption good sector, housing producers, and capital goods producers. Each type has a unit mass. In the consumption goods sector, wholesale firms operate under perfect competition, and retail firms operate under monopolistic competition. The retail firms purchase consumption goods from the wholesale firms and sell them at a markup over the marginal cost. The wholesale firms hire labor from households, purchase physical capital with funds borrowed from financial intermediaries, and produce consumption goods under the CRS technology. The housing producers hire labor from households and rent land as an input from patient households to produce new houses. The capital producers purchase final goods as an input to produce new capital and are subject to an adjustment cost.

Banks are assumed to operate in a national retail market only. At the beginning of each period, they obtain deposits from patient households and issue loans to impatient households and non-housing sectors. In the model, we assume that banks are subject to an incentive constraint. In particular, each bank with a given portfolio is constrained in its ability to issue deposits to its savers and to make loans to its borrowers. Both incentive constraints and collateral constraints interact and reinforce each other in equilibrium so that banks are credit-constrained in how much they can accept deposits from patient households, and impatient households are credit-constrained in how much they can borrow from banks. In this way, the effects of shocks on the economy are amplified and prorogated over time.

### 2.1 Households

#### 2.1.1 Patient Households (Savers)

In the economy, a representative patient household chooses consumption  $c_{p,t}$ , housing  $h_{p,t}$ , hours supplied to the final goods (wholesale) producers and housing producers,  $l_{pc,t}$  and  $l_{ph,t}$ , to solve the following

expected discounted utility:

$$U_p = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_p^t A_{p,t} \left\{ \Gamma_p \ln(c_{p,t} - \tau_p c_{p,t-1}) + j_t \ln h_{p,t} - \frac{A_{n,t}}{1 + \eta_p} \left( l_{pc,t}^{1+\epsilon_p} + l_{ph,t}^{1+\epsilon_p} \right)^{\frac{1+\eta_p}{1+\epsilon_p}} \right\},$$

where  $\eta$  is the inversed Frisch elasticity of labor supply, and  $\epsilon$  captures the degree of sector specificity. Following Horvath (2000), hours are less perfect substitutes if  $\epsilon > 0$  while they are perfect substitutes if  $\epsilon = 0$ . The term  $\tau_p$  captures the degree of habits in consumption. The parameter  $\beta_p$  denotes the discount factor of patient households. The scaling factor  $\Gamma_p = (1 - \tau_p)/(1 - \beta_p \tau_p)$  ensures that the marginal utility of consumption for patient households is  $1/c_p$  in the steady state.  $A_{p,t}$ ,  $A_{n,t}$  and  $j_t$  captures the shocks to intertemporal preference, labor supply and housing preference, respectively, and follow the AR(1) process as follows:

$$\begin{aligned} \ln A_{p,t} &= \rho_p \ln A_{p,t-1} + u_{p,t}, \\ \ln A_{n,t} &= \rho_n \ln A_{n,t-1} + u_{n,t}, \\ \ln j_t &= (1 - \rho_j) \ln j + \rho_j \ln j_{t-1} + u_{j,t}, \end{aligned}$$

where  $u_{p,t}$ ,  $u_{n,t}$  and  $u_{j,t}$  are independently and identically distributed with mean 0, and variances  $\sigma_p^2$ ,  $\sigma_n^2$  and  $\sigma_j^2$ , respectively. The term  $j$  is the steady-state value of the housing preference weight.

A representative patient household faces the following budget constraint:

$$c_{p,t} + q_t h_{p,t} + p_{x,t} x_t + d_t = w_{pc,t} l_{pc,t} + w_{ph,t} l_{ph,t} + q_t (1 - \delta_h) h_{p,t-1} + (p_{x,t} + R_t^x) x_{t-1} + \frac{R_t^d d_{t-1}}{\pi_t} + \Pi_t + T_t,$$

where  $w_{pc,t}$  and  $w_{ph,t}$  are real wages from supplying labor hours to the wholesale and housing sectors, and  $q_t$  and  $p_{x,t}$  are house prices and land prices. The term  $d_t$  denotes deposits (loans if  $d_t$  is negative), which yield a riskless nominal return of  $R_t^d$  from period  $t - 1$  to period  $t$ . Land is rented to the housing sector at a real rental rate of  $R_t^x$ . The parameter  $\delta_h$  denotes the depreciation rate of housing. Finally,  $\pi_t = p_{c,t}/p_{c,t-1}$  is the inflation rate in the consumption sector,  $\Pi_t$  is the net average transfer received by the patient household from banks upon their exit, and  $T_t$  is a lump sum profit transfer from the retail firms and capital goods firms.

## 2.2 Impatient Households (Borrowers)

A representative impatient household chooses consumption  $c_{i,t}$ , housing  $h_{i,t}$ , hours  $l_{ic,t}$  and  $l_{ih,t}$  to maximize the following expected discounted utility:

$$U_i = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_i^t A_{p,t} \left\{ \Gamma_i \ln(c_{i,t} - \tau_i c_{i,t-1}) + j_t \ln h_{i,t} - \frac{A_{n,t}}{1 + \eta_i} \left( l_{ic,t}^{1+\epsilon_i} + l_{ih,t}^{1+\epsilon_i} \right)^{\frac{1+\eta_i}{1+\epsilon_i}} \right\},$$

subject to the budget constraint

$$c_{i,t} + q_t h_{i,t} + \frac{R_t^b b_{t-1}}{\pi_t} = w_{ic,t} l_{ic,t} + w_{ih,t} l_{ih,t} + q_t (1 - \delta_h) h_{i,t-1} + b_t,$$

and the collateral constraint

$$b_t \leq m_t \mathbb{E}_t \left( \frac{q_{t+1} h_{i,t} \pi_{t+1}}{R_{t+1}^b} \right),$$

where  $w_{ic,t}$  and  $w_{ih,t}$  are real wage rates from supplying hours to the wholesale and housing sectors, respectively. The term  $b_t$  denotes loans (savings if  $b_t$  is negative), which yield a nominal rate of return of  $R_{t+1}^b$  from period  $t$  to period  $t+1$ . The term  $\beta_i$  is the discount factor of impatient households. We set  $\beta_i < \beta_p$  to ensure that impatient households are credit-constrained in the neighborhood of the steady state, given other parameters calibrated in the model. The term  $\tau_i$  captures the degree of habits in consumption. The scaling factor  $\Gamma_i = (1 - \tau_i)/(1 - \beta_i \tau_i)$  so that the marginal utility of consumption for impatient households is  $1/c_i$  in the steady state. The term  $m_t$  denotes the loan-to-value (LTV) ratio which measures the effective degree of liquidity of houses, and is assumed to follow the AR(1) process:

$$\ln m_t = (1 - \rho_m) \ln m + \rho_m \ln m_{t-1} + u_{m,t},$$

where  $u_{m,t}$  is identically and independently distributed with mean 0 and variance  $\sigma_m^2$ , and  $m$  is the steady-state value of the LTV ratio.

### 2.3 Banks

We formulate the problem of financial intermediaries with a modified version of the model proposed by Gertler and Kiyotaki (2010) and Gertler and Karadi (2010). In the economy, there are a large number of banks operating in a national financial market. At each period, each bank obtains deposits  $d_t$  from patient households, and pays a nominal interest rate of  $R_{t+1}^d$  in the next period. After obtaining funds in the retail market, it issues residential loans  $b_t$  to impatient households at a nominal rate of  $R_{t+1}^b$ , and nonresidential loans to non-financial firms (wholesale producers) in exchange for state-contingent equities at a price of  $p_t$ . For simplicity, we assume no frictions associated with nonresidential borrowing, since banks are not only more efficient at evaluating and monitoring all activities of non-financial sectors, but are also more effective in enforcing contractual obligations. In addition, we assume there are no costs for a bank performing these activities. Given these assumptions, a bank can issue frictionless loans to the wholesale firms on the one hand, and a borrowing firm is able to offer the bank state-contingent equities on the other hand. Each unit of equity is a state-contingent claim to the future returns from one unit of new capital investment.

Let  $s_t$  be the quantity of equities held by a representative bank, and  $n_t$  be the net worth of the bank in period  $t$ . The flow-of-funds constraint for a bank is

$$p_t s_t + b_t = n_t + d_t, \tag{1}$$

with

$$n_t = [Z_t + (1 - \delta_k) p_t] \psi_t s_{t-1} + \frac{R_t^b b_{t-1}}{\pi_t} - \frac{R_t^d d_{t-1}}{\pi_t}, \tag{2}$$

where  $\delta_k$  is the depreciation rate of capital,  $Z_t$  are dividends on equities issued in period  $t - 1$ . The term  $\psi_t$  captures shocks to capital quality, and follows the AR(1) process:

$$\ln \psi_t = \rho_k \ln \psi_{t-1} + u_{k,t},$$

where  $u_{k,t}$  is identically and independently distributed with mean 0 and variance  $\sigma_k^2$ . In the economy, a capital quality shock will directly reduce bank net worth, inducing a disruption in the bank's balance sheet. If the losses on the balance sheet initiated by the shock cannot be fully absorbed by banks, a credit crunch may arise.

To motivate an endogenous financial constraint on the bank's ability to obtain funds in the retail market, we follow a moral hazard problem along the lines of [Gertler and Kiyotaki \(2010\)](#): at the beginning of each period, a bank may divert a fraction  $\theta$  of its assets to its owners (patient households) after obtaining funds (deposits) in the retail market. The bank's assets comprise the value of equities held by the bank,  $p_t s_t$ , and residential loans issued to impatient households,  $b_t$ . If the bank diverts its assets to its owners, it defaults on its debts and is then forced to shut down. The creditors may reclaim the remaining fraction  $1 - \theta$  of funds. Given the risks of banks' default on their debts, creditors restrict the amount they lend to the bank at the beginning of each period. Accordingly, banks are constrained in their ability to obtain funds in the retail financial market, and in this way a financial constraint may arise.

Let  $V_t(s_t, b_t, d_t)$  be the value function of a bank at the end of period  $t$ , given its portfolio holdings  $(s_t, b_t, d_t)$ . Banks are subject to the following incentive constraint

$$V_t(s_t, b_t, d_t) \geq \theta(p_t s_t + b_t). \quad (3)$$

An increase in  $\theta$  will tighten the incentive constraint and, hence banks are less willing to issue loans to their borrowers for any given level of net worth, vice-versa.

In order to limit banks' ability to save to overcome financial constraint, we assume that each bank survives until the next period with a probability of  $\sigma$ , and exits with a probability of  $1 - \sigma$ . If a bank exits, a new bank will enter the market with a "startup" fund transferred from patient households, and takes over the business of the exiting bank with no costs. Recall that in each period patient households receive an average net transfer  $\Pi_t$  from banks. The net transfer then must equal the funds transferred from exiting banks minus funds transferred to start-ups.

Let  $\Lambda_{t,t+i}$  be the stochastic discount factor for a bank between date  $t$  and date  $t + i$ . Since banks are owned by patient households, we assume  $\beta_b = \beta_p > \beta_i$ . Then, the stochastic discount factor for a bank is  $\Lambda_{t,t+i} = \beta_p^i \frac{u_{c,t+i}}{u_{c,t}}$ . In each period, a representative bank maximizes the expected net worth:

$$V_t(s_t, b_t, d_t) = \mathbb{E}_t \sum_{i=1}^{\infty} (1 - \sigma) \sigma^{i-1} \Lambda_{t,t+i} n_{t+i}, \quad (4)$$

subject to the flow-of-funds constraint (1) and the incentive constraint (3).



