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Financial wealth, investment, and confidence in a DSGE model for China

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ABSTRACT

Based on a DSGE model, we investigate the interconnection between China's stock market and macroeconomic cycles. Our results show that consumption, investment, and capacity utilization exhibit significant and positive responses to stock market booms triggered by the financial and confidence shocks, while the responses of inflation are more muted and insignificant. There is a significant 'leaning-against-the-wind' reaction of China's monetary policy to the credit-to-GDP gap at business cycle frequencies. Decomposing stock prices into fundamental values influenced by the financial shock and bubbles driven by the confidence shock, the confidence shock's contribution to stock return fluctuations is estimated to be 14.8%.

1. Introduction

History is replete with scenarios where large swings in stock prices have coincided with prolonged booms and busts. As China's economy develops and financial markets deepen, stock market wealth becomes as an essential component of household wealth, while equity financing emerges as an important ingredient of corporate financing. China's stock market influences the business cycle mainly through three channels. First, stock prices affect consumption directly through household financial wealth and the equilibrium stochastic discount factor. Second, stock prices influence capital reallocation directly through firm value, borrowing capacity, and financial slack. Finally, stock prices impact the aggregate economy indirectly via interest rates, corporate loans, and inflation.

In panels (a) and (b) of Fig. 1, China's stock return, confidence growth, and loan growth all exhibit procyclicality, whereas interest rate displays slight countercyclicality. In particular, stock market booms seem to be accompanied by the increases in confidence, the growth in loans, the rises in interest rates, and the expansions in production.

Stock prices influence real activity mainly through financial wealth and collateral values, and subsequently, inflation and interest rates. Castelnuovo and Nisticò (2010), Funke et al. (2011), and Nisticò (2012) investigate the demand-side interaction between stock wealth and consumption in a Dynamic Stochastic General Equilibrium (DSGE) framework. By introducing a household turnover mechanism and examining intertemporal consumption smoothing, they find that stock prices are essential in influencing financial

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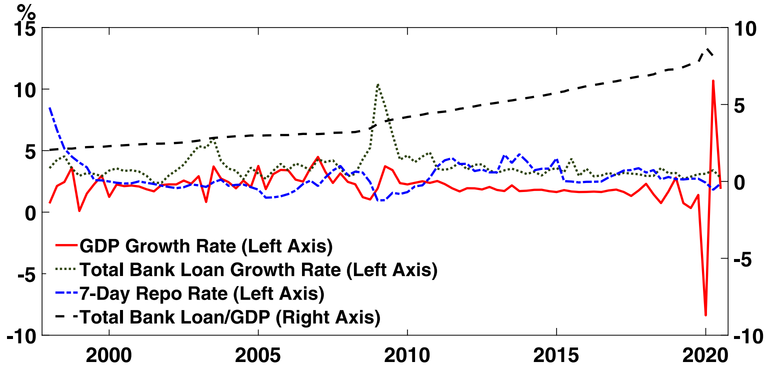
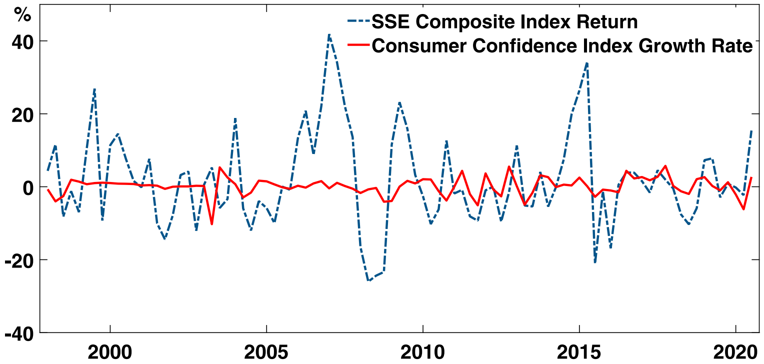


(a) GDP Growth, Loan Growth, Credit-to-GDP Ratio, and Interest Rate



(b) Stock Return and Consumer Confidence Index Growth

Fig. 1. Key macroeconomic and financial indicators. Note: Data stems from Chang et al. (2016) and Chen et al. (2016), CEIC, and Wind.

wealth and consumption, as well as identifying significant and counteractive responses of the central bank to financial slack (i.e., 'leaning against the wind'). Ikeda (2013) and Miao et al. (2015) study the supply-side interplay between stock bubbles and capital reallocation in a DSGE framework. By establishing a firm entry and exit mechanism and assessing intratemporal capital reallocation, they find that stock bubbles are crucial in affecting firms' borrowing capacity and investment, as well as quantifying an essential contribution of the sentiment shock to stock price fluctuations. However, the joint effects of China's financial wealth and capital reallocation have not yet been inspected in a DSGE framework. Besides, the roles of Chinese traders' confidence in driving stock bubble evolution and explaining stock price misalignments have not yet been examined explicitly.

In this paper, we develop and estimate a DSGE model that incorporates both the demand-side and supply-side interactions between China's stock market and macroeconomy. Our main findings are as follows. Stock market booms stimulate current consumption and investment by increasing stock wealth and enhancing borrowing capacity, respectively. We validate the coexistence of a financial wealth effect and a capital reallocation effect based on data for China's economy. We detect a significant rise in the 7-Day Interbank Repo Rate in response to the credit-to-GDP gap. Also, more than half of SSE Composite Index return fluctuations are attributable to the financial and confidence shocks.

This paper mainly contributes to the literature along four key dimensions.

First, we include both household and firm turnover mechanisms to capture China's financial wealth and capital reallocation effects. On the demand-side, individual consumption smoothing does not imply the same extent of aggregate consumption smoothing due to a household turnover mechanism. During a current stock market boom, all current households increase consumption, but in the next period, new households, who hold no financial wealth to smooth consumption and consume relatively less, replace the commensurate fraction of incumbent households, who use accumulated financial wealth to smooth consumption and consume relatively more, resulting in less expected future aggregate consumption than otherwise. The gap between current and expected future aggregate consumption widens, influencing equilibrium stochastic discount factor and creating a financial wealth effect. In consistency with Castelnuovo and Nisticò (2010), a higher household replacement rate is associated with a larger financial wealth effect. On the supply-side, recurrent stock bubbles facilitated by a firm turnover mechanism enhance borrowing capacity and ease credit constraints, stimulating firm investment and improving capacity utilization. Investment good price rises due to higher investment demand, and Tobin's marginal Q declines because of more capital accumulation, pushing up the idiosyncratic investment productivity shock's threshold. Firms with productivity above this threshold invest, and capital moves from unproductive to productive firms, creating a capital reallocation effect. Stock bubbles' intensive positive effect on productive investment typically exceeds extensive negative effect on unproductive investment, inducing positive net impacts on aggregate investment. When firm replacement rate increases and expected future aggregate stock bubble return exceeds a certain cutoff, new wholesale firms are more likely to contain stock bubbles than incumbent counterparts. More stock bubbles further lessen credit constraints, strengthen debt capacity, and bolster more investment. As investment may crowd out consumption, a higher firm replacement rate may weaken the financial wealth effect. China's data supports our DSGE model with both financial wealth and capital reallocation effects.

Second, Chen et al. (2020) contend that People's Bank of China (PBC) is mandated with maintaining financial stability and may attach higher priority to fighting inflation. Cecchetti et al. (2011) argue that central banks concerned with price stability, are likely to achieve superior performance by adjusting policy instruments, not only in response to inflation and output gaps, but also to their forecasts conveyed by asset price misalignments. PBC does not incorporate the stock price gap as a direct monetary policy target, but monitors stock markets from a macroeconomic perspective. Since excess stock market fluctuations exert effects on inflation expectations and stock price misalignments, the monetary policy rule is specified to respond to financial slack indirectly through a credit-to-GDP gap. We find a counteractive and significant reaction of China's monetary policy rule to the credit-to-GDP gap at business cycle frequencies.

Third, to investigate the interplay between the stock market and the production sector, our DSGE model is not only specified with variable capital utilization, capital accumulation, and credit constraints, but is also buffeted with the labor intensity, investment, financial, and confidence shocks. We specify the labor intensity shock to capture frictions in utilizing labor capacity, as well as incorporating capacity utilization data to explore impacts of pandemics on production. These specifications provide channels, which include labor efficiency, capacity utilization, financial slack, and investor perception, to examine the propagation of shocks in the production sector to the stock market.

Last but not least, our DSGE model quantifies the contributions of the financial and confidence shocks in driving China's stock return fluctuations. The financial shock, which captures financial frictions in corporate external financing, controls collateral constraint tightness, and affects borrowing capacity. The confidence shock, which reflects proportional size changes between old and new stock bubbles, conveys market expectations and affects credit limit. Both the financial and confidence shocks play essential roles in amplifying business cycles. In accordance with Miao et al. (2015)'s work, we find that stock bubbles relax corporate credit constraints and enhance firms' borrowing capacity, producing capital reallocation effects. Impulse responses suggest that output, consumption, and investment growth rates all exhibit positive and significant reactions to positive financial and confidence shocks, which induce stock market booms. Forecast error variance decompositions indicate that the financial and confidence shocks explain about 18.5% and 14.8% of SSE Composite Index return fluctuations, respectively.