To solve the bank's problem, one may write the bank's sequential problem as the Bellman equation

$$V_{t-1}(s_{t-1}, b_{t-1}, d_{t-1}) = \mathbb{E}_{t-1} \Lambda_{t-1,t} \{(1 - \sigma)n_t + \sigma \max_{s_t, b_t, d_t} V_t(s_t, b_t, d_t)\}. \quad (5)$$

We guess that the value function  $V_t$  is linear in  $(s_t, b_t, d_t)$ ,

$$V_t(s_t, b_t, d_t) = v_{s,t}s_t + v_{b,t}b_t - v_{d,t}d_t, \quad (6)$$

where  $v_{s,t}$  is the marginal value of equities at the end of period  $t$ ,  $v_{b,t}$  is the marginal value of residential loans, and  $v_{d,t}$  is the marginal cost of deposits.

Given the Bellman equation and the conjectured value function, the bank's optimality conditions are:

$$\frac{v_{s,t}}{p_t} - v_{b,t} = 0, \quad (7)$$

$$(1 + \lambda_t^b)(v_{b,t} - v_{d,t}) = \theta \lambda_t^b, \quad (8)$$

$$[\theta - (v_{b,t} - v_{d,t})]b_t + \left[ \theta - \left( \frac{v_{s,t}}{p_t} - v_{d,t} \right) \right] p_t s_t \leq v_{d,t} n_t. \quad (9)$$

Moreover, the value function  $V(s_t, b_t, d_t)$  is linear in  $(s_t, b_t, d_t)$  if and only if the following conditions are satisfied:

$$v_{b,t} = \mathbb{E}_t \Lambda_{t,t+1} \Omega_{t+1} \frac{R_{t+1}^b}{\pi_{t+1}}, \quad (10)$$

$$v_{d,t} = \mathbb{E}_t \Lambda_{t,t+1} \Omega_{t+1} \frac{R_{t+1}^d}{\pi_{t+1}}, \quad (11)$$

$$v_{s,t} = \mathbb{E}_t \Lambda_{t,t+1} \Omega_{t+1} \psi_{t+1} [Z_{t+1} + (1 - \delta_k)p_{t+1}], \quad (12)$$

with

$$\Omega_{t+1} = 1 - \sigma + \sigma(v_{d,t+1} + \phi_{t+1}\mu_{t+1}), \quad (13)$$

$$\mu_t = \mathbb{E}_t \Lambda_{t,t+1} \Omega_{t+1} \left( R_{t+1}^k - \frac{R_{t+1}^d}{\pi_{t+1}} \right), \quad (14)$$

$$R_{t+1}^k = \psi_{t+1} \frac{Z_{t+1} + (1 - \delta_k)p_{t+1}}{p_t}, \quad (15)$$

where  $\Omega_{t+1}$  is the marginal value of net worth at period  $t + 1$ , and  $\mu_t$  is the excess value of returns on assets over liabilities. Note that if  $0 < \mu_t < \theta$ , the incentive constraint implies that the leverage is

$$\phi_t = \frac{v_{d,t}}{\theta - \mu_t}. \quad (16)$$

From the bank's optimality conditions, one may easily derive the following relationship between assets and liabilities in terms of their returns

$$R_{t+1}^k = \frac{R_{t+1}^b}{\pi_{t+1}} > \frac{R_{t+1}^d}{\pi_{t+1}}. \quad (17)$$

Let  $S_t$  be total equities held by all banks at date  $t$ ,  $B_t$  be total residential loans, and  $N_t$  be total net worth of all banks. Due to the homogeneity of banks, we obtain the flow-of-funds constraint of the banking system given by

$$p_t S_t + B_t = N_t + D_t, \quad (18)$$

and the relation between total assets and total net worth given by

$$p_t S_t + B_t = \phi_t N_t, \quad (19)$$

Let  $N_{o,t}$  be total net worth of ongoing banks at date  $t$ , and  $N_{y,t}$  be total net worth of new banks. Then total net worth of the banking system is written as

$$N_t = N_{o,t} + N_{y,t}. \quad (20)$$

Since in each period a fraction  $\sigma$  of banks survive until the next period, the total net worth of ongoing banks is given by

$$N_{o,t} = \sigma \left\{ [Z_t + (1 - \delta_k)p_t] \psi_t S_{t-1} + \frac{R_t^b B_{t-1}}{\pi_t} - \frac{R_t^d D_{t-1}}{\pi_t} \right\}. \quad (21)$$

As we noted earlier, a fraction  $1 - \sigma$  of banks exit from the banking system at the end of each period, while new banks enter with a “start-up” fund transferred from patient households. We assume that each period patient households transfer a fraction  $\xi/(1 - \sigma)$  of total assets held by ongoing banks. Accordingly, the total net worth of new banks is given by

$$N_{y,t} = \xi \left\{ [Z_t + (1 - \delta_k)p_t] \psi_t S_{t-1} + \frac{R_t^b B_{t-1}}{\pi_t} \right\}. \quad (22)$$

## 2.4 Nonfinancial Firms

### 2.4.1 The Final Goods Firms (Wholesale Firms)

To motivate price rigidity in the consumption sector, we differentiate between the wholesale firms that operate under competitive competition, and the retail firms that operate under monopolistic competition. At date  $t$ , each wholesale producer hires labors  $l_{pc,t}$  and  $l_{ic,t}$  from patient and impatient households, and pays a real wage of  $w_{pc,t}$  and  $w_{ic,t}$  to them, respectively. As we noted earlier, wholesale producers face no borrowing constraints. Instead, they borrow funds from banks by issuing new state-contingent equities at a price of  $p_t$ . In particular, each unit of equity is a state-contingent claim to the future returns from one unit of capital investment. Conditional on funds borrowed from banks, they purchase new capital as inputs from capital producers. In addition, we assume that wholesale producers combine labor and capital to produce final goods under a CRS technology in a Cobb-Douglas fashion. Due to perfect competition, the wholesale producers earn zero economic profits state-by-state.

A representative wholesale producer chooses hours  $(l_{pc,t}, l_{ic,t})$  and capital  $k_t$  to produce final goods  $Y_t$ . The producer solves the firm’s profit maximization problem as follows:

$$\max \frac{Y_t}{X_t} - w_{pc,t} l_{pc,t} - w_{ic,t} l_{ic,t} - Z_t k_t,$$

where  $X_t$  is the markup of final goods over the marginal cost. The production technology is given by

$$Y_t = [A_{c,t} (l_{pc,t}^\alpha l_{ic,t}^{1-\alpha})]^{1-\mu_c} k_t^{\mu_c}, \quad (23)$$

where  $\alpha$  is the labor income share of patient households, reflecting labor complementarity across different labor skills among households, and  $\mu_c$  is the income share of capital used in the production of final goods. Note that capital stock  $k_t$  is predetermined in period  $t-1$ . The term  $A_{c,t}$  captures shocks to labor productivity in the wholesale sector, and follows the AR(1) process:

$$\ln A_{c,t} = \rho_c \ln A_{c,t-1} + u_{c,t},$$

where  $u_{c,t}$  is identically and independently distributed with mean 0 and variance  $\sigma_c^2$ .

## 2.4.2 The Retail Firms

As in [Bernanke et al. \(1999\)](#), retail firms operate under monopolistic competition at the retail market. There are a continuum of retail firms of mass 1 in the market. Retail firms buy final goods  $Y_t$  from wholesale firms at the competitive/flexible price  $p_{c,t}^w$ , differentiate the goods at no costs, and sell them at a markup of  $X_t = \frac{p_{c,t}}{p_{c,t}^w}$ . Following [Smets and Wouters \(2003\)](#), the aggregate output index is given by the CES aggregator with *time-varying* desired markup  $1 + \zeta_t$ :

$$Y_t = \left[ \int_0^1 Y_t(i)^{\frac{1}{1+\zeta_t}} di \right]^{1+\zeta_t},$$

where  $Y_t(i)$  is the quantity of good  $i$  supplied by the retail firm in period  $t$ , and  $\zeta_t = \zeta + u_{cp,t}$  where  $u_{cp,t}$  is the markup shock. In equilibrium,  $u_{cp,t}$  will also be the cost-push shock. Note that in this setup, the elasticity of substitution is time-varying as well, determined according to  $\varepsilon_t = 1 + 1/\zeta_t$  with  $\varepsilon = 1 + 1/\zeta$  as the steady state value.<sup>4</sup> Given the aggregate output index above, the aggregate price index then is

$$p_{c,t} = \left[ \int_0^1 p_{c,t}(i)^{-\frac{1}{\zeta_t}} di \right]^{-\zeta_t},$$

where  $p_{c,t}(i)$  is the price of good  $i$  in period  $t$ . It follows that the demand function for good  $i$  can be written as

$$Y_t(i) = \left( \frac{p_{c,t}(i)}{p_{c,t}} \right)^{-\frac{1+\zeta_t}{\zeta_t}} Y_t. \quad (24)$$

Retail firms choose price according to Calvo pricing, so that a fraction  $1 - \lambda$  of retail firms reset their prices optimally in any given period, while a fraction  $\lambda$  of retail firms index their prices automatically. As in [Smets and Wouters \(2003\)](#), we allow for partial indexation. Consequently, a representative retail firm sets its optimal price  $p_{c,t}^*(i)$  to maximize the discount profits as follows:

$$\sum_{\tau=0}^{\infty} \lambda^\tau \mathbb{E}_t \left\{ \Lambda_{t,t+\tau} \left( \frac{p_{c,t}^*(i)}{p_{c,t+\tau}} \frac{(P_{t-1+\tau}/P_{t-1})^t}{P_{t+\tau}/P_t} - (1 + \zeta_{t+\tau}) \frac{X}{X_{t+\tau}} \right) Y_{t+\tau}^*(i) \right\}, \quad (25)$$

where  $Y_{t+\tau}^*(i)$  is the demand function for good  $i$  in period  $t + \tau$ , given the optimal reset price  $p_{c,t}^*(i)$ . The resulting Phillips curve is given by:

$$\ln \pi_t - \lambda \ln \pi_{t-1} = \beta_p (\mathbb{E}_t \ln \pi_{t+1} - \ln \pi_t) - \frac{(1-\lambda)(1-\beta_p \lambda)}{\lambda} \ln \frac{X_t}{X} + u_{cp,t}, \quad (26)$$

<sup>4</sup>In our estimation, we will report  $\varepsilon$  instead of  $\zeta$ , since the former parameterization is more widely reported in the literature.

where  $u_{cp,t}$  denotes the cost-push shock, which is independently and identically distributed with mean 0 and variance  $\sigma_{cp}^2$ . For simplicity, we assume that profits from retail firms will be redistributed to patient households.

### 2.4.3 The Housing Firms

Housing producers hire labor  $(l_{ph,t}, l_{ih,t})$  from the two groups of households, and rent land  $x_{t-1}$  from patient households to produce new houses  $I_{h,t}$  under the CRS technology in a perfectly competitive market. Accordingly, a representative housing producer solves

$$\max q_t I_{h,t} - w_{ph,t} l_{ph,t} - w_{ih,t} l_{ih,t} - R_t^x x_{t-1}.$$

The production technology is given by

$$I_{h,t} = [A_{h,t} (l_{ph,t}^\alpha l_{ih,t}^{1-\alpha})]^{1-\mu_h} x_{t-1}^{\mu_h}, \quad (27)$$

where  $\mu_h$  is the income share of land used to produce new houses. The term  $A_{h,t}$  captures shocks to labor productivity in the housing sector, and follows the AR(1) process:

$$\ln A_{h,t} = \rho_h \ln A_{h,t-1} + u_{h,t},$$

where  $u_{h,t}$  is identically and independently distributed with mean 0 and variance  $\sigma_h^2$ .

### 2.4.4 The Capital Goods Firms

Capital goods producers produce new capital using consumption goods as inputs, and are subject to an adjustment cost. A capital producer chooses capital investment  $I_{k,t}$  to solve

$$\max \mathbb{E}_t \sum_{i=t}^{\infty} \Lambda_{t,i} \left\{ p_i I_{k,i} - \left[ 1 + \frac{\chi_k}{2} \left( \frac{I_{k,i}}{I_{k,i-1}} - 1 \right)^2 \right] I_{k,i} \right\},$$

where  $p_t$  is the price of new capital,  $\chi_k$  is the parameter of the adjustment cost, and  $\Lambda_{t,i}$  is the patient household's stochastic discount factor from date  $i$  to date  $t$ .

The optimality condition then yields the price function for capital:

$$p_t = 1 + \frac{\chi_k}{2} \left( \frac{I_{k,t}}{I_{k,t-1}} - 1 \right)^2 + \chi_k \left( \frac{I_{k,t}}{I_{k,t-1}} - 1 \right) \frac{I_{k,t}}{I_{k,t-1}} - \chi_k \Lambda_{t,t+1} \left( \frac{I_{k,t+1}}{I_{k,t}} - 1 \right) \left( \frac{I_{k,t+1}}{I_{k,t}} \right)^2. \quad (28)$$

Note that profits will arise only outside of the steady state, and will be redistributed to patient households by a lump sum transfer.

## 2.5 The Central Bank

To close the model, the central bank sets the nominal interest rate  $R_t^d$ , based on a Taylor rule that responds to inflation and GDP gaps:

$$\frac{R_t^d}{R^d} = \left( \frac{R_{t-1}^d}{R^d} \right)^{\alpha_r} \left[ \pi_t^{\alpha_\pi} \left( \frac{GDP_t}{GDP} \right)^{\alpha_y} \right]^{1-\alpha_r} \exp(u_{mp,t}), \quad (29)$$

where  $GDP$  and  $R^d$  are steady-state values of GDP and nominal interest rate, respectively. The monetary policy shock  $u_{mp,t}$  is independently and identically distributed with mean 0 and variance  $\sigma_{mp}^2$ .

## 2.6 Equilibrium

In equilibrium, the market clearing conditions for goods, housing, and equities/capital are as follows,

$$Y_t = C_t + \left[ 1 + \frac{\chi_k}{2} \left( \frac{I_{k,t}}{I_{k,t-1}} - 1 \right)^2 \right] I_{k,t}, \quad (30)$$

$$I_{h,t} = H_t - (1 - \delta_h)H_{t-1}, \quad (31)$$

$$S_t = I_{k,t} + (1 - \delta_k)K_t, \quad (32)$$

$$K_{t+1} = \psi_{t+1}[I_{k,t} + (1 - \delta_k)K_t]. \quad (33)$$

Note that  $C_t = c_{p,t} + c_{i,t}$  is aggregate consumption,  $H_t = h_{p,t} + h_{i,t}$  is aggregate housing stock. The equation (33) is the law of motion for capital in the presence of an exogenous capital quality shock. Total land is fixed and normalized to one. The model  $GDP_t$  is defined as the sum of consumption output and the housing investment evaluated at house prices:

$$GDP_t = Y_t + q_t I_{h,t}. \quad (34)$$

The dynamic system of the baseline model is described in details in Appendix B.

A final remark before discussing the quantitative results is about the capital quality shock. [Gertler and Kiyotaki \(2010\)](#) and [Gertler and Karadi \(2011\)](#) make the capital quality shock  $\psi_t$  a standard modeling device for studying financial friction. Yet viewing through the lens of capital accumulation process (33), it is evident that the capital quality shock is closely related to the so called investment specific shock, which is identified as the major source of business cycle fluctuations for the US by [Justiniano et al. \(2010\)](#). More precisely, we can write the law of motion for capital as  $K_{t+1} = \psi_{t+1}I_{k,t} + \psi_{t+1}(1 - \delta)K_t$ , where the capital quality shock  $\psi_{t+1}$  associated with investment  $I_{k,t}$  is equivalent to the marginal efficiency of investment shock named by [Justiniano et al. \(2011\)](#). In the quantitative evaluation of [Justiniano et al. \(2011\)](#), this shock is shown to be the most important driving force for the US business cycles, and its “news” shock version is also confirmed by [Schmitt-Grohé and Uribe \(2012\)](#) to play the major role in investment fluctuations. Given that the investment shock plays such an important role in an advanced country such as the US, it is intuitive to expect that the closely related capital quality shock can play an even more significant role in an emerging economy such as China, where investment and capital accumulation at large claim a much bigger share of the economy compared to advanced countries.

## 3 Model Calibration and Estimation

We proceed to parameterize the model by dividing parameters into two sets. For the first set, we calibrate the parameters so that the model steady state replicates the key features of China’s macroeconomy. For

Table 1: Calibrated Parameters

Parameters	Description	Value
$\beta_p$	Discount factor for savers	0.9975
$\beta_i$	Discount factor for borrowers	0.965
$\delta_k$	Depreciation rate of capital	0.03
$\delta_h$	Depreciation rate of houses	0.0097
$\mu_c$	Share of capital	0.30
$\mu_h$	Share of land	0.3097
$\theta$	Fraction of assets diverted by banks	0.5961
$\xi$	Fraction of funds transferred to new banks	0.0089
$j$	Housing preference weight	0.2502
$m$	Steady state loan-to-value ratio	0.70
$\sigma$	Survival rate of banks	0.95
$\alpha$	Labor income share of patient households	0.64
$X$	Steady state gross markup	1.15

the second set, mostly related to shock processes, we use the standard Bayesian method to estimate the parameters. Taken together, the model is able to capture the both the steady state structure and the dynamics of China's macroeconomy.

### 3.1 Data and Calibration

We first calibrate a subset of parameters to match a range of targeted ratios of key economic quantities consistent with the Chinese data from 2000Q1 to 2018Q4. Table 1 summarizes our calibrations. The discount factor of patient households  $\beta_p$  is set equal to 0.9975, implying that a steady-state annual real interest rate of 1%. Following [Iacoviello and Neri \(2010\)](#), the discount factor of impatient households  $\beta_i$  is arbitrarily set equal to 0.965, which is less than the value of  $\beta_p$ , ensuring that the borrowing constraint of impatient households is binding around the neighborhood of the steady state. In general, the lower is the value of  $\beta_i$ , the more likely will the borrowing constraint bind away from the steady state. The survival rate of banks  $\sigma$  is arbitrarily set equal to 0.95, implying that the expected survival horizon of banks are five years on average.<sup>5</sup> The fraction of funds transferred from patient households  $\xi$ , and the fraction of assets that can be diverted from banks to patient households  $\theta$  are set equal to 0.0089 and 0.5961, respectively, in order to match two targets: an average leverage ratio of 2.96 from all commercial banks in China and an

<sup>5</sup>Although the expected survival time of banks might be longer, we only require that the expected time horizon is finite in order to prevent the banks from accumulating assets to overcome the incentive constraints. An alternative choice of the survival rate has little effect on the business cycle properties reproduced by the model.

average annual interest spread of 3%. We set the target for the annual interest spread to 3%, based on a rough average of the following two spreads: AA-corporate bond rates versus government bond rates, and mortgage rates versus government bond rates.

Due to the availability of the data, we choose the depreciation rate of capital  $\delta_k = 0.03$ , and the capital share in the wholesale sector  $\mu_c = 0.3$  in line with the existing literature.<sup>6</sup> The depreciation rate of housing  $\delta_h$  is set equal to 0.0097, and the land share in the housing production  $\mu_h$  is set equal to 0.3097, implying a steady-state residential investment to GDP ratio of 12% and a steady-state land value to annual GDP ratio of 3.7. Land share in the housing production in China is greater than that in the United States, since land prices relative to wages on average are higher in the former than that in the latter.<sup>7</sup> The housing preference weight  $j$  is set equal to 0.25. Given the value of input shares in the housing production function and other parameters calibrated, the choice of housing preference weight implies a steady-state housing wealth to annual GDP ratio of 3.1. The value of housing preference weight calibrated is greater than that for the United State.<sup>8</sup> Due to the differences in culture and saving behaviors, households in China exhibit more preference towards housing than households in the United States. This partially explains why the ownership rate of housing in China is much higher than that in the United States.<sup>9</sup> According to the recent housing policies in China, home buyers are allowed to borrow up to a limit equal to 70 percent of the housing value when they buy their first home with mortgages. In this regard, we set the LTV ratio equal to 0.70.

The labor income share  $\alpha$ , obtained by unconstrained households from wholesale good production, is not available in China's data. As a result, we follow [Iacoviello \(2005\)](#) and set  $\alpha = 0.64$ , which is within the range of the estimates reported by the existing literature such as [Jappelli \(1990\)](#) and [Kiyotaki et al. \(2011\)](#). We choose  $X = 1.15$  in line with [Iacoviello and Neri \(2010\)](#), implying a markup of 15% in the consumption good market.

## 3.2 Bayesian Estimation

We estimate the remaining structural parameters and shock processes using the standard Bayesian method ([An and Schorfheide, 2007](#)). The prior distribution of the parameters used are along the lines of [Iacoviello and Neri \(2010\)](#) and [Iacoviello \(2015\)](#). Table 2 reports the prior distribution of the parameters. The observables we used in the estimation include (i) real private consumption, (ii) real residential investment, (iii) real house

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<sup>6</sup>The data for capital stock in China is not available. For simplicity, we set the values of the capital depreciation rate and capital share equal to that used commonly in the literature.

<sup>7</sup>Land share is only 0.1 in the U.S., as calibrated by [Iacoviello and Neri \(2010\)](#).

<sup>8</sup>The housing preference weight for the U.S. calibrated by [Iacoviello and Neri \(2010\)](#) is only 0.12.

<sup>9</sup>According to the Current Population Survey conducted by the U.S. Census Bureau, the ownership rate of housing is roughly 65 percent in 2018. The ownership rate of housing in China is about 90 percent in recent years, based on the report by the National Bureau of Statistics of China.

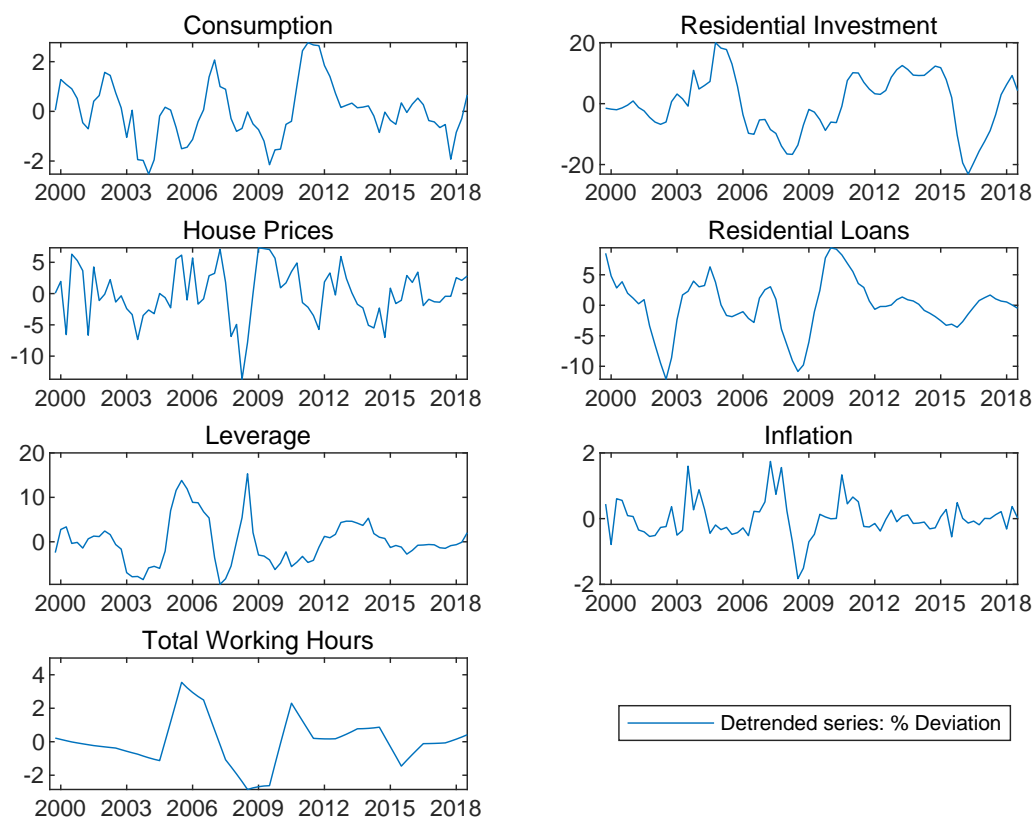


Figure 1: Data Used in Estimation

**Notes:** All time series are detrended using the HP filter with the smoothing parameter equal to 1,600.

prices, (iv) real residential loans, (v) bank leverage ratio, (vi) inflation, and (vii) total working hours.<sup>10</sup> We choose the set of observables with the aim of describing the dynamics of the housing and financial sector in aggregate as accurately as possible. Except for inflation, all data are log-transformed and detrended using the HP-filter with the smoothing parameter equal to 1,600. The detrended data are plotted in Figure 1. We combine different data sources to construct the set of observables. In particular, we overcome a host of typical data limitations to construct the sectoral bank loan series dating back to 2000, and to construct a total labor series measured in working hours rather than persons. See Appendix A for data description and construction in details.