This paper proceeds as follows. Section 2 lays out the theoretical model. Section 3 performs estimation. Section 4 elaborates on model dynamics. Section 5 concludes.

2. The benchmark DSGE model

The economy encompasses a household sector, a wholesale sector, a retail sector, a final good sector, a capital good sector, commercial banks, and monetary and fiscal authorities. Households offer labor service, possess deposits, consume final goods, pay taxes, trade bonds and equities. Capital producers convert final goods into investment goods. Wholesale firms acquire corporate loans, issue stocks, recruit labor, accumulate capital, produce and sell wholesale goods to retailers. Retailers transform homogeneous wholesale goods into heterogeneous retail goods. Final good firms bundle retail goods purchased from retailers into final goods, and sell them to households, capital producers, and the fiscal authority. Commercial banks absorb deposits from households and credit-unconstrained wholesale firms, and grant loans to credit-constrained wholesale firms. The fiscal authority imposes taxes and issues bonds to finance public spending. The monetary authority conducts monetary policies. Final good price and retail price are nominal variables.

2.1. The household sector

Household behavior is modeled in a similar way to the specifications of Castelnuovo and Nisticò (2010), Funke et al. (2011), and Nisticò (2012). The household sector comprises a unit continuum of cohorts. Intercohort heterogeneity classifies j-period-old households into cohort j as they enter financial markets at age j. Households in the same cohort display homogeneity, and cohort behavior is captured by the representative household behavior within each cohort. In each period, incumbent household traders face a probability ξ_H of dying, exiting financial markets, and being replaced by a commensurate fraction of new households with no financial wealth.[4] All households purchase consumption goods from final good firms, supply labor to wholesale firms, and pay taxes to the fiscal authority. Endowed with labor, all households own capital good firms and retail firms. Only incumbent household traders hold financial assets, and they trade financial assets at the end of each period.

Households of cohort j supply labor $H_t(j)$ to wholesale firms, and attain capital profits and retail proceeds. At the beginning of each period, cohort j possesses human wealth $HW_t(j)$, which is the present discounted sum of future labor wages $W_{t+\iota}\varepsilon_{H,t+\iota}H_{t+\iota}(j)$,[5] capital profits $\aleph_{K,t+\iota}(j)$, and retail proceeds $\int_0^1 \aleph_{Y,t+\iota}(z)dz$ from a continuum of retailers indexed by z, net of lump-sum taxes $T_{t+\iota}(j)$.

[4] In period t, aggregate household population $= \sum_{j=-\infty}^{t} \xi_H(1-\xi_H)^{t-j} = \xi_H \sum_{j=-\infty}^{t}(1-\xi_H)^{t-j} = 1$, where ξ_H is cohort size, and $(1-\xi_H)^{t-j}$ is cohort j's accumulated survival probability. In period 0, cohort j's average economic lifespan $= \sum_{t=0}^{+\infty}(1-\xi_H)^t = \frac{1}{\xi_H}$.

[5] Note that labor wages $W_{t+\iota}V_{H,t+\iota}H_{t+\iota}(i)$ are composed of real wage $W_{t+\iota}$, the labor intensity shock $V_{H,t+\iota}$, and labor hour endowment $H_{t+\iota}(i)$.

Given cohort homogeneity in labor productivity and firm ownership, wage income, profits, and taxes are uniformly distributed across cohorts and independent of index j:

$$HW_t(j) = E_t \sum_{\iota=0}^{+\infty} \chi_{t,t+\iota} \left(1-\xi_H\right)^{\iota} \pi_{t,t+\iota}[W_{t+\iota}\varepsilon_{H,t+\iota}H_{t+\iota} + \aleph_{K,t+\iota} + \int_0^1 \aleph_{Y,t+\iota}(z)dz - T_{t+\iota}] \tag{1}$$

where $\chi_{t,t+\iota}$ is equilibrium nominal stochastic discount factor. $\left(1-\xi_H\right)$ is household survival probability. $\pi_{t,t+\iota}$ is inflation from period t to period $t+\iota$.

Households of cohort j enter financial markets at age j. At the beginning of each period, incumbent cohort j obtains bond wealth $GW_t(j)$ from bond holdings $G_t(j)$, attains deposit wealth $DW_t(j)$ from deposit holdings $DE_t(j)$, and collects dividends $\int_0^1 D_t(i)di$ from shareholdings $\int_0^1 S_t(j,i)di$ indexed by firm i. Stock wealth $SW_t(j)$ consists of aggregate ex-dividend stock value $\int_0^1 P_{E,t}(i)S_t(j,i)di$ and aggregate dividend $\int_0^1 D_t(i)S_t(j,i)di$:

$$SW_t(j) = \int_0^1 [P_{E,t}(i) + D_t(i)]S_t(j,i)di \tag{2}$$

Incumbent household traders balance expenditure with income. Expenditure comprises consumption $C_t(j)$, tax payment T_t, new deposits $\frac{E_t[\pi_{t,t+1}DE_{t+1}(j)]}{R_{D,t}}$, purchase of stocks $\int_0^1 P_{E,t}(i)S_{t+1}(j,i)di$ and government bonds $E_t[\chi_{t,t+1}\pi_{t,t+1}G_{t+1}(j)]$.[6] Income includes wages $W_t\varepsilon_{H,t}H_t(j)$, capital profits $\aleph_{K,t}$, retail proceeds $\int_0^1 \aleph_{Y,t}(z)dz$, and financial wealth $FW_t(j)$, which contains bond wealth $GW_t(j)$, deposit wealth $DW_t(j)$, and a fractional stock wealth $(1-\xi_W)SW_t(j)$. Assuming no linkage between incumbent and new household traders, cohorts have no bequest motivation and private insurance firms supply insurance risklessly. In each period, cohort j obtains a fractional financial wealth $\frac{FW_t(j)}{1-\xi_H}$ from insurance firms if its households survive, but pays its entire financial wealth $FW_t(j)$ to insurance firms if its households exit. The insurance contract's gross yield, which is the inversed household survival probability $\frac{1}{1-\xi_H}$, arises from redistributing financial wealth of exiting households among surviving households within the same cohort. Without bequest incentive, cohort j consumes all its resources and ensures a binding budget constraint in each period. Similar to Kocherlakota (2009), the existence of stock bubbles requires that the incumbent cohort j holds a non-negative bank deposit $DE_{t+1}(j) \geq 0$:

$$\begin{aligned} &C_t(j) + \int_0^1 [P_{E,t}(i) + D_t(i)]S_{t+1}(j,i)di + E_t[\chi_{t,t+1}\pi_{t,t+1}G_{t+1}(j)] + \frac{E_t[\pi_{t,t+1}DE_{t+1}(j)]}{R_{D,t}} \\ &+T_t \leq W_t\varepsilon_{H,t}H_t(j) + \aleph_{K,t} + \int_0^1 \aleph_{Y,t}(z)dz + \frac{GW_t(j)}{1-\xi_H} + \frac{DW_t(j)}{1-\xi_H} + \frac{1-\xi_W}{1-\xi_H}SW_t(j) \end{aligned} \tag{3}$$

New household traders' budget constraint reduces to Eq. (4). Consumption $C_t(j)$ and taxes T_t are funded by capital profits $\aleph_{K,t}$, retail proceeds $\int_0^1 \aleph_{Y,t}(z)dz$, and wages $W_t\varepsilon_{H,t}H_t(j)$:

$$C_t(j) + T_t = W_t\varepsilon_{H,t}H_t(j) + \aleph_{K,t} + \int_0^1 \aleph_{Y,t}(z)dz \tag{4}$$

Because households derive utility from consumption but incur disutility from working, cohort j's utility function is increasing and concave in habit-adjusted consumption $\widetilde{C_t(j)}$, which is the difference between current consumption $C_t(j)$ and a fraction ς of past consumption $C_{t-1}(j)$, but is decreasing and convex in supply of efficient labor service $\varepsilon_{H,t}H_t(j)$. Following Auernheimer and Trupkin (2014)'s variable labor utilization, we normalize household time endowment to 1, and embed the labor intensity shock $\varepsilon_{H,t}$ into utility via effective leisure $[1-\varepsilon_{H,t}H_t(i)]$.[7] The intertemporal preference shock $\varepsilon_{P,t}$, which generates impacts on utilities in adjacent periods, follows an autoregressive of order one [AR(1)] process in logs driven by an independently and identically distributed normal $(i.i.d.N)$ innovation $\epsilon_{P,t} \sim N(0,\sigma_P^2)$. The labor intensity shock $\varepsilon_{H,t}$, which measures the extent of utilizing labor capacity and captures hour loss during unexpected public events,[8] follows an AR(1) process in logs driven by an innovation $\epsilon_{H,t} \sim i.i.d.N(0,\sigma_H^2)$, In period 0, the representative household of cohort j optimally chooses consumption $C_t(j)$, labor hours $H_t(j)$, and a portfolio of deposits $DE_{t+1}(j)$, government bonds $G_{t+1}(j)$, and equity shares $\int_0^1 S_{t+1}(j,i)di$ to maximize expected lifetime utility $U_0(j)$:

$$U_0(j) = E_0 \sum_{t=0}^{+\infty} \beta^t \left(1-\xi_H\right)^t \varepsilon_{P,t}\{ln[C_t(j) - \varsigma C_{t-1}(j)] + \varrho ln[1-\varepsilon_{H,t}H_t(j)]\} \tag{5}$$

where discount factor β conveys consumption impatience, survival probability $\left(1-\xi_H\right) \in (0,1)$, leisure weight $\varrho \in (0,+\infty)$, habit persistence parameter ς measures habit formation intensity and introduces inseparability of periodic preferences, subject to a sequence of intertemporal budget constraints in Eq. (3) and non-negative deposit constraints $DE_{t+1}(j) \geq 0$.[9]

6 Equilibrium stochastic discount factor $\chi_{t,t+1}$ discounts future bond payoffs and, under a no-arbitrage condition, it equals the government bond price, which is the inversed riskless gross interest rate $\frac{1}{Rn_t}$.