Table 2 also reports the posterior mean and 90% confidence interval for the parameters being estimated.

<sup>10</sup>Within the model, consumption refers to consumption of non-durable goods and services net of housing services. Since the data on consumption of durables and consumption of non-durables for China is not available, the use of consumption expenditure (including both durables and non-durables) is a compromise.



Table 2: Prior and Posterior Distribution of the Parameters

Parameter	Prior Distribution			Posterior Distribution		
	Dist. type	Mean	Std. Dev.	Mean	5%	95%
$\chi_k$	Gamma	1	0.50	2.6554	1.8223	3.4940
$\iota$	Beta	0.50	0.20	0.1969	0.0362	0.3577
$\lambda$	Beta	0.667	0.05	0.6659	0.6164	0.7172
$\alpha_r$	Beta	0.75	0.10	0.7899	0.7158	0.8609
$\alpha_\pi$	Normal	1.50	0.10	1.5323	1.4014	1.6770
$\alpha_y$	Normal	0	0.10	0.0779	0.0033	0.1555
$\tau_p$	Beta	0.50	0.075	0.3621	0.2882	0.4299
$\tau_i$	Beta	0.50	0.075	0.4372	0.2954	0.5413
$\eta_p$	Gamma	0.50	0.10	0.6408	0.4814	0.7976
$\eta_i$	Gamma	0.50	0.10	0.5492	0.3815	0.6819
$\epsilon_p$	Normal	1.00	0.10	1.0519	0.9345	1.1916
$\epsilon_i$	Normal	1.00	0.10	1.0210	0.8370	1.1906
$\rho_c$	Beta	0.80	0.10	0.9176	0.8791	0.9698
$\rho_h$	Beta	0.80	0.10	0.8939	0.8350	0.9495
$\rho_k$	Beta	0.80	0.10	0.9648	0.9391	0.9903
$\rho_j$	Beta	0.80	0.10	0.9928	0.9879	0.9974
$\rho_p$	Beta	0.80	0.10	0.8979	0.8227	0.9596
$\rho_m$	Beta	0.80	0.10	0.7050	0.6077	0.8181
$\rho_n$	Beta	0.80	0.10	0.7818	0.6870	0.8785
$\sigma_c$	Inv. Gamma	0.001	0.01	0.0164	0.0138	0.0181
$\sigma_h$	Inv. Gamma	0.001	0.01	0.0474	0.0423	0.0543
$\sigma_k$	Inv. Gamma	0.001	0.01	0.0018	0.0012	0.0023
$\sigma_j$	Inv. Gamma	0.001	0.01	0.0728	0.0573	0.0864
$\sigma_p$	Inv. Gamma	0.001	0.01	0.0159	0.0110	0.0202
$\sigma_m$	Inv. Gamma	0.001	0.01	0.0384	0.0320	0.0431
$\sigma_n$	Inv. Gamma	0.001	0.01	0.0237	0.0194	0.0282
$\sigma_{mp}$	Inv. Gamma	0.001	0.01	0.0005	0.0003	0.0007
$\sigma_{cp}$	Inv. Gamma	0.001	0.01	0.0008	0.0002	0.0012

**Notes:** The upper panel reports the prior and posterior distribution of the structural parameters, and the lower panel reports the prior and posterior distribution of the shock parameters.

Most shocks are quite persistent, with autocorrelation coefficients ranging from 0.70 to 0.99. The volatility of housing preference shocks is found to be much higher than that of the other shocks, with a standard deviation of 0.0728, implying that the housing preference shocks play an important role in China's business

cycles. The volatilities of the monetary and cost-push shocks are quite small, and are only 0.0005 and 0.0008, respectively. The labor supply elasticities of the two types of households are approximately close to 0.5 (i.e.  $\eta_p = 0.6408$  and  $\eta_i = 0.5492$ ), and the values of the parameters that measure the degree of labor mobility across the production sectors are approximately close to 1 (i.e.  $\epsilon_p = 1.0519$  and  $\epsilon_i = 1.0210$ ), both of which are consistent with the literature. Moreover, the degree of habits in consumption for impatient households is larger than that for patient households ( $\tau_p = 0.3621$  and  $\tau_i = 0.4372$ ), along the lines of [Iacoviello and Neri \(2010\)](#). Last, our estimation gives a reasonable value of the cost adjustment parameter (i.e.  $\chi_k = 2.6554$ ). According to [Born and Pfeifer \(2014\)](#) and [Christiano et al. \(2015\)](#), the value of the parameter in general is within the range between 1 and 6.

## 4 Quantitative Results

### 4.1 The Fitting of the Baseline Model

In this section, we investigate whether our estimated model fits the business cycle properties observed in the Chinese data, focusing in particular on the volatility and cyclicity of the observed variables, and then determine the main driving forces of business cycle fluctuations in the housing and financial markets and the macroeconomy in China. [Table 3](#) reports the model implied volatility and cyclicity of the variables of interest. We find that most of the data statistics are within the 95% probability interval simulated from the baseline model, and it replicates well the volatility and cyclicity of these observed variables. In particular, the estimated model approximately reproduces the volatilities of consumption, nonresidential investment, house prices, net worth, nonresidential loans, deposits, bank leverage, inflation and hours relative to GDP. However, it overestimates the volatility in residential investment and residential loans. In addition, the model replicates well the comovement of output with consumption, investment, net worth, loans, deposits, leverage and inflation, but it overstates the comovement with house prices and hours. Though the baseline model has its own shortcomings in replicating few data statistics, it is successful in its ability in accounting for the volatility and cyclicity of most variables being concerned.

### 4.2 Further Validation of the Baseline Model

One of the main critiques on DSGE models is that they can do a good job at fitting the data in sample, but might have poor performance otherwise ([Iacoviello, 2015](#)). To address this problem, we conduct an external validation test to assess the reliability of the model in fitting time series that were not used as observables in the estimation. [Figure 2](#) plots the time series for net worth, nonresidential loans and deposits simulated by the estimated model against their data counterparts. In particular, net worth simulated by the model mimics its data counterpart over the sample period. Both nonresidential loans and deposits simulated by the model mimic their data counterparts in most of the sample period, especially during the post-crisis

Table 3: Business Cycle Properties of the Baseline Model

Variables	Data	Model	2.5%	97.5%
<i>Panel A: SD of GDP and relative SD w.r.p.t GDP (%)</i>				
GDP	1.48	1.86	1.28	2.61
Consumption	0.78	0.75	0.52	1.06
Invest., capital	2.12	2.92	1.68	4.60
Invest., housing	6.49	3.66	2.42	5.30
House prices	2.83	2.78	1.80	4.10
Net worth	4.95	4.34	2.80	6.46
Loans, non-res.	2.46	1.80	1.17	2.67
Loans, res.	3.03	8.79	5.81	12.78
Deposits	1.96	2.12	1.45	3.01
Bank leverage	3.48	3.78	2.41	5.63
Inflation	0.39	0.38	0.23	0.58
Labor, total	0.91	1.22	0.84	1.72
<i>Panel B: Correlations with GDP</i>				
Consumption	0.38	0.66	0.32	0.87
Invest., capital	0.49	0.41	-0.07	0.76
Invest., housing	0.57	0.58	0.23	0.82
House prices	0.13	0.54	0.15	0.80
Net worth	0.24	0.13	-0.23	0.46
Loans, non-res.	0.25	0.17	-0.18	0.49
Loans, res.	0.38	0.39	0.03	0.67
Deposits	0.29	0.48	0.16	0.72
Bank leverage	-0.12	0.08	-0.27	0.41
Inflation	0.01	-0.03	-0.34	0.27
Labor, total	0.20	0.55	0.21	0.79

**Notes:** The table reports the mean value of the main simulated variables and its 95% confidence interval. The statistics are computed with a random selection of 500 draws from the posterior distribution and, for each of them, 100 artificial time series of the variables of length equal to that of the data. Each simulated time series has been detrended using the HP filter with the smoothing parameter equal to 1,600.

period. Accordingly, the estimated model is reliable in accounting for the China's business cycles, since it replicates well the business cycle statistics of most variables being concerned.

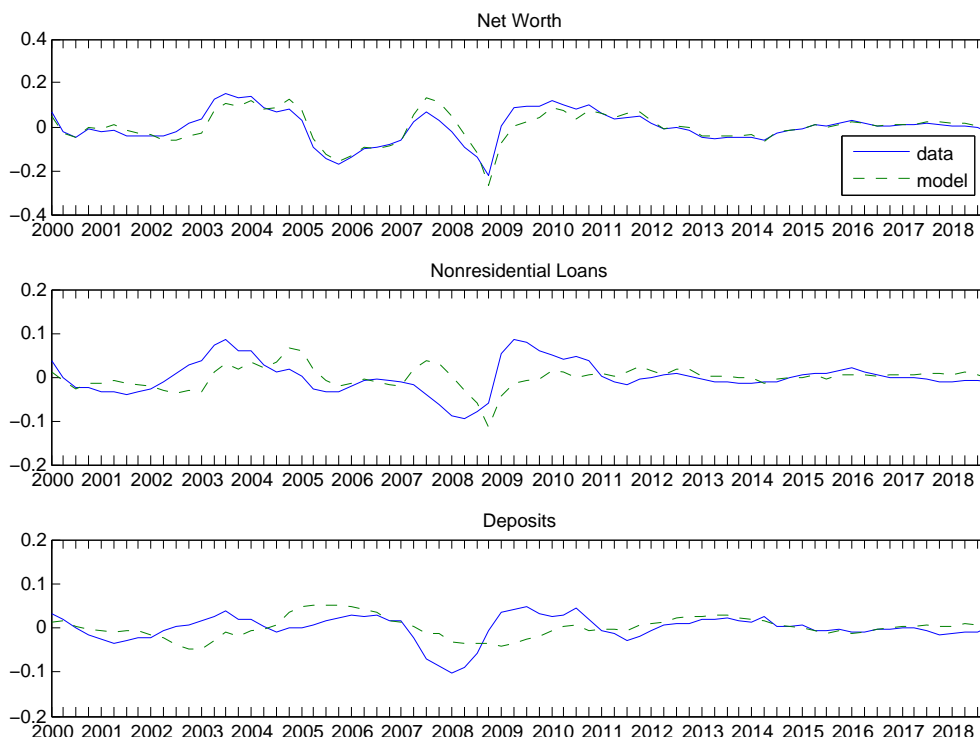


Figure 2: External Validation Test

**Notes:** The solid line plots actual data over the period of 2000–2018, and the dash line plots time series simulated by the model. The y-axis measures deviation from the trend. All time series are detrended using the HP filter with smoothing parameter equal to 1,600.