7 The labor intensity shock ranges between 0 and 1, with 1 denoting full utilization of labor service.

8 For example, the COVID-19 Pandemic, which triggers a labor intensity shock with a size less than one, lowers labor hours worked due to government containment policies.

9 Because cohort j has no collateralized assets, it can neither borrow nor issue stocks.

First order conditions are derived in Appendix A. The intratemporal substitution between consumption $C_t(j)$ and labor service $H_t(j)$ elucidates that wage W_t accords with marginal rate of substitution of leisure $[LE_t(j) = 1 - \varepsilon_{H,t} H_t(j)]$ for consumption $C_t(j)$[10]:

$$\frac{[C_t(j) - \varsigma C_{t-1}(j)]\varrho\varepsilon_{H,t}}{1 - \varepsilon_{H,t} H_t(j)} = W_t \tag{6}$$

Intertemporal conditions of consumption $C_t(j)$ and government bond holdings $G_{t+1}(j)$ express equilibrium nominal stochastic discount factor $\chi_{t,t+1}$, which discounts future fund flows, as intertemporal substitution in consumption $[\frac{\Delta C_t(j)}{\Delta C_{t+1}(j)} = \frac{MU_{C,t+1}(j)}{MU_{C,t}(j)}]$ multiplied by subjective discount factor β, divided by future inflation $\left(\pi_{t,t+1} = \frac{P_{Y,t+1}}{P_{Y,t}}\right)$, and driven by the ratio of future preference shock $\varepsilon_{P,t+1}$ to current preference shock $\varepsilon_{P,t}$:

$$\chi_{t,t+1} = \frac{\beta\varepsilon_{P,t+1} MU_{C,t+1}(j) P_{Y,t}}{\varepsilon_{P,t} MU_{C,t}(j) P_{Y,t+1}} \tag{7}$$

where $MU_{C,t}(j)$ is marginal utility of consumption, and $P_{Y,t}$ is final good price.

The intertemporal condition of deposit holdings $DE_{t+1}(j)$ ensures the inversed deposit interest rate $\frac{1}{R_{D,t}}$ no less than equilibrium nominal stochastic discount factor $\chi_{t,t+1}$:

$$\frac{1}{R_{D,t}} \geq \chi_{t,t+1} \tag{8}$$

The intertemporal condition of shareholdings $S_{t+1}(j,i)$ makes ex-dividend stock value $P_{E,t}(i)$ equal the expected sum of future ex-dividend stock value $P_{E,t+1}(i)$ and dividends $D_{t+1}(i)$, both of which are multiplied by future inflation $\pi_{t,t+1}$, equilibrium nominal stochastic discount factor $\chi_{t,t+1}$, and wholesale firm survival probability $(1 - \xi_W)$:

$$P_{E,t}(i) = (1 - \xi_W) E_t\{\chi_{t,t+1}\pi_{t,t+1}[P_{E,t+1}(i) + D_{t+1}(i)]\} \tag{9}$$

The government bond pays one unit of currency in the next period with certainty, and its return equals the ex ante nominal gross interest rate Rn_t. Given no-arbitrage, the government bond price coincides with the nominal stochastic discount factor $\chi_{t,t+1}$:

$$Rn_t E_t \chi_{t,t+1} = E_t R_{t+1} E_t \pi_{t,t+1} E_t \chi_{t,t+1} = 1 \tag{10}$$

where $E_t R_{t+1}$ is ex post real gross interest rate, $E_t \pi_{t,t+1}$ is expected future inflation. Aggregation across cohorts yields generation-specific per capita variables in Appendix B.

The evolution of aggregate consumption in Eq. (11) elucidates the financial wealth effect. The product of habit-adjusted aggregate consumption $\widetilde{C}_t$ and the component $\left(\frac{1}{MPC_t} - 1\right)$ is the present discounted weighted average of future aggregate bond wealth GW_{t+1}, deposit wealth DW_{t+1}, stock wealth SW_{t+1}, and the ratio of future habit-adjusted aggregate consumption $\widetilde{C_{t+1}}$ to marginal propensity to consume MPC_{t+1}, with weights given by ξ_H, ξ_H, $\xi_H\left(1 - \xi_W\right)$, and $\left(1 - \xi_H\right)$, respectively:

$$\begin{aligned}\left(\frac{1}{MPC_t} - 1\right)\widetilde{C}_t = {} & E_t\{\chi_{t,t+1}\pi_{t,t+1}[\xi_H GW_{t+1} + \xi_H DW_{t+1} \\ & + \xi_H\left(1 - \xi_W\right) SW_{t+1} + \left(1 - \xi_H\right)\frac{\widetilde{C_{t+1}}}{MPC_{t+1}}]\}\end{aligned} \tag{11}$$

where ξ_H is household replacement rate. ξ_W is firm replacement rate.

A current stock market boom stimulates current consumption of all households. In the next period, a fraction ξ_H of incumbent household traders are replaced by a commensurate fraction of new household entrants, incumbent households use accumulated financial wealth to smooth consumption and consume relatively more, whereas new households have no financial wealth to smooth consumption and consume relatively less. New household entrants in the next period do not enter current stock market so that their wealth and consumption in the next period are not affected by current stock market booms. Because the household turnover mechanism introduces heterogeneity into financial wealth and consumption, individual consumption smoothing does not carry over in aggregate terms. A current stock market boom boosts current habit-adjusted aggregate consumption $\widetilde{C}_t$ more than expected future counterpart $\widetilde{C_{t+1}}$, and widens the gap between current and expected future aggregate consumption, creating a financial wealth effect.

A larger financial wealth effect is associated with a higher household replacement rate ξ_H. When the household replacement rate increases, more newcomers' consumption in the next period is less affected by current stock market booms, less aggregate consumption smoothing in the next period indicates less expected future aggregate consumption, and the wedge between current and expected future aggregate consumption widens further. A larger financial wealth effect is also related to more expected future aggregate stock wealth SW_{t+1}. When households anticipate more future aggregate stock wealth, all current households increase consumption smoothing and bolster current consumption to a larger extent.

When the firm replacement rate ξ_W increases, more new wholesale firms replace incumbent counterparts. Conditioning on that expected future aggregate stock bubble return $\frac{E_t[\chi_{t,t+1}(O_{t+1}+1)B^*_{t+1}]}{B^*_t}$ exceeds a certain threshold, new wholesale firms are more likely to

[10] The marginal rate of substitution $[MRS_t(j) = \frac{\Delta LE_t(j)}{\Delta C_t(j)} = \frac{\frac{\partial U_t(j)}{\partial C_t(j)}}{\frac{\partial U_t(j)}{\partial H_t(j)}\frac{dH_t(j)}{dLE_t(j)}}]$, which is equivalent to the ratio of the marginal disutility of labor service $\frac{\varrho\varepsilon_{H,t}}{1-\varepsilon_{H,t}H_t(j)}$ to the marginal utility of consumption $\frac{1}{C_t(j)}$, is linear in consumption and guarantees the existence of a balanced-growth path.

contain stock bubbles than incumbent counterparts according to Appendix D.[11] More stock bubbles imply looser credit constraints, and more financial resources for new wholesale firms with newborn stock bubbles, in comparison with incumbent counterparts. Given the aforementioned threshold condition, a higher firm replacement rate pertains to more stock bubbles and higher credit limits, stimulating more investment. The subsequent investment increment crowds out consumption and reduces the gap between current and expected future aggregate consumption, contaminating the stock wealth effect. Compared with Castelnuovo and Nisticò (2010)'s analysis, the financial wealth effect is smaller, because the weight ξ_H for expected future stock wealth $E_t(\chi_{t,t+1}\pi_{t,t+1}SW_{t+1})$ is weaken by the firm replacement rate ξ_W. As the firm replacement rate ξ_W increases, expected future financial wealth is discounted further to have a smaller weight $\xi_H(1-\xi_W)$. Given that household replacement estimates exceed firm replacement estimates in most cases in the literature, the positive influence of stock wealth on consumption generally dominates over the negative crowding out impact of investment on consumption.

2.2. The wholesale sector

Resembling the specifications of Ikeda (2013) and Miao et al. (2015), the wholesale sector includes a unit continuum of heterogeneous wholesale firms. The γ-period-old wholesale firm, which is set up in period $t-\gamma$ and indexed by i, launches into the stock market by issuing new shares in period t. Firm i purchases investment goods $I_t(i)$ from capital producers at investment good price $P_{I,t}$ in a perfectly competitive investment good market, and recruits efficient labor service $\varepsilon_{H,t}H_t(i)$ from households at wage W_t in a perfectly competitive labor market. Wholesale firms produce homogeneous wholesale goods, and sell them to retailers in a perfectly competitive wholesale market. Incumbent wholesale firms face a probability ξ_W of exiting financial markets and being replaced by new counterparts.[12] Financial resources of exiting wholesale firms are reallocated to the surviving counterparts. Endowed with startup capital K_{0t}, new wholesale firms enter the stock market without entrance cost, operate identically to incumbent counterparts, and bring in new stock bubbles with a probability τ_B. Firm i employs a Cobb–Douglas technology to produce wholesale goods $M_t(i)$ by combining utilized capital $U_{K,t}(i)K_t(i)$, efficient labor service $\varepsilon_{H,t}H_t(i)$, and aggregate efficiency captured by the total factor productivity shock $\varepsilon_{A,t}$, which follows an AR(1) process in logs with an innovation $\epsilon_{A,t} \sim i.i.d.N(0,\sigma_A^2)$:

$$M_t(i) = \varepsilon_{A,t}[U_{K,t}(i)K_t(i)]^{\alpha}[\varepsilon_{H,t}H_t(i)]^{1-\alpha} \tag{12}$$

where $U_{K,t}(i)$ is capital utilization rate, the labor intensity shock $\varepsilon_{H,t}$ controls labor utilization, $\alpha \in (0,1)$ and $(1-\alpha)$ are elasticities of wholesale production $M_t(i)$ with respect to utilized capital $U_{K,t}(i)K_t(i)$ and efficient labor service $\varepsilon_{H,t}H_t(i)$, respectively.

Firm i accumulates capital $K_{t+1}(i)$ by combining undepreciated capital $\{1-\delta[U_{K,t}(i)]\}\ K_t(i)$ with investment $I_t(i)$,[13] perturbed by the idiosyncratic investment shock $\varepsilon_{I,t}(i)$ and the aggregate marginal efficiency of investment shock $\varepsilon_{\mu,t}$, which follows an AR(1) process in logs driven by an innovation $\epsilon_{\mu,t} \sim i.i.d.N(0,\sigma_\mu^2)$. A positive marginal efficiency of investment shock enhances aggregate investment efficiency. Firm i selects optimal capital utilization endogenously before observing the idiosyncratic investment shock:

$$K_{t+1}(i) = \{1-\delta[U_{K,t}(i)]\}K_t(i) + \varepsilon_{\mu,t}\varepsilon_{I,t}(i)I_t(i) \tag{13}$$

Drawing on Liu and Wang (2014), transitory investment shocks, which gauge wholesale firms' idiosyncratic investment productivity, are independently, identically, and normally distributed across firms and over time. Before production, wholesale firm i is subject to an idiosyncratic investment shock $\varepsilon_{I,t}(i)$ from a Pareto distribution defined over the support region $[1,+\infty)$, with a cumulative probability distribution function Φ:

$$\Phi(\varepsilon_I) = 1 - \varepsilon_I^{-\kappa} \tag{14}$$

where shape parameter $\kappa > 1$ controls the dispersion of Pareto distribution.

Wholesale firms finance by issuing shares $S_t(i)$ to households and getting loans $L_t(i)$ from commercial banks. The γ-period-old wholesale firm i's value $V_{t,\gamma}[K_t(i), L_t(i), \varepsilon_{\mu,t}, \varepsilon_{I,t}(i)]$ hinges on capital asset $K_t(i)$, corporate loan liability $L_t(i)$, the marginal efficiency of investment shock $\varepsilon_{\mu,t}$, and the idiosyncratic investment shock $\varepsilon_{I,t}(i)$. Prior to investment, wholesale firm i acquires working capital by purchasing investment goods from capital producers and hiring labor from households, and promises a fraction $\varepsilon_{L,t}$ of capital assets $K_t(i)$ as a collateral for borrowing from commercial banks, due to costly state verification and monitoring expenses. The collateral fraction $\varepsilon_{L,t}$ represents the loan-to-value shock. Wholesale firm i faces a credit constraint such that the budget limit of investment cost $P_{I,t}I_t(i)$ and labor wages $W_t\varepsilon_{H,t}H_t(i)$ equals firm value adjusted by survival rate $(1-\xi_W)$:

$$P_{I,t}I_t(i) + W_t\varepsilon_{H,t}H_t(i) \le (1-\xi_W)E_t\chi_{t,t+1}V_{t+1,\gamma+1}[\varepsilon_{L,t}K_t(i), L_{t+1}(i), \varepsilon_{\mu,t+1}, \varepsilon_{I,t+1}(i)] \tag{15}$$

[11] New wholesale firms enter the stock market with a probability τ_B of containing stock bubbles, a stock bubble bursts before or on its associated wholesale firm's death, and a new stock bubble cannot reemerge in the same incumbent wholesale firm after bursting, due to no-arbitrage.

[12] In period t, wholesale firm number $= \sum_{\gamma=0}^{+\infty}\xi_W(1-\xi_W)^{\gamma} = \xi_W\sum_{\gamma=0}^{+\infty}(1-\xi_W)^{\gamma} = 1$, where ξ_W is firm size, $(1-\xi_W)^{\gamma}$ is the γ-period-old firms' accumulated survival probability. In period 0, the γ-period-old firms' average business lifespan $= \sum_{t=0}^{+\infty}(1-\xi_W)^t = \frac{1}{\xi_W}$, preventing the wholesale sector from eventually accumulating sufficient income to be fully self-financing.

[13] Capital depreciation rate $\delta[U_{K,t}(i)]$ is an increasing, convex, and twice continuously differentiable function of capital utilization rate $U_{K,t}(i)$ with function range [0,1], because using capital more intensively incurs higher cost and raises the rate at which capital depreciates.

Funds generated by revenues $P_{W,t}M_t(i)$ and loans $\frac{L_{t+1}(i)}{R_{L,t}}$ are allocated as dividend outlay $D_t(i)$,[14] loan repayment $L_t(i)$, investment expenses $P_{I,t}I_t(i)$, and wage bills $W_t\varepsilon_{H,t}H_t(i)$:

$$D_t(i) + L_t(i) + P_{I,t}I_t(i) + W_t\varepsilon_{H,t}H_t(i) = P_{W,t}M_t(i) + \frac{L_{t+1}(i)}{R_{L,t}} \tag{16}$$

Wholesale firm i chooses optimal labor $H_t(i)$ to maximize operating proceeds in terms of wholesale income $P_{W,t}M_t(i)$ less working capital $W_t\varepsilon_{H,t}H_t(i)$, given wage W_t, capital utilization rate $U_{K,t}$, wholesale price $P_{W,t}$, and final good price $P_{Y,t}$:

$$max_{H_t(i)} P_{W,t}M_t(i) - W_t\varepsilon_{H,t}H_t(i) \tag{17}$$

subject to wholesale technological constraint in Eq. (12), with derivations in Appendix C. The first order condition with respect to labor $H_t(i)$ yields optimal labor:

$$H_t(i) = [\frac{P_{W,t}(1-\alpha)\varepsilon_{A,t}}{W_t}]^{\frac{1}{\alpha}} \frac{U_{K,t}(i)K_t(i)}{\varepsilon_{H,t}} \tag{18}$$

Wholesale firm i chooses optimal investment $I_t(i)$ and loans $L_{t+1}(i)$ to maximize dividends $D_t(i)$ implied by value function $V_{t,\gamma}[K_t(i), L_t(i), \varepsilon_{\mu,t}, \varepsilon_{I,t}(i)]$ subject to capital accumulation in Eq. (13), credit constraint, and flow-of-funds constraint, with derivations in Appendix C. The first order condition with respect to investment $I_t(i)$ determines the Lagrange multiplier $\lambda_{W,t}(i)$, representing the net gain of additional investment:

$$\lambda_{W,t}(i) = \frac{Q_t^*\varepsilon_{I,t}(i)}{P_{I,t}} - 1 = \frac{\varepsilon_{I,t}(i)}{\varepsilon_{I,t}^*} - 1 \geq 0 \tag{19}$$