### 4.3 Shock Decomposition

Since the estimated model fits the data reasonably well, we use it to determine the sources of China’s business cycles. Table 4 reports the decomposition of the variance of the forecast errors at business cycle frequencies. As shown in Table 4, capital quality shocks explain roughly 11 and 28 percent of the variance in consumption and nonresidential investment, respectively, and explain a large fraction of the variance in net worth, nonresidential loans, leverage and inflation at business cycle frequencies, between 16 and 32 percent. But, the contribution of capital quality shocks to the variance in housing and labor quantities is small. Housing demand and supply shocks together explain a significant portion of the variance in all variables, indicating that the housing market is at the center in driving the China’s business cycles in our sample period. LTV shocks and labor supply shocks also play an important role in the China’s business cycles. In particular, LTV shocks explain more than 30 percent of the variance in financial variables, and relatively less of the variance in nonresidential investment, inflation and hours, between 9 and 17 percent roughly. Labor supply shocks explains more than one-fifth of the variance in consumption, output, inflation, hours, but the effects on the variance in housing quantities are relatively small. Non-housing technology

Table 4: Decomposition of the Variance of the Forecast Errors to Each Shock

Variables	Capital q.	Tech., n-h	Tech., h	Dem., h	Int. pref.	LTV	Labor	Money	Cost push
GDP	2.84	37.72	13.75	15.48	1.88	2.22	25.99	0.09	0.03
Consumption	10.68	43.28	0.21	7.00	11.09	5.91	21.63	0.14	0.05
Invest., capital	27.53	21.58	0.14	15.22	11.01	16.84	7.63	0.04	0.00
Invest., housing	0.12	0.10	80.47	11.14	1.11	1.23	5.82	0.00	0.00
House prices	1.55	3.82	0.26	88.31	3.59	0.24	2.18	0.04	0.01
Net worth	32.03	1.96	0.11	30.30	0.40	33.87	0.94	0.39	0.01
Loans, non-res.	24.58	5.42	0.10	32.03	2.61	30.35	4.70	0.19	0.03
Loans, res.	2.58	1.87	0.10	57.29	1.56	35.97	0.47	0.15	0.00
Deposits	6.39	6.63	0.10	42.10	7.44	32.76	4.49	0.07	0.02
Bank leverage	18.84	0.29	0.14	38.68	0.96	40.68	0.23	0.18	0.00
Inflation	16.73	14.69	0.21	16.56	16.52	9.50	23.99	1.37	0.43
Labor, total	2.83	10.11	13.91	13.91	1.00	15.52	42.68	0.04	0.02

**Notes:** The table reports the posterior mean value of the variance of the forecast errors at business cycle frequencies (extracted using the HP filter with smoothing parameter equal to 1,600). All values are measured in percentage.

shocks explains a large portion of the variance in consumption, nonresidential investment, output, inflation and hours, between 10 and 43 percent, implying that the non-housing technology shocks are critical to the business cycle fluctuations along the lines of the literature such as [Kydland and Prescott \(1982\)](#), [King and Rebelo \(1999\)](#), [Smets and Wouters \(2007\)](#).

One may find that both monetary shocks and cost-push shocks are trivial to the China's business cycles. Monetary shocks do not contribute much to the fluctuations of the China's business cycles due to the fact that the central bank of China uses the quantitative monetary tool (money growth rule) much more frequently than the price-based monetary tool (interest rate rule).

Taken together, capital quality, non-housing technology, housing demand and supply, LTV and labor supply shocks are the main driving forces of the China's business cycles, accounting for more than 80 percent of the variance in inflation, and nearly 90 percent of the variance in other macroeconomic variables. A related question that one might ask is how these shocks contribute to cyclical movements of business cycles, or perhaps, how important were the shocks in shaping the recent business cycles in China. To answer these questions, we provide a visual representation of historical decompositions for several key variables being concerned. [Figure 3](#) illustrates the historical contribution of these driving forces under our estimated parameters. The solid line plots actual data, which is expressed in deviation from its trend. The bars show the historical contribution of the six factors under our estimated parameters. As shown in [Figure 3](#), capital quality shocks play an important role in accounting for the variations in inflation and leverage, especially during the Great Recession. Notice that they also explain a relatively large fraction of

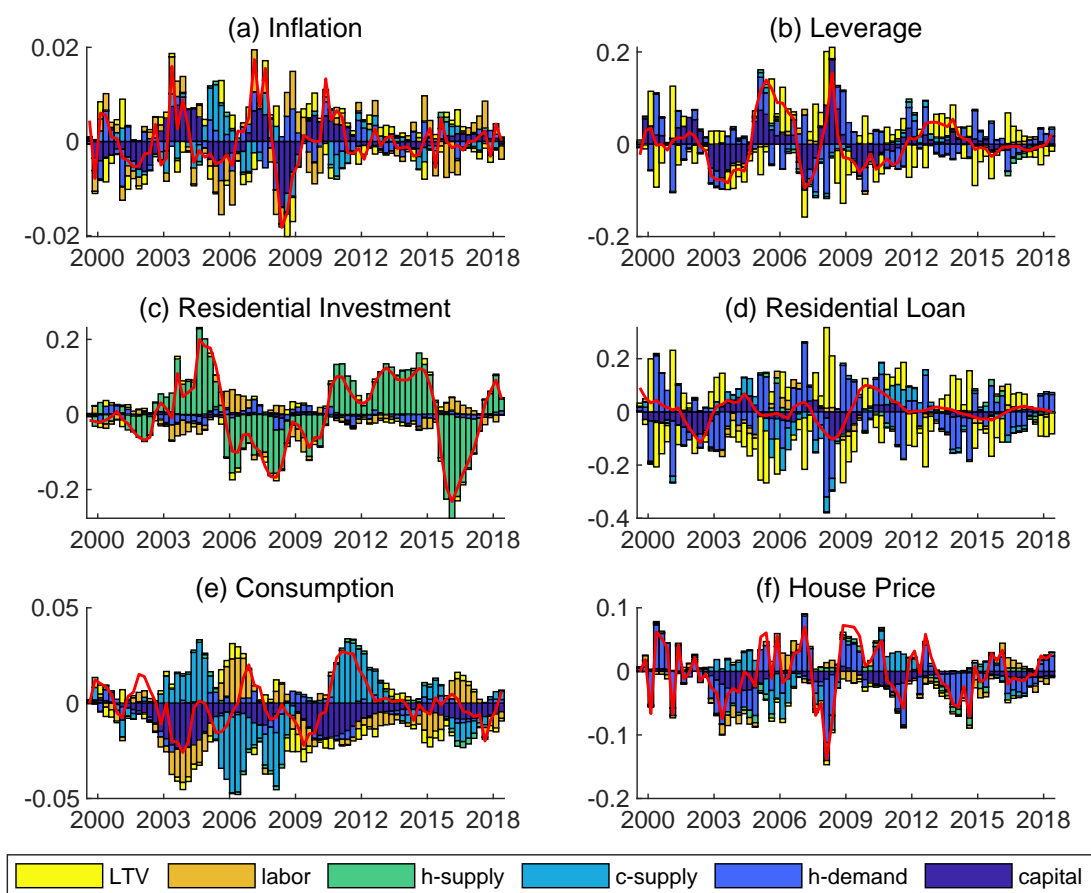


Figure 3: Historical Decomposition of the Estimated Model

**Notes:** The solid lines plot actual data series over the period of 2000–2018, and the bars show the contributions of the estimated shocks. The y-axis measures deviation from the trend. All time series are detrended using the HP filter with smoothing parameter equal to 1,600.

the variations in consumption over the sample period. It suggests that capital quality shocks are critical to the China’s business cycles, and thus cannot be neglected. The contribution of housing demand shocks to the fluctuations in house prices appears relatively more important than the contribution of other shocks, accounting for the variations in house prices at a significantly large degree. In addition, housing demand shocks are important to the fluctuations in financial variables, such as leverage and residential loans, which supports the prevalent view that financial cycles are also driven by housing disturbances. Housing demand and supply shocks together account for almost the entire variations in residential investment, but the latter dominates the former over the sample period. Not surprisingly, the contributions of the LTV shocks to the fluctuations in financial variables are larger than that to the fluctuations in non-financial variables, since the LTV shocks have a direct impact on the bank’s balance sheet. The contribution of non-housing

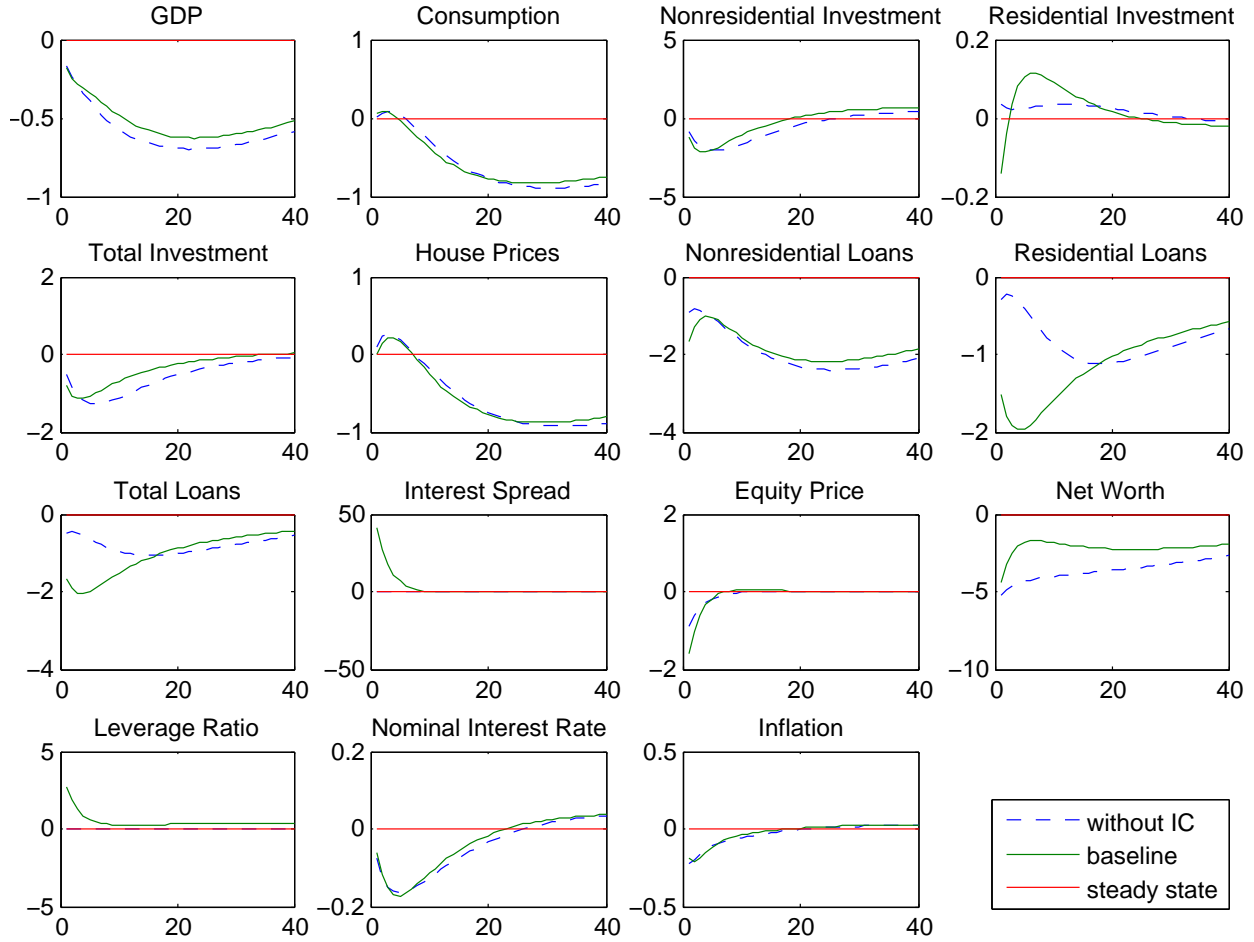


Figure 4: Impulse Responses to a Negative Capital Quality Shock

**Notes:** The vertical axis measures percent deviation from the steady state.

technology shocks to the fluctuations in consumption is large, whereas it is modest to the fluctuations in other macroeconomic variables.