The idiosyncratic investment shock's time-varying threshold ($\varepsilon_{I,t}^* = \frac{P_{I,t}}{Q_t^*}$) is the ratio of investment good price $P_{I,t}$ to capital's shadow price Q_t^*. Marginal cost of investment is investment good price $P_{I,t}$, and marginal benefit of investment is capital's shadow price Q_t^* multiplied by the idiosyncratic investment shock $\varepsilon_{I,t}(i)$. When the idiosyncratic investment shock $\varepsilon_{I,t}(i)$ exceeds its threshold $\varepsilon_{I,t}^*$, marginal benefit $Q_t^*\varepsilon_{I,t}(i)$ rises above marginal cost $P_{I,t}$, and investment return is high, firm i incurs a productive investment opportunity and operates at full capacity with a binding credit constraint. Otherwise, firm i incurs an unproductive investment and remains inactive with a non-binding credit constraint. With credit tightness being contingent on investment productivity, credit-constrained wholesale firms borrow from commercial banks, whereas credit-unconstrained counterparts deposit at commercial banks. The aggregate stock bubble B_t^* influences capital's shadow price, investment productivity threshold, and the number of investing firms $\int_{\varepsilon_I \geq \varepsilon_{I,t}^*} d\Phi(\varepsilon_I)$. Efficient production reallocates capital from unproductive to productive wholesale firms, inducing a capital reallocation effect. Stock bubble $B_{t,\gamma}^*$ enters optimal firm investment such that higher investment $I_t(i)$ pertains to a larger stock bubble:

$$P_{I,t}I_t(i) = \begin{cases} [R_{K,t}U_{K,t}(i) + \varepsilon_{L,t}Q_t^* + \varepsilon_{E,t}]K_t(i) + B_{t,\gamma}^* - L_t(i) & if \;\; \varepsilon_{I,t}(i) \geq \varepsilon_{I,t}^* \\ 0 & if \;\; \varepsilon_{I,t}(i) < \varepsilon_{I,t}^* \end{cases} \tag{20}$$

Stock bubbles' expected benefit O_t includes dividends $(\frac{\varepsilon_I}{\varepsilon_{I,t}^*} - 1)$ generated by additional investment when the idiosyncratic investment shock $\varepsilon_{I,t}(i)$ exceeds its cutoff level $\varepsilon_{I,t}^*$:

$$O_t = \int_{\varepsilon_I \geq \varepsilon_{I,t}^*} (\frac{\varepsilon_I}{\varepsilon_{I,t}^*} - 1) d\Phi(\varepsilon_I) \tag{21}$$

Higher capital utilization $U_{K,t}$ generates investment benefits $R_{K,t}$ and additional dividends $O_tR_{K,t}$ at the cost of faster capital depreciation $\delta'(U_{K,t})Q_t^*$. Capital utilization's marginal benefit $(1+O_t)R_{K,t}$ accords with associated marginal cost $\delta'(U_{K,t})Q_t^*$, delivering the common optimal capital utilization rate $U_{K,t}$ for all wholesale firms:

$$(1 + O_t)R_{K,t} = \delta'(U_{K,t})Q_t^* \tag{22}$$

A stock bubble $B_{t,\gamma}^*$ is not predetermined. If no one believes in bubbles, then stock bubbles $\{B_{t+\iota,\gamma+\iota}^*\}_{\iota=0}^{+\infty}$ cannot exist. Otherwise, there is a non-zero stock bubble in equilibrium. Stock bubbles not only ease credit constraints by increasing wholesale firm value and improving borrowing capacity, but also generate additional benefits O_t by stimulating firm investment and improving capital allocation. These benefits O_t capture liquidity premiums and ensure that the stock bubble growth rate $\frac{B_{t+1,\gamma+1}^*}{B_{t,\gamma}^*}$ does not exceed nominal interest rate Rn_t. Transversality conditions cannot exclude stock bubbles. Because benefits attached to productive capital are identical to dividends, stock bubbles coexist with fundamental assets in dynamically efficient economies. The no-arbitrage condition of stocks S_t, which pertain to wholesale firms born in period $t-\gamma$, determines the stock bubble size by ensuring that the cost $B_{t,\gamma}^*$ of sustaining stock bubbles accords with the expected benefit, which is the present discounted sum of future stock bubble $B_{t+1,\gamma+1}^*$ and additional investment's dividends $O_{t+1}B_{t+1,\gamma+1}^*$ adjusted by survival rate $(1-\xi_W)$:

$$B_{t,\gamma}^* = (1-\xi_W)E_t[\chi_{t,t+1}(1+O_{t+1})B_{t+1,\gamma+1}^*] \tag{23}$$

[14] Negative dividends indicate new equity issuance, whereas negative loans imply firm saving.

The aforementioned equations are proved in Appendix C. Stock price movements reflect expectations about future stock market wealth and convey beliefs regarding future stock market capitalization. Stock traders believe new stocks may contain a bubble of size ($B^*_{t,0} = b^*_t$) with a probability τ_B in period t, and the expected aggregate new bubble is $\xi_W \tau_B b^*_t$. The confidence shock $\varepsilon_{C,t}$, which follows an AR(1) process in logs driven by an innovation $\epsilon_{C,t} \sim i.i.d.N(0, \sigma^2_C)$, conveys a time-varying expectation about stock bubble evolution and drives the expected stock bubble ratio $\frac{B^*_{t+\gamma,\gamma}}{B^*_{t+\gamma,\gamma-1}}$, which measures the relative size of stock bubbles in period $t+\gamma$ for wholesale firms set up in period t and period t+1:

$$\frac{B^*_{t+\gamma,\gamma}}{B^*_{t+\gamma,\gamma-1}} = \varepsilon_{C,t} \tag{24}$$

The aggregate behavior of wholesale firms is derived in Appendix D. The combination of the equity issuance shock $\varepsilon_{E,t}$ divided by the expected capital value Q^*_t and the loan-to-value shock $\varepsilon_{L,t}$ defines the financial shock $\varepsilon_{F,t}$, which follows an AR(1) process in logs driven by an innovation $\epsilon_{F,t} \sim i.i.d.N(0, \sigma^2_F)$. The financial shock captures equity issuance frictions in stock markets, measures collateral constraint tightness in credit markets, and controls firm borrowing capacity:

$$\varepsilon_{E,t} K_t + Q^*_t \varepsilon_{L,t} K_t + B^*_{t,\gamma} = (\frac{\varepsilon_{E,t}}{Q^*_t} + \varepsilon_{L,t}) Q^*_t K_t + B^*_{t,\gamma} = \varepsilon_{F,t} Q^*_t K_t + B^*_{t,\gamma} \tag{25}$$

2.3. The final good sector

A continuum of final good producers, which live infinitely, acquire retail goods $Y_t(z)$ at retail price $P_{Y,t}(z)$ from retailers, combine heterogeneous retail goods to produce homogeneous final goods, which are sold to households, capital producers, and the fiscal authority in the perfectly competitive final good market. Final good production Y_t packs a continuum of retail goods $Y_t(z)$ with retail good index $z \in (0, 1)$, in the Dixit-Stiglitz form:

$$Y_t = [\int_0^1 Y_t(z)^{\frac{1}{\varepsilon_{Y,t}}} dz]^{\varepsilon_{Y,t}} \tag{26}$$

where $\frac{\varepsilon_{Y,t}}{1-\varepsilon_{Y,t}}$ controls the size of substitution among retail goods. The price markup shock $\varepsilon_{Y,t}$ follows an autoregressive moving average [ARMA(1,1)] process in logs driven by an innovation $\epsilon_{Y,t} \sim i.i.d.N(0, \sigma^2_Y)$. The moving average component captures high frequency variations in inflation. As indicated by Del Negro and Schorfheide (2006) and Justiniano et al. (2010), the price markup shock conveys time-varying elasticity of substitution among retail goods, measures retail market power variability, captures final good price markup over marginal cost, and represents a cost-push shock. A higher price markup shock conveys more inelastic retail good demand and signals more monopolistic distortions. The typical final good producer chooses an optimal basket of retail goods $Y_t(z)$ to maximize its profit $P_{Y,t}\aleph_{Y,t}$, which equals final good sales $P_{Y,t}Y_t$ net of retail good purchase $\int_0^1 P_{Y,t}(z)Y_t(z)dz$:

$$P_{Y,t}\aleph_{Y,t} = P_{Y,t}Y_t - \int_0^1 P_{Y,t}(z)Y_t(z)dz \tag{27}$$

subject to final good technological constraint in Eq. (26). Equilibrium final good profit equals zero due to perfect competition in Appendix E. Final good price $P_{Y,t}$ is a Dixit-Stiglitz aggregator of the continuum of retail prices $P_{Y,t}(z)$:

$$P_{Y,t} = [\int_0^1 P_{Y,t}(z)^{\frac{1}{1-\varepsilon_{Y,t}}} dz]^{1-\varepsilon_{Y,t}} \tag{28}$$

Retail good z's production equals demand $Y_t(z)$, which hinges on retail good z's price $P_{Y,t}(z)$, final good price $P_{Y,t}$, final good production Y_t, and the price markup shock $\varepsilon_{Y,t}$:

$$Y_t(z) = [\frac{P_{Y,t}(z)}{P_{Y,t}}]^{\frac{\varepsilon_{Y,t}}{1-\varepsilon_{Y,t}}} Y_t \tag{29}$$

2.4. The retail sector

A unit continuum of retailers populates the retail sector, and each retailer produces a differentiated retail good. Retailer z pays wholesale price $P_{W,t}$ to buy wholesale goods M_t from wholesale firms, packages homogeneous wholesale goods into specialized retail goods $Y_t(z)$, and sells them to final good producers. Based on Calvo (1983) staggering mechanism featuring inflation inertia and endogenous persistence, a fraction ξ_P of retailers index past retail price $P_{Y,t-1}(z)$ to a geometrically weighted average of past price inflation $\pi_{t-2,t-1}$ and time-varying inflation target $\varepsilon_{\pi,t}$, with weights τ and $(1-\tau)$, respectively:

$$P_{Y,t}(z) = \pi^{\tau}_{t-2,t-1} \varepsilon^{(1-\tau)}_{\pi,t} P_{Y,t-1}(z) \tag{30}$$