## 5 Inspecting the Mechanisms of China’s Macroeconomic Dynamics

### 5.1 Capital Quality Shocks

Figure 4 plots the impulse responses of the key variables of interest to a negative capital quality shock. The solid line represents the dynamic paths for the baseline model, and the dash line represents the dynamic paths for the model without incentive constraints (financial frictions).

With financial frictions, a decline in capital quality immediately leads to a decrease in bank net worth. The decline in net worth is fundamentally a product of a high bank leverage ratio and a large loss in asset values. In particular, an exogenous shock affects bank net worth in two ways. First, an initial capital quality

shock directly reduces the value of equities held by banks, and hence their net worth. Because the bank is highly leveraged, the effect on its net worth would be magnified by a factor equal to the bank's leverage ratio. Second, the decline in bank net worth then tightens the bank's incentive constraint, causing a decrease in assets (equities) demanded. Eventually, the price of equities falls. This second round effect further depresses the value of equities, and thereby induces a large loss in bank net worth and a significant rise in the spread.

In order to respond to the decline in net worth, the bank must reduce the amount of funds lent to impatient households and wholesale firms. This leads to a significant decline in residential loans and nonresidential loans. Since nonresidential investment is financed by nonresidential loans, the former declines as the latter falls. As a result, both capital stock and output decrease. Because the decline in bank net worth exceeds that in loans, the bank leverage ratio rises. Banks can restore their leverage ratio either by deleveraging or accumulating more net worth. In the process of deleveraging, banks have to increase their net worth. As shown in Figure 4, an increase in net worth is accompanied by a decline in the spread. So long as the spread is above its trend, net worth cannot immediately revert to its steady-state level. Throughout the transition path to the long-run trend, the convergence process is slow and it takes a long time for a bank to restore its leverage ratio. Strictly speaking, the change in the spread between expected returns on assets and costs on liabilities induced by the financial frictions slows down the pace of economic recovery. In this way, our baseline model is able to capture the mechanism through which the deleveraging process slows down the recovery of the economy during the recession in line with [Gertler and Kiyotaki \(2010\)](#).

Next, we consider the responses of residential investment and consumption. The dynamics of these variables are affected by the behaviors of households. For impatient households, both housing investment and consumption fall since the shock mitigates their collateral capacities. For patient households, residential investment rises but consumption declines over time. This can be attributed to a dominant substitution effect by which patient households substitute towards housing and away from consumption goods, since the expected gains from housing exceeds the temporary losses induced by a decline in house prices. Due to the offsetting mechanism between the two types of households, both house prices and residential investment fall. Note that house prices rise initially due to the fact that the increase in residential investment of patient households outweighs the decline in residential investment of impatient households. But, house prices eventually fall as the negative effects on residential investment of impatient households dominate.

Figure 4 also displays the impulse responses for the model without financial frictions, while holding the parameters at the benchmark values. Absent financial frictions, interest spread and bank leverage ratio remain constant over time. Accordingly, a frictionless model is unable to capture the dynamics of these variables. In addition, residential investment tends to increase over time in response to the capital quality shocks. This result is inconsistent with what we have observed in the recent financial crisis.

Last, we consider the responses of nominal interest rate (policy rate) and inflation. When GDP decreases in response to a negative capital quality shock, inflation falls, causing a decline in policy rate.



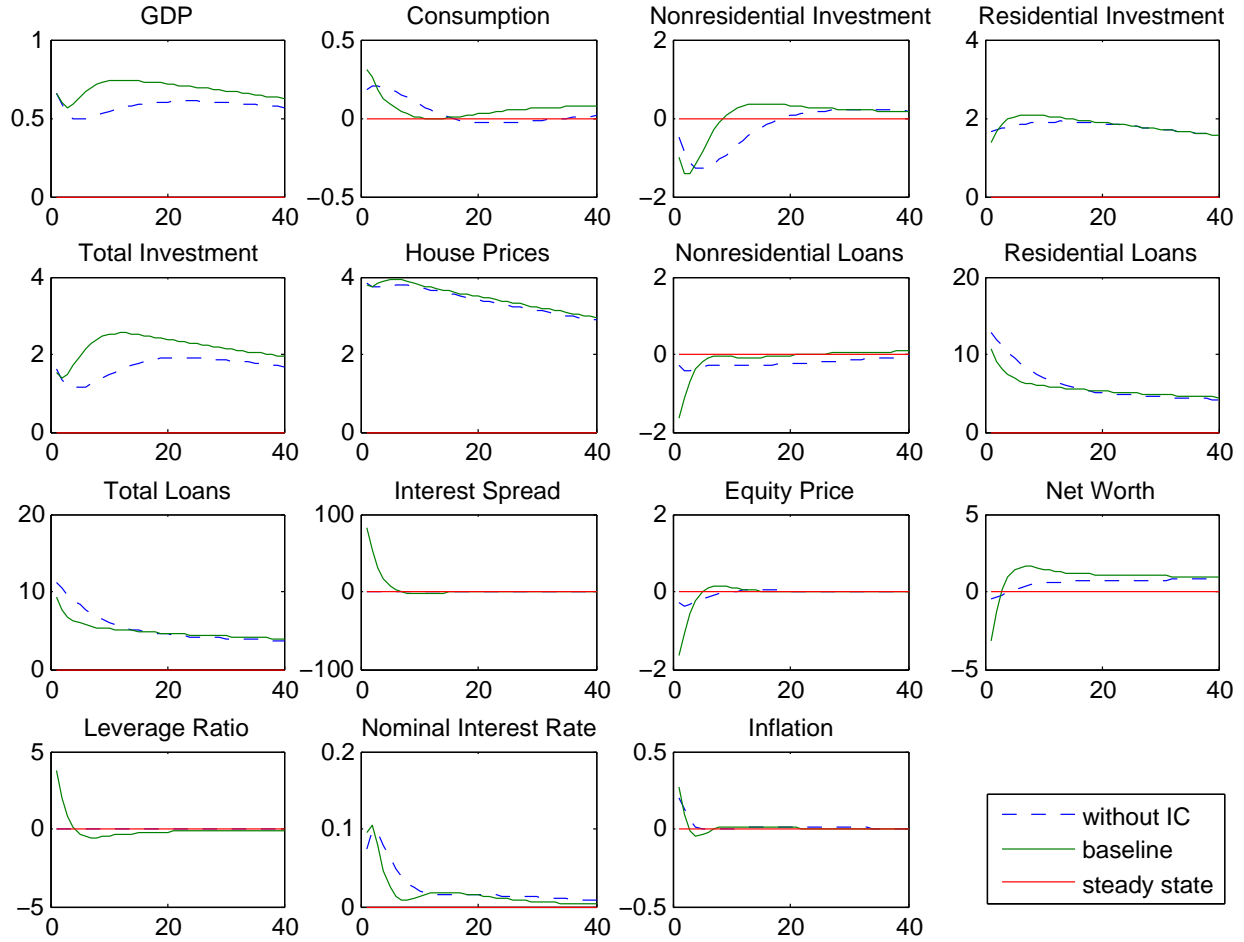


Figure 5: Impulse Responses to a Housing Preference Shock

Notes: The vertical axis measures percent deviation from the steady state.

## 5.2 Housing Preference Shocks

Figure 5 plots impulse responses to an estimated housing preference shock. The housing preference shock is the one type of housing demand shocks. In the baseline model, a positive housing preference shock drives up housing demand and house prices, and in turn, relaxes the collateral constraints of borrowers. Consequently, residential loans increase. Aggregate consumption rises on impact as a consequence of the increase in consumption of credit-constrained households, even if consumption of unconstrained households falls. Since an increase in residential loans crowds out nonresidential loans, both nonresidential investment and equity prices fall over time. In particular, when the demand for capital decreases, equity prices must fall, and thus a drop in net worth. So long as net worth is below the trend, the spread must rise. Similar to the case with capital quality shocks, bank leverage rises on impact as an outcome of the decline in net worth. When both consumption and residential investment increase, GDP rises over time, even if nonresidential investment falls.

### 5.3 Other Shocks

Next, we summarize the responses of aggregate variables to the other shocks (not reported).<sup>11</sup> A contractionary monetary shock reduces loans and house prices. The negative response of nonresidential investment to the shock is primarily due to a decline in nonresidential loans. When the demand for capital decreases, equity prices fall over time, and bank net worth is then reduced. Consequently, both the spread and leverage rise. The responses of consumption and residential investment to the shock are affected by the behaviors of households. In particular, a decrease in residential loans tightens the budget constraints of credit-constrained households, leading to a decline in consumption and housing demand. However, consumption and the housing demand of unconstrained households vary in a different way. Due to the substitution effects induced by the decline in house prices, consumption falls but housing demand rises. When the substitution effects dominate, aggregate consumption falls, and aggregate residential investment rises. Residential investment is sensitive to the interest rate only when wage rigidity is present, following [Iacoviello and Neri \(2010\)](#). Absent this friction, residential investment may rise in response to a contractionary monetary shock.

Positive technology shocks in the consumption goods sector drive up consumption, nonresidential investment, GDP and house prices, but crowd out residential investment, implying that the model with supply-side shocks alone is unable to account for the positive comovement between residential investment and house prices observed in the data. Positive technology shocks in the housing sector lead to an increase in consumption, residential investment and GDP, and a decrease in nonresidential investment and house prices. The negative comovement between residential investment and house prices reproduced by the model is a general outcome of the supply-side shocks. Positive LTV shocks would eventually drive up consumption, investment, GDP and house prices, thanks to a relaxation of collateral constraints.

## 6 Sensitivity Analysis

In this section, we investigate the ability of the model to match certain statistics observed in the data by shutting off one or more frictions or shocks or by changing the values of parameters which are fixed in the baseline model each time. [Table 5](#) reports the business cycle properties of the alternative models shutting off certain frictions or shocks.

Column (c) in [Table 5](#) reports the business cycle statistics of the model without capital quality shocks. A model without capital quality shocks underestimates the volatility in net worth and nonresidential loans, and leaves the business cycle statistics of other variables similar to that reproduced by the baseline model. Because the capital quality shock is one of the main driving forces in China's financial cycles, a removal of the shock inevitably reduces the volatility in these variables. In the baseline model, a negative capital quality shock directly lowers bank net worth and tightens the banks' incentive constraints, causing an amplified

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<sup>11</sup>Impulse responses to the other shocks are provided upon requests.