Similar to Justiniano et al. (2010) and Nisticò (2012), to maximize expected proceeds $P_{Y,t}\aleph_{Y,t}(z)$, the remaining fraction $\left(1-\xi_P\right)$ of retailers charge optimal retail price $P^*_{Y,t}(z)$, which is indexed to $\prod_{\zeta=0}^{\iota} \pi^{\tau}_{t+\zeta-2,t+\zeta-1} \varepsilon^{(1-\tau)}_{\pi,t}$, up to period $t+\iota$ with a probability ξ^{ι}_P, in the monopolistic competitive retail market. With retail profits rebated to households, retailers weigh proceeds using equilibrium nominal stochastic discount factor $\chi_{t,t+\iota}$.

$$P_{Y,t}\aleph_{Y,t}(z) = E_t \sum_{\iota=0}^{+\infty} \beta^{\iota} \xi^{\iota}_P \chi_{t,t+\iota} Y_{t+\iota}(z) [P^*_{Y,t}(z) \prod_{\zeta=0}^{\iota} \pi^{\tau}_{t+\zeta-2,t+\zeta-1} \varepsilon^{(1-\tau)}_{\pi,t} - P_{Y,t+\iota} P_{W,t+\iota}] \tag{31}$$

subject to a sequence of retail good z's demand $Y_{t+\iota}(z) = [\frac{P^*_{Y,t+\iota}(z)}{P_{Y,t+\iota}}]^{-\frac{\epsilon_{Y,t+\iota}}{1-\epsilon_{Y,t+\iota}}} Y_{t+\iota}$. Individual optimization behavior and aggregation of individual behavior are derived in Appendix F and Appendix G, respectively.

2.5. The capital good sector

A unit continuum of perfectly competitive capital producers populates the capital good sector. Capital producers purchase final goods Y_t from final good producers at final good price $P_{Y,t}$, transform final goods into investment goods I_t, and obtain income from selling investment goods I_t to wholesale firms at nominal investment good price $P_{Y,t}P_{I,t}$. Capital producers incur final good purchase cost and capital installation cost $J\left(\frac{I_t}{I_{t-1}}\right) = \frac{\Omega}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2$,[15] which captures accrued opportunity cost of underutilized goods, obsolescence cost, and transition cost. Capital producers, which belong to households, discount proceeds using equilibrium nominal stochastic discount factor $\chi_{t,t+\iota}$, and choose optimal investment goods I_t to maximize expected nominal proceeds $P_{Y,t}\aleph_{K,t}$:

$$P_{Y,t}\aleph_{K,t} = E_t \sum_{\iota=0}^{+\infty} \chi_{t,t+\iota}\{P_{Y,t+\iota}P_{I,t+\iota} - [1 - J(\frac{I_{t+\iota}}{I_{t+\iota-1}})]P_{Y,t+\iota}\}I_{t+\iota} \tag{32}$$

Profit maximization in Appendix H yields the Euler equation of optimal investment I_t, and ensures that optimal nominal investment price $P_{Y,t}P_{I,t}$ balances marginal cost:

$$P_{Y,t}P_{I,t} = \{[1 - J(\frac{I_t}{I_{t-1}})] + J'(\frac{I_t}{I_{t-1}})\frac{I_t}{I_{t-1}}\}P_{Y,t} - E_t[\chi_{t,t+1}J'(\frac{I_{t+1}}{I_t})\frac{I^2_{t+1}}{I^2_t}P_{Y,t+1}] \tag{33}$$

2.6. The commercial banking sector

Banks dominate China's financial system and provide credit to firms. A continuum of commercial banks, which perform financial intermediation, collect deposits from households and credit-unconstrained wholesale firms at deposit interest rate $R_{D,t}$, and issue one-period corporate loans to credit-constrained wholesale firms at loan interest rate $R_{L,t}$. Since financial flows are channeled through a perfectly competitive commercial banking sector, deposit interest rate $R_{D,t}$ coincides with loan interest rate $R_{L,t}$ adjusted by firm survival rate $(1-\xi_W)$. Because loan holders are reimbursed for enduring extra firm replacement risk, a risk premium exists between loan interest rate and deposit interest rate.

$$R_{D,t} = (1 - \xi_W)R_{L,t} \tag{34}$$

Based on Proposition 5 in Appendix C, given positive expected future aggregate benefit of stock market bubble O_{t+1}, deposit interest rate $R_{D,t}$ is smaller than government bond interest rate Rn_t. Households tend to invest in government bonds instead of depositing in commercial banks, leading to binding borrowing constraints and zero aggregate deposit. Credit market clearing ensures that aggregate deposit balances aggregate loan. Nil aggregate loan L_t conveys that productive wholesale firms borrow and invest with binding credit constraints, whereas unproductive wholesale firms save and lend with non-binding credit constraints.

$$\frac{1}{R_{D,t}} = \frac{1}{(1 - \xi_W)R_{L,t}} = E_t[\chi_{t,t+1}(O_{t+1} + 1)] > \chi_{t,t+1} = \frac{1}{Rn_t} \tag{35}$$

When the aggregate stock bubble's expected benefit O_{t+1} is nil, no-arbitrage and transversality conditions exclude stock bubbles, the borrowing constraint is not binding, and deposit interest rate $R_{D,t}$ equals government bond interest rate Rn_t, inducing households to deposit in commercial banks, as well as investing in government bonds.

2.7. The monetary authority

Under economic marketization and interest rate liberalization, increases in China's money velocity and money multiplier pose challenges in observing money demand and monitoring money supply. Koivu (2009) indicates that credit demand becomes more dependent on interest rate in China. Zhang (2009) finds that the price rule is likely to be more effective in managing China's economy than the quantity rule. Chen et al. (2020) highlight that PBC embraces a gradual switch from quantity-based to price-based measures for guiding monetary policy. Dai et al. (2015) and Wang et al. (2020) specify China's economy with a Taylor-type monetary policy rule. Effective banking supervision and credit market regulation tame credit cycles, but are inefficient in eliminating excess credit market volatility. We assume that the credit-to-GDP gap, which conveys the stance of excess credit, enters China's monetary policy rule to curtail financial cycles. The monetary authority manages the nominal interest rate[16] rn_t in response to inflation gap π_t,[17]

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[15] $J(\frac{I_t}{I_{t-1}})$ is increasing and convex in $\frac{I_t}{I_{t-1}}$, and in the steady state, capital installation cost $J(1) = 0$, marginal capital installation cost $J'(1) = 0$, $J''(1) = 2J > 0$, because investment irreversibility and credit constraint impose cost upon capital installation. Ω gauges the extent of capital installation.

[16] Interest rate $(rn_t = Rn_t - \overline{Rn})$ is deviation of the nominal interest rate Rn_t from its steady state $\overline{Rn}$.

[17] Inflation gap $(\pi_t = \pi_{t-1,t} - \varepsilon_{\pi,t})$ is deviation of gross inflation $\pi_{t-1,t}$ from its time-varying target $\varepsilon_{\pi,t}$, which follows an AR(1) process in logs driven by an innovation $\epsilon_{\pi,t} \sim i.i.d.N(0, \sigma^2_\pi)$.

output gap y_t,[18] and the credit-to-GDP gap l_t,[19] in the log-linearized augmented Taylor-type rule. The unsystematic monetary policy shock $\varepsilon_{R,t}$ corresponds to an innovation $\epsilon_{R,t} \sim N(0, \sigma_R^2)$. A positive monetary policy shock signals a contractionary monetary policy, inducing a rise in the interest rate that discourages consumption, loans, and investment, whereas an adverse monetary policy shock conveys an expansionary monetary policy, triggering a fall in the interest rate that spurs consumption, loans, and investment.

$$rn_t = \rho_R rn_{t-1} + \left(1 - \rho_R\right)\left(\phi_\pi \pi_t + \phi_Y y_t + \phi_L l_t\right) + \varepsilon_{R,t} \tag{36}$$

where inertia parameter $\rho_R \in (0,1)$. ϕ_π, ϕ_Y, and ϕ_L are elasticities of interest rate rn_t with respect to inflation gap π_t, output gap y_t, and the credit-to-GDP gap l_t, respectively.

2.8. The fiscal authority

The fiscal authority, which aims to reduce distortions, consumes fiscal goods, issues one-period risk-free government bonds, and imposes taxes. Fiscal expenses include nominal fiscal spending $P_{Y,t}F_t$ and government bond repurchase $P_{Y,t}G_t$. Fiscal revenues comprise nominal taxes $P_{Y,t}T_t$ and government bond issuance $P_{Y,t+1}G_{t+1}$ at bond value $\frac{1}{Rn_t}$, which is the inverse of nominal gross interest rate Rn_t. The fiscal policy shock $\varepsilon_{G,t}$, which follows an AR(1) process in logs driven by an innovation $\epsilon_{G,t} \sim i.i.d.N(0, \sigma_G^2)$, captures the ratio of fiscal consumption to other consumption of final goods $\frac{F_t}{Y_t - F_t}$, and controls public debt capacity. A positive fiscal policy shock conveys a fiscal stimulus and entails an increase in fiscal consumption F_t relative to other sectors' consumption $(Y_t - F_t)$. Fiscal spending F_t behaves as a time-varying fraction $\frac{\varepsilon_{G,t}}{1+\varepsilon_{G,t}}$ of final good production Y_t. Public debt adjustment ensures that consolidated fiscal budget constraint holds in each period:

$$P_{Y,t}G_t + P_{Y,t}F_t = P_{Y,t}T_t + \frac{1}{Rn_t}P_{Y,t+1}G_{t+1} \tag{37}$$

2.9. Resource allocation

Since new wholesale firms bring about stock bubbles with positive probability, and confidence drives stock bubble evolution, there exists a bubbly equilibrium. Final good production Y_t balances final good demand Y_t^D, which consists of consumption C_t, fiscal spending F_t, investment I_t, and investment adjustment cost $\frac{\Omega}{2}(\frac{I_t}{I_{t-1}} - 1)^2 I_t$:

$$Y_t = Y_t^D = C_t + F_t + [1 + \frac{\Omega}{2}(\frac{I_t}{I_{t-1}} - 1)^2]I_t \tag{38}$$

The clearance of all markets produces a general equilibrium. Our DSGE model features inequalities at the individual level but no inequalities at the aggregate level. We have proved that household borrowing constraints are always binding, as well as corroborating the co-existence of wholesale firms with binding credit constraints and those with non-binding credit constraints. We log-linearize the non-linear system around its steady state.

3. Bayesian estimation of the DSGE model

3.1. Data structure

To prevent stochastic singularity and utilize data information, we select ten observed variables to identify ten DSGE structural shocks. We use China's quarterly data ranging from 1998Q1 to 2020Q3.[20] The observed variables of the GDP growth rate ΔlnY_t, household consumption growth rate ΔlnC_t, business investment growth rate ΔlnI_t, total industrial capacity utilization rate KU_t, the wage growth rate ΔlnW_t, the Consumer Confidence Index growth rate $\Delta lnCI_t$,[21] Shanghai Stock Exchange (SSE) Composite Index return $\Delta lnSP_t$,[22] total bank loan growth rate ΔlnL_t, inflation $\Delta lnPD_t$,[23] and 7-Day Interbank Repo Rate R_t,[24] identify structural shocks corresponding to government spending $\varepsilon_{G,t}$, intertemporal preferences $\varepsilon_{P,t}$, marginal efficiency of investment $\varepsilon_{I,t}$, labor intensity $\varepsilon_{H,t}$, price markups $\varepsilon_{Y,t}$, confidence $\varepsilon_{C,t}$, financial conditions $\varepsilon_{F,t}$, total factor productivity $\varepsilon_{A,t}$, inflation target $\varepsilon_{\pi,t}$, and monetary policy $\varepsilon_{R,t}$ in Appendix I. In light of Barsky and Sims (2012) and Miao et al. (2015), we specify the Consumer Confidence Index

[18] Output gap ($y_t = lnY_t - ln\overline{Y}$) is percentage deviation of output Y_t from its frictionless benchmark $\overline{Y}$.

[19] The credit-to-gdp gap ($l_t = \frac{L_t}{Y_t} - \frac{\overline{L}}{\overline{Y}}$) is the credit-to-GDP ratio $\frac{L_t}{Y_t}$ from its long-run level $\frac{\overline{L}}{\overline{Y}}$.

[20] Data sources include the updated work of Chang et al. (2016) and Chen et al. (2016), CEIC, and Wind databases. To obtain per capita real values, nominal GDP, nominal household consumption, nominal business investment, nominal wages, and SSE Composite Index are deflated by both GDP Deflator PD_t and population, real total bank loan is adjusted by population. Data series are adjusted seasonally and by Chinese New Year Effect when necessary. All variables, except for 7-Day Interbank Repo Rate and total industrial capacity utilization rate, are log-differenced to ensure stationarity. All data are not percentualized.

[21] Given that Miao et al. (2015) indicate a high correlation between the smoothed sentiment shock and the Consumer Confidence Index, which quantifies the degree of optimism about aggregate economy, and Consumer Confidence Index growth rate $\Delta lnCI_t$ is log-differenced Consumer Confidence Index.

[22] Real SSE Composite Index per capita return $\Delta lnSP_t$ is log-differenced ex-dividend closing price of SSE Composite Index adjusted by GDP Deflator PD_t and population. ARCH and Breush-Pagan tests upon quarterly SSE Composite Index growth rate detect no significant conditional heteroscedasticity.

[23] Inflation $\Delta lnPD_t$ is log-differenced GDP Deflator PD_t.

[24] 7-Day Interbank Repo Rate R_t represents a market-based interest rate and exhibits relatively high volatility in comparison with other interest rates in China.

Table 1
Calibration of parameters.

Structural parameter description	Symbol	Value
Intertemporal discount factor	β	0.99
Quarterly gross inflation target's steady state	$\overline{\epsilon_\pi}$	1.0074
Capital share in production	α	0.5
Capital depreciation rate	δ_K	0.035
Investment adjustment cost	Ω	2
Fraction of new wholesale entrants with stock bubbles	τ_B	0.5
Share of fiscal spending in output	$\frac{\overline{F}}{\overline{Y}}$	0.14
Shape parameter of Pareto distribution	κ	2.4

Note: Quarterly gross inflation target's steady-state $\overline{\epsilon_\pi} = 1.0074$ ensures annual gross inflation target's steady state $\overline{\epsilon_\pi}^4$=1.03.

growth rate $\Delta lnCI_t$ as a linear combination of its sample mean $\Delta ln\overline{CI}$, log-linearized confidence shock $v_{C,t}$, which captures the 'animal spirits' component, and log-linearized output growth rate $\left(y_t - y_{t-1}\right)$, which conveys the 'fundamental news' component:

$$\Delta lnCI_t = \Delta ln\overline{CI} + \rho_V v_{C,t} + \rho_M \left(y_t - y_{t-1}\right) \tag{39}$$

Observed macroeconomic series are connected with the state variables of the log-linearized DSGE model through the matrix of linearized measurement equations:

$$\begin{bmatrix} \Delta lnY_t \\ \Delta lnC_t \\ \Delta lnI_t \\ KU_t \\ \Delta lnW_t \\ \Delta lnCI_t \\ \Delta lnSP_t \\ \Delta lnL_t \\ \Delta lnPD_t \\ R_t \end{bmatrix} = \begin{bmatrix} \Delta ln\overline{Y} \\ \Delta ln\overline{C} \\ \Delta ln\overline{I} \\ \overline{KU} \\ \Delta ln\overline{W} \\ \Delta ln\overline{CI} \\ \Delta ln\overline{SP} \\ \Delta ln\overline{L} \\ \Delta ln\overline{PD} \\ \overline{R} \end{bmatrix} + \begin{bmatrix} y_t - y_{t-1} \\ c_t - c_{t-1} \\ i_t - i_{t-1} \\ u_{K,t} \\ w_t - w_{t-1} \\ \rho_V v_{C,t} + \rho_M \left(y_t - y_{t-1}\right) \\ s_t \\ l_t - l_{t-1} \\ \pi_t \\ rn_t \end{bmatrix} \tag{40}$$

where observed variables with bars denote corresponding sample means. Log-linearized series y_t, c_t, i_t, w_t, and l_t refer, respectively, to log deviations of final good production, consumption, investment, wages, and loans from their respective steady state values. $v_{C,t}$ is log deviation of the confidence shock $\epsilon_{C,t}$ from its steady state $\overline{\epsilon_C}$. ρ_V and ρ_Y are coefficients of log-linearized confidence shock $v_{C,t}$ and log-linearized output growth rate $\left(y_t - y_{t-1}\right)$ respectively in consumer confidence measurement equation. $u_{K,t}$ is deviation of capital utilization rate from its steady state. s_t is log deviation of stock market index from its frictionless level. π_t is deviation of inflation $\pi_{t-1,t}$ from its time-varying inflation target's steady state $\overline{\epsilon_\pi}$. rn_t is deviation of interest rate from its steady state.

3.2. Calibration of parameters

Table 1 presents calibration of parameters. Similar to He et al. (2017), the intertemporal discount factor is calibrated to be 0.99. Capital share in production is calibrated to be 0.5, which is aligned with Brandt et al. (2008)'s and Zhu (2012)'s empirical evidence. The capital depreciation rate, investment adjustment cost, and share of fiscal spending in production are assigned to be 0.035, 2, and 0.14, respectively, in accordance with Chang et al. (2019). Prior distributions for the remaining parameters are in Table 2.

3.3. Prior and posterior distributions of parameters

By applying Bayesian estimation to our DSGE models using Dynare in MatLab, we initially evaluate the likelihood function using the Kalman filter, then combine the likelihood function and the prior distributions to derive the posterior distributions, and finally simulate from the posterior kernel using the Metropolis–Hastings sampling algorithm. Based on trace plots and multivariate MCMC diagnostics, all structural parameters converge to their ergodic distributions. Table 2 reports prior means, prior standard deviations, posterior means, and 90% highest posterior density intervals for all parameters.