Table 5: Business Cycle Properties of the Alternative Models

Variables	Data	Baseline model	No capital quality shocks	No incentive constraints	<i>LTV</i> = 0.6	Full labor mobility	Homogenous labor preference
	(a)	(b)	(c)	(d)	(e)	(f)	(g)
<i>Panel A: SD of GDP and relative SD w.r.p.t GDP (%)</i>							
GDP	1.48	1.86	1.82	1.93	1.86	2.04	1.85
Consumption	0.78	0.75	0.73	0.70	0.71	0.68	0.76
Invest., capital	2.12	2.92	2.51	2.50	2.83	2.71	2.93
Invest., housing	6.49	3.66	3.71	3.57	3.63	6.89	3.66
House prices	2.83	2.78	2.80	2.74	2.83	1.92	2.79
Net worth	4.95	4.34	3.66	3.54	3.85	3.73	4.34
Loans, non-res.	2.46	1.80	1.60	0.88	1.51	1.51	1.80
Loans, res.	3.03	8.79	8.84	10.36	8.44	6.87	8.77
Deposits	1.96	2.12	2.11	2.60	1.74	1.75	2.13
Bank leverage	3.48	3.78	3.49	–	3.17	3.19	3.78
Inflation	0.39	0.38	0.35	0.33	0.33	0.28	0.38
Labor, total	0.91	1.22	1.22	1.10	1.11	1.12	1.19
<i>Panel B: Correlations with GDP</i>							
Consumption	0.38	0.66	0.70	0.68	0.68	0.39	0.66
Invest., capital	0.49	0.41	0.42	0.50	0.44	0.27	0.41
Invest., housing	0.57	0.58	0.60	0.57	0.59	0.69	0.58
House prices	0.13	0.54	0.55	0.50	0.55	0.48	0.54
Net worth	0.24	0.13	0.09	0.26	0.14	0.14	0.12
Loans, non-res.	0.25	0.17	0.12	0.45	0.26	0.19	0.17
Loans, res.	0.38	0.38	0.37	0.32	0.40	0.27	0.39
Deposits	0.29	0.48	0.46	0.39	0.54	0.35	0.48
Bank leverage	-0.12	0.08	0.12	0.01	0.08	0.02	0.09
Inflation	0.01	-0.03	-0.08	0.00	-0.08	-0.12	-0.04
Labor, total	0.20	0.55	0.57	0.60	0.63	0.63	0.55

effect on equity prices. Consequently, the volatility in net worth and nonresidential loans would be larger. To better account for the volatility in financial variables, capital quality shocks need to be incorporated in the model.

Column (d) in Table 5 reports the business cycle statistics of the model without incentive constraints. A version without incentive constraints overestimates the volatility in residential loans and deposits, and underestimates the volatility in net worth and nonresidential loans. In the absence of the incentive constraints, banks are allowed to accept more deposits from savers and issue more loans to their borrowers. Since borrowers can now borrow more funds from banks, their debt burdens will be driven up over time. As a result, the volatility in residential loans increases. Moreover, the model without incentive constraints would not generate an amplified effect on equity prices and leverage, and thus the volatility in net worth and nonresidential loans would be mitigated. Not surprisingly, a version without incentive constraints is unable to account for the volatility of the leverage ratio as in this case banks earn zero excess returns on their assets over liabilities so that the leverage remains constant over time. Last, the cyclicity of the variables reproduced by the model is quite similar to that reproduced by the baseline model, except for that in net worth and nonresidential loans. In particular, the procyclicality of net worth and nonresidential loans is enhanced in the version without incentive constraints.

Column (e) in Table 5 reports the business cycle statistics of the model with higher downpayment requirements. In the baseline model, the steady-state LTV ratio is fixed at 0.70. We now decrease the ratio to 0.60, reflecting that borrowers make more downpayment than before while borrowing funds from banks with their houses as collateral. Higher downpayment requirements lead to a decrease in the volatility of nonresidential loans, residential loans, deposits, net worth and leverage, and leave the volatility of other variables virtually unchanged. That a tightening of the LTV ratio depresses the volatility of financial variables is primarily attributed to the effects on the behaviors of impatient households. As the LTV ratio falls, impatient households would borrow less from the banks, and thus their debt burdens are mitigated. As a result, the volatility of residential loans falls, and thus the volatility in other financial variables. The cyclicity of the variables reproduced in this version of the model is quite similar to that in the baseline model.

Column (f) in Table 5 reports the business cycle statistics of the model with full labor mobility across the production sectors. In this version of the model, we assume that labor hours are perfect substitutes by setting the labor supply parameters  $\epsilon_p$  and  $\epsilon_i$  to zero. A version with full labor mobility exacerbates the volatility in residential investment and GDP, and attenuates the volatility in consumption, nonresidential investment, house prices, inflation and financial variables. The underlying reason is quite straightforward. With perfect labor mobility, households are more likely to substitute hours between the non-construction and construction sectors, exacerbating the fluctuations of hours in these sectors. Since households would like to substitute hours towards the construction sector away from the non-construction sector in response to a large housing demand shock, the volatility of hours in the construction sector rises, and thus the volatility

in residential investment and GDP. Moreover, the model with perfect labor mobility reproduces a larger procyclicality of residential investment, and a smaller procyclicality of nonresidential investment, relative to that in the baseline model. Recall that a positive housing demand shock would crowd out nonresidential investment, and in this way, residential investment rises and nonresidential investment falls. In the presence of perfect labor mobility, hours are more likely to shift to the construction sector, and consequently, the procyclicality of residential investment is raised, while the procyclicality of nonresidential investment is lowered.

Column (g) in Table 5 reports the business cycle statistics of the model with homogenous labor preferences. Recall that in the baseline model we assume that the two types of households differ in their labor supply parameters, reflecting the heterogenous labor supplied to a particular non-financial sector across households. We now constrain  $\eta$  and  $\epsilon$  to be the same across the two types of households in order to investigate the role of the homogenous labor preferences in accounting for several key properties of the business cycles. The business cycle statistics reproduced by the version with homogenous labor preferences are essentially unchanged, relative to that in the baseline model. Accordingly, the restriction of homogenous labor preferences does not matter for the simulated statistics of the business cycles.

## 7 Conclusion

In this paper, we develop and estimate a DSGE model with housing and banking to address several important questions related to the China's business cycles: Do the business cycle models with housing and banking better account for the volatility and cyclicity of macroeconomic variables in the China's business cycles? What are the main driving forces of the China's business cycles? We show that the estimated model fits the data very well, when it allows for an interaction between housing and banking. Capital quality, non-housing technology, housing demand and supply, LTV and labor supply shocks are the main driving forces of the China's business cycles, accounting for approximately 90 percent of the variations in most macroeconomic variables at business cycle frequencies. Of them, the contributions of financial and housing shocks (capital quality shocks, housing demand shocks and LTV shocks) to the fluctuations in the China's business cycles are particularly large, suggesting that these shocks are at the core of the China's business cycles in the past two decades.

The model presented in this paper could be extended in various directions to address a number of other issues associated with housing and financial cycles in China. For instance, what are the joint behaviors between land prices and financial factors in a general equilibrium framework? and how are the dynamics of the firm's leverage associated with financial factors over the business cycle? Since our baseline model rules out financial frictions tied to the firms, and does not pay more attentions to the land-price dynamics and its joint behaviors with financial fluctuations, these issues remain to be answered. To address these issues, one could extend our baseline model to introduce financial frictions (collateral constraints) tied to the firms

along the lines of [Liu et al. \(2013\)](#). Moreover, identifying and quantifying the source of business cycles are challenging but critical to the authorities while designing policies. This paper, however, provides a deeper understanding of the driving forces of the China's business cycles, and would increase the confidence in using this type of model for policy and welfare analysis. Perhaps, one could extend the model to investigate how monetary authority in China coordinates with macroprudential and fiscal authorities in an efficient way to tackle with financial risks sustained by a rapid growth of house prices and credit expansions. From our point of views, addressing these issues is challenging but important task in future research.

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# Appendix

## A Data and Sources

The following list includes all variables with sources we use in the Bayesian estimation and calculation of the business cycle moments reported in Table 3.

**Real Private Consumption:** Nominal Household Consumption Expenditure divided by Consumer Price Index (2005Q3 = 100), and divided by the Population. Source: China's Macroeconomic Time Series (CMTS) from Federal Reserve Bank of Atlanta (FRBA), <https://www.frbatlanta.org/cqer/research/china-macroeconomy.aspx?panel=1>.

**Real Residential Investment:** Nominal Residential Investment divided by Consumer Price Index (2005Q3 = 100), and divided by the Population. Source: CMTS from FRBA, <https://www.frbatlanta.org/cqer/research/china-macroeconomy.aspx?panel=1>.

**Real Nonresidential Investment:** Nominal Gross Fixed Capital Formation excluding government and residential investment divided by Consumer Price Index (2005Q3 = 100), and divided by the Population. Source: CMTS from FRBA, <https://www.frbatlanta.org/cqer/research/china-macroeconomy.aspx?panel=1>.

**Real Gross Domestic Product:** The sum of Real Private Consumption, Real Nonresidential Investment and Real Residential Investment. Source: CMTS from FRBA, <https://www.frbatlanta.org/cqer/research/china-macroeconomy.aspx?panel=1>.

**Real House Prices:** We first calculate the nominal housing price using the housing sales value and housing sales volume reported by the National Bureau of Statistics of China (NBSC). The nominal house price is normalized by setting 2005Q3 = 100. Then, we divide the nominal housing price by Consumer Price Index (2005Q3 = 100) to obtain the real housing price. Source: NBSC.

**Real Nonresidential Loans:** Loans to Non-financial Corporations and Others divided by Consumer Price Index (2005Q3 = 100), and divided by the Population. Source: Sources & Uses of Credit Funds of Financial Institutions (by Sectors), the People's Bank of China (PBC). Since the data on loans to non-financial firms is not available prior to 2007, we estimate it by multiplying aggregate loans (source: Sources & Uses of Credit Funds of Financial Institutions, PBC) by the loan ratio for the non-financial firms (source: China Banking Database (CBD)). We choose not to use the corresponding data series from CMTS (NonFinBusinessLoans), since the total bank loans from CMTS (BankLoansTotal) can be smaller in magnitude than the non-financial business loans for the early 2000, resulting in negative residential loans.

**Real Residential Loans:** Loans to Resident Sector divided by Consumer Price Index (2005Q3 = 100), and divided by the Population. Source: Sources & Uses of Credit Funds of Financial Institutions (by Sectors), PBC. Since the data on household loans is not available prior to 2007, we estimate it by multiplying aggregate loans (source: Sources & Uses of Credit Funds of Financial Institutions, PBC) by the loan ratio for the household sector (source: CBD).

**Real Household Deposits:** Deposits of Resident Sector divided by Consumer Price Index (2005Q3 = 100), and divided by the Population. Source: Sources & Uses of Credit Funds of Financial Institutions, PBC.

**Real Net Worth:** The sum of Real Nonresidential Loans and Real Residential Loans minus Real Household Deposits. Source: PBC.

**Bank Leverage Ratio:** The sum of Real Nonresidential Loans and Real Residential Loans divided by Real Net Worth. Source: PBC.

**Inflation:** Quarter on quarter log differences in Consumption Price Index (2005Q3 = 100). Source: FRBA, <https://www.frbatlanta.org/cqer/research/china-macroeconomy.aspx?panel=1>.

**Total Working Hours:** Total labor input measured in working hours are not available directly from the NBSC. Typical choice of labor series is the total employment in persons. However, this ignores the variations in working hours across time, hence potentially underestimates the fluctuations in labor input in aggregate. To overcome this shortcoming, we utilize the data of average weekly working hours per employed worker for the urban sector reported in China Labour Statistical Yearbook (CLSY) for each year in our sample periods, and then adjust this measure by considering the average weekly working hours per person for the rural area, which is based on data from the 2005 1% population survey and 2010 population census, both reported in CLSY as well. We construct the aggregate total working hours series by first interpolating the weekly working hours series in annual frequency to arrive at a measure in quarterly frequency, second multiplying the weekly working hours in quarterly frequency by the quarterly employment (interpolated from annual data from the NBSC), and lastly multiplying again by 13 to convert the weekly working hours into quarterly working hours. As for other observables, we divide the total quarterly working hours by the population to obtain the final total working hours series. Figure A.1 plots the aggregate working hours and weekly working hours over the sample periods considered in this paper. Evidently, there is considerable variation in average weekly working hours over time.

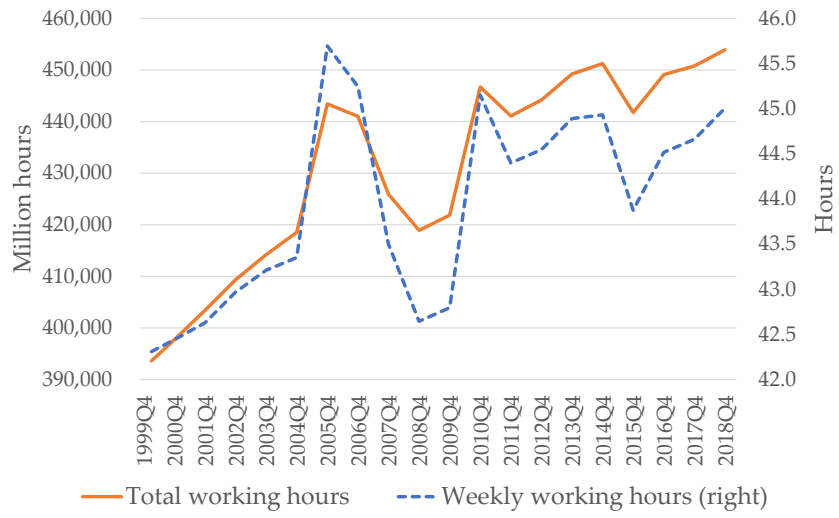


Figure A.1: Aggregate working hours and average weekly working hours

## B Dynamic System of the Baseline Model

$$u_{cp,t} = \Gamma_p \left( \frac{A_{p,t}}{c_{p,t} - \tau_p c_{p,t-1}} - \frac{\beta_p \tau_p A_{p,t+1}}{c_{p,t+1} - \tau_p c_{p,t}} \right) \quad (\text{B.1})$$

$$1 = \beta_p \mathbb{E}_t \left( \frac{u_{cp,t+1} R_{t+1}^d}{u_{cp,t} \pi_{t+1}} \right) \quad (\text{B.2})$$

$$q_t = \frac{A_{p,t} j_t}{u_{cp,t} h_{p,t}} + \beta_p \mathbb{E}_t \left[ \frac{u_{cp,t+1}}{u_{cp,t}} (1 - \delta_h) q_{t+1} \right] \quad (\text{B.3})$$

$$p_{x,t} = \beta_p \mathbb{E}_t \left[ \frac{u_{cp,t+1}}{u_{cp,t}} (p_{x,t+1} + R_{t+1}^x) \right] \quad (\text{B.4})$$

$$w_{pc,t} = \frac{A_{p,t} A_{n,t}}{u_{cp,t}} \left( l_{pc,t}^{1+\epsilon_p} + l_{ph,t}^{1+\epsilon_p} \right)^{\frac{\eta_p - \epsilon_p}{1+\epsilon_p}} l_{pc,t}^{\epsilon_p} \quad (\text{B.5})$$

$$w_{ph,t} = \frac{A_{p,t} A_{n,t}}{u_{cp,t}} \left( l_{pc,t}^{1+\epsilon_p} + l_{ph,t}^{1+\epsilon_p} \right)^{\frac{\eta_p - \epsilon_p}{1+\epsilon_p}} l_{ph,t}^{\epsilon_p} \quad (\text{B.6})$$

$$u_{ci,t} = \Gamma_i \left( \frac{A_{p,t}}{c_{i,t} - \tau_i c_{i,t-1}} - \frac{\beta_i \tau_i A_{p,t+1}}{c_{i,t+1} - \tau_i c_{i,t}} \right) \quad (\text{B.7})$$

$$\frac{A_{p,t} j_t}{u_{ci,t} h_{i,t}} + \beta_i \mathbb{E}_t \left[ \frac{u_{ci,t+1}}{u_{ci,t}} (1 - \delta_h) q_{t+1} \right] = q_t - \lambda_{i,t} m_t \mathbb{E}_t \left( \frac{q_{t+1} \pi_{t+1}}{u_{ci,t} R_{t+1}^b} \right) \quad (\text{B.8})$$

$$1 = \beta_i \mathbb{E}_t \left( \frac{u_{ci,t+1} R_{t+1}^b}{u_{ci,t} \pi_{t+1}} \right) + \frac{\lambda_{i,t}}{u_{ci,t}} \quad (\text{B.9})$$

$$w_{ic,t} = \frac{A_{p,t} A_{n,t}}{u_{ci,t}} \left( l_{ic,t}^{1+\epsilon_i} + l_{ih,t}^{1+\epsilon_i} \right)^{\frac{\eta_i - \epsilon_i}{1+\epsilon_i}} l_{ic,t}^{\epsilon_i} \quad (\text{B.10})$$

$$w_{ih,t} = \frac{A_{p,t} A_{n,t}}{u_{ci,t}} \left( l_{ic,t}^{1+\epsilon_i} + l_{ih,t}^{1+\epsilon_i} \right)^{\frac{\eta_i - \epsilon_i}{1+\epsilon_i}} l_{ih,t}^{\epsilon_i} \quad (\text{B.11})$$

$$b_t = m_t \mathbb{E}_t \left( \frac{q_{t+1} h_{i,t} \pi_{t+1}}{R_{t+1}^b} \right) \quad (\text{B.12})$$

$$c_{i,t} + q_t h_{i,t} + \frac{R_t^b b_{t-1}}{\pi_t} = w_{ic,t} l_{ic,t} + w_{ih,t} l_{ih,t} + q_t (1 - \delta_h) h_{i,t-1} + b_t \quad (\text{B.13})$$

$$w_{pc,t} = \alpha (1 - \mu_c) \frac{Y_t}{X_t l_{pc,t}} \quad (\text{B.14})$$

$$w_{ic,t} = (1 - \alpha) (1 - \mu_c) \frac{Y_t}{X_t l_{ic,t}} \quad (\text{B.15})$$

$$Z_t = \mu_c \frac{Y_t}{X_t k_t} \quad (\text{B.16})$$

$$\ln \pi_t - \iota \ln \pi_{t-1} = \beta_p [\mathbb{E}_t \ln(\pi_{t+1}) - \iota \ln \pi_t] - \frac{(1 - \lambda)(1 - \beta_p \lambda)}{\lambda} \ln \frac{X_t}{X} + u_{cp,t} \quad (\text{B.17})$$

$$Y_t = [A_{c,t} (l_{pc,t}^\alpha l_{ic,t}^{1-\alpha})]^{1-\mu_c} k_t^{\mu_c} \quad (\text{B.18})$$

$$w_{ph,t} = \alpha (1 - \mu_h) \frac{q_t l_{h,t}}{l_{ph,t}} \quad (\text{B.19})$$

$$w_{ih,t} = (1 - \alpha) (1 - \mu_h) \frac{q_t l_{h,t}}{l_{ih,t}} \quad (\text{B.20})$$

$$R_t^x = \mu_h \frac{q_t l_{h,t}}{x_{t-1}} \quad (\text{B.21})$$

$$I_{h,t} = [A_{h,t} (I_{ph,t}^\alpha I_{ih,t}^{1-\alpha})]^{1-\mu_h} x_{t-1}^{\mu_h} \quad (\text{B.22})$$

$$\Lambda_{t,t+1} = \beta_p \frac{u_{cp,t+1}}{u_{cp,t}} \quad (\text{B.23})$$

$$p_t = 1 + \frac{\chi_k}{2} \left( \frac{I_{k,t}}{I_{k,t-1}} - 1 \right)^2 + \chi_k \left( \frac{I_{k,t}}{I_{k,t-1}} - 1 \right) \frac{I_{k,t}}{I_{k,t-1}} - \chi_k \Lambda_{t,t+1} \left( \frac{I_{k,t+1}}{I_{k,t}} - 1 \right) \left( \frac{I_{k,t+1}}{I_{k,t}} \right)^2 \quad (\text{B.24})$$

$$v_{b,t} = \mathbb{E}_t \Lambda_{t,t+1} \Omega_{t+1} \frac{R_{t+1}^b}{\pi_{t+1}} \quad (\text{B.25})$$

$$v_{d,t} = \mathbb{E}_t \Lambda_{t,t+1} \Omega_{t+1} \frac{R_{t+1}^d}{\pi_{t+1}} \quad (\text{B.26})$$

$$v_{s,t} = \mathbb{E}_t \Lambda_{t,t+1} \Omega_{t+1} \psi_{t+1} [Z_{t+1} + (1 - \delta_k) p_{t+1}] \quad (\text{B.27})$$

$$\Omega_{t+1} = 1 - \sigma + \sigma (v_{d,t+1} + \phi_{t+1} \mu_{t+1}) \quad (\text{B.28})$$

$$\mu_t = \mathbb{E}_t \Lambda_{t,t+1} \Omega_{t+1} \left( R_{t+1}^k - \frac{R_{t+1}^d}{\pi_{t+1}} \right) \quad (\text{B.29})$$

$$R_{t+1}^k = \psi_{t+1} \frac{Z_{t+1} + (1 - \delta_k) p_{t+1}}{p_t} \quad (\text{B.30})$$

$$R_{t+1}^k = \frac{R_{t+1}^b}{\pi_{t+1}} \quad (\text{B.31})$$

$$p_t S_t + B_t = N_t + D_t \quad (\text{B.32})$$

$$p_t S_t + B_t = \phi_t N_t \quad (\text{B.33})$$

$$\phi_t = \frac{v_{d,t}}{\theta - \mu_t} \quad (\text{B.34})$$

$$N_t = (\sigma + \xi) \left\{ [Z_t + (1 - \delta_k) p_t] \psi_t S_{t-1} + \frac{R_t^b B_{t-1}}{\pi_t} \right\} - \sigma \frac{R_t^d D_{t-1}}{\pi_t} \quad (\text{B.35})$$

$$Y_t = C_t + \left[ 1 + \frac{\chi_k}{2} \left( \frac{I_{k,t}}{I_{k,t-1}} - 1 \right)^2 \right] I_{k,t} \quad (\text{B.36})$$

$$I_{h,t} = H_t - (1 - \delta_h) H_{t-1} \quad (\text{B.37})$$

$$S_t = I_{k,t} + (1 - \delta_k) K_t \quad (\text{B.38})$$

$$C_t = c_{p,t} + c_{i,t} \quad (\text{B.39})$$

$$H_t = h_{p,t} + h_{i,t} \quad (\text{B.40})$$

$$K_{t+1} = \psi_{t+1} [I_{k,t} + (1 - \delta_k) K_t] \quad (\text{B.41})$$

$$GDP_t = Y_t + q I_{h,t} \quad (\text{B.42})$$

$$\frac{R_t^d}{R^d} = \left( \frac{R_{t-1}^d}{R^d} \right)^{\alpha_r} \left[ \pi_t^{\alpha_\pi} \left( \frac{GDP_t}{GDP} \right)^{\alpha_y} \right]^{1-\alpha_r} \exp(u_{mp,t}) \quad (\text{B.43})$$

$$\ln \psi_t = \rho_k \ln \psi_{t-1} + u_{k,t} \quad (\text{B.44})$$

$$\ln A_{c,t} = \rho_c \ln A_{c,t-1} + u_{c,t} \quad (\text{B.45})$$

$$\ln A_{h,t} = \rho_h \ln A_{h,t-1} + u_{h,t} \quad (\text{B.46})$$

$$\ln A_{p,t} = \rho_p \ln A_{p,t-1} + u_{p,t} \quad (\text{B.47})$$

$$\ln A_{n,t} = \rho_n \ln A_{n,t-1} + u_{n,t} \quad (\text{B.48})$$

$$\ln m_t = (1 - \rho_m) \ln m + \rho_m \ln m_{t-1} + u_{m,t} \quad (\text{B.49})$$

$$\ln j_t = (1 - \rho_j) \ln j + \rho_j \ln j_{t-1} + u_{j,t} \quad (\text{B.50})$$