Our estimated firm replacement rate ξ_W is 0.027 with 90% posterior bands [0.016, 0.038], which completely lies above zero. This indicates that about 2.7% of incumbent wholesale firms are replaced by new counterparts in the stock market, as well as that firm financial planning horizon spans between 28 quarters (7 years) and 64 quarters (16 years) on average. Our estimated firm replacement rate is marginally higher than Miao et al. (2015)'s calibrated firm exit rate 0.02, and not significantly so. Our estimated household replacement rate ξ_H is 0.095 with 90% posterior bands [0.052, 0.138], which lies above zero, is lower than Castelnuovo and Nisticò (2010)'s estimated household replacement rate 0.129 with 90% posterior bands [0.080, 0.183] and Funke et al. (2011)'s estimated household replacement rate 0.13 with 90% posterior bands [0.0003,0.2713]. This not only implies that around 9.5% of incumbent household traders are replaced by new counterparts in financial markets, but also suggests that household financial planning horizon ranges approximately between 8 quarters (2 years) and 20 quarters (5 years). These are in line with the

Table 2
Prior and posterior distributions of structural parameters.

Parameter description	Symbol	Prior distribution	Posterior mean	Posterior bands[5th,95th]
Households				
Household replacement rate	ξ_H	U[0,1]	0.095	[0.052, 0.138]
Leisure weight	ϱ	G(1.5,1)	1.294	[1.116, 1.457]
Habit persistence	ς	B(0.7,0.2)	0.839	[0.751, 0.887]
Firms				
Firm replacement rate	ξ_W	U[0,1]	0.027	[0.016, 0.038]
Calvo probability	ξ_P	B(0.75,0.05)	0.806	[0.779, 0.831]
Price indexation	τ	B(0.5,0.15)	0.361	[0.194, 0.482]
Central bank				
Interest rate inertia	ρ_R	B(0.7,0.15)	0.865	[0.851, 0.880]
Response to inflation gap	ϕ_π	G(1,0.25)	1.791	[1.464, 2.145]
Response to output gap	ϕ_Y	G(0.5,0.25)	0.587	[0.368, 0.812]
Response to credit-to-GDP gap	ϕ_L	N(0,0.25)	0.092	[0.037, 0.147]
AR(1) coefficient of shocks				
Intertemporal preference	ρ_P	B(0.5,0.2)	0.691	[0.639, 0.743]
Total factor productivity	ρ_A	B(0.5,0.2)	0.710	[0.660, 0.771]
Price markup	ρ_Y	B(0.5,0.2)	0.706	[0.529, 0.873]
Labor intensity	ρ_H	B(0.5,0.2)	0.642	[0.585, 0.699]
Investment efficiency	ρ_I	B(0.5,0.2)	0.765	[0.578, 0.947]
Financial	ρ_F	B(0.6,0.2)	0.820	[0.803, 0.836]
Fiscal	ρ_G	B(0.5,0.2)	0.754	[0.671, 0.827]
Inflation target	ρ_π	B(0.9,0.05)	0.938	[0.924, 0.952]
Confidence	ρ_C	B(0.6,0.2)	0.685	[0.627, 0.743]
MA(1) coefficient of shocks				
Price markup	φ_Y	B(0.5,0.2)	0.883	[0.799, 0.987]
Standard deviation of innovations				
Intertemporal preference	σ_P	IG(0.01,2)	0.044	[0.038, 0.050]
Total factor productivity	σ_A	IG(0.01,2)	0.041	[0.032, 0.048]
Price markup	σ_Y	IG(0.01,2)	0.043	[0.013, 0.073]
Labor intensity	σ_H	IG(0.01,2)	0.025	[0.016, 0.034]
Investment efficiency	σ_I	IG(0.01,2)	0.069	[0.019, 0.115]
Financial	σ_F	IG(0.01,2)	0.020	[0.039, 0.052]
Fiscal	σ_G	IG(0.01,2)	0.013	[0.011, 0.015]
Inflation target	σ_π	IG(0.01,2)	0.050	[0.041, 0.059]
Confidence	σ_C	IG(0.1,2)	0.113	[0.109, 0.117]
Monetary policy	σ_R	IG(0.01,2)	0.017	[0.013, 0.020]
Measurement equations' coefficients				
Coefficient of confidence shock	ρ_V	G(1, 0.25)	1.072	[0.671, 1.794]
Coefficient of output growth	ρ_M	G(1, 0.25)	0.340	[0.198, 0.447]

Note: Symbols B, U, N, G, and IG refer, respectively, to beta, uniform, normal, gamma, and inverse gamma distributions. For uniform prior distributions, the two numbers in brackets denote the lower and upper bounds of their supports. For other prior distributions, the two numbers in parentheses denote the prior mean and prior standard deviation, respectively. [5th,95th] posterior percentiles convey 90% highest probability densities. Prior information is based on the literature, microeconomic data, and long-term averages of macroeconomic aggregates.

fact that household replacement rate is larger than firm replacement rate, because firms generally incur higher costs of entering or exiting the stock market.

Our estimated interest rate inertia parameter ρ_R is 0.865 with 90% posterior bands [0.851, 0.880], and this is significantly higher than Castelnuovo and Nisticò (2010)'s estimated interest rate inertia 0.753 with 90% posterior bands [0.707, 0.803] when considering U.S. data, implying a larger monetary policy inertia in China. Our estimated monetary policy response to inflation gap ϕ_π is 1.791 with 90% posterior bands [1.464, 2.145], and this exceeds Castelnuovo and Nisticò (2010)'s estimated monetary policy response to inflation gap 1.675 with 90% posterior bands [1.449, 1.883]. Our estimated monetary policy response to output gap ϕ_Y is 0.587 with 90% posterior bands [0.368, 0.812], and this is significantly larger than Castelnuovo and Nisticò (2010)'s estimated monetary policy response to output gap 0.023 with 90% posterior bands [0.006, 0.040], due to differences in model specifications and country-specific data. To capture the capital reallocation effect, our DSGE model specifies the stock bubble evolution driven by the confidence shock, and utilizes the data of investment, capacity utilization, and the consumer confidence index.

Our estimated monetary policy response to the credit-to-GDP gap parameter ϕ_L is 0.092 with 90% posterior bands [0.037, 0.147], and this is smaller than Castelnuovo and Nisticò (2010)'s estimated monetary policy response to financial slack 0.118 with 90% posterior bands [0.072, 0.166] when considering U.S. data. We conduct robustness analysis upon ϕ_L in Table 3. While maintaining the same prior standard deviation 0.25 of ϕ_L, we change prior shape of ϕ_L to a uniform distribution in the first column,[25] and change prior mean of ϕ_L to 0.1 and −0.1 in the second and third columns, respectively, we find corresponding posterior means of ϕ_L are 0.102, 0.105, and 0.075, respectively, all these posterior means fall inside [0.037, 0.147] and indicate insignificant differences from

[25] Prior distributions U[-$\frac{\sqrt{3}}{4}$, $\frac{\sqrt{3}}{4}$] and N(0, 0.25^2) have the same mean 0 and standard deviation 0.25.

Table 3
Robustness analysis for parameter ϕ_L.

Prior distributions						
$U[-\frac{\sqrt{3}}{4}, \frac{\sqrt{3}}{4}]$	$N(0.1, 0.25^2)$	$N(-0.1, 0.25^2)$	$U[-\sqrt{3}, \sqrt{3}]$	$N(0, 1^2)$	$N(0.2, 1^2)$	$N(-0.2, 1^2)$
Posterior means and corresponding 90% posterior bands						
0.102 [0.079, 0.126]	0.105 [0.089, 0.122]	0.075 [0.064, 0.087]	0.085 [0.055, 0.115]	0.082 [0.012, 0.152]	0.112 [0.073, 0.151]	0.062 [0.011, 0.113]

that in our benchmark model. In the remaining columns, while increasing prior standard deviation of ϕ_L to 1, we change prior shape of ϕ_L to a uniform distribution in the fourth column,[26] maintain prior mean of ϕ_L to 0 in the fifth column, and change prior mean of ϕ_L to 0.2 and −0.2 in the sixth and seventh columns, respectively, we find corresponding posterior means of ϕ_L are 0.085, 0.082, 0.112, and 0.062, respectively, all these posterior means fall inside [0.037, 0.147] and suggest insignificant differences from that in our benchmark model. Our results are robust to variations in ϕ_L's prior distributions.

3.4. Model comparison

Table 4 reports results for model comparison between our benchmark DSGE model and a set of its variants, as well as examining household replacement mechanism, firm replacement mechanism, and monetary policy responses to financial slack, which is captured by the credit-to-GDP gap, the stock price gap, the confidence shock, the financial shock, and the loan growth gap. The second column presents key parameter estimates in our benchmark model.

To inspect firm replacement mechanism and related capital reallocation effect, the third column displays Variant 1, in which firm turnover mechanism is muted and wholesale firms interact with the stock market perpetually. To examine household replacement mechanism and associated financial wealth effect, the fourth column presents Variant 2, in which household turnover mechanism is muted and households trade in the stock market forever. On both occasions, Calvo probability ξ_P, price indexation τ, monetary policy responses to inflation gap ϕ_π and output gap ϕ_Y are all estimated to be smaller, whereas interest rate inertia ρ_R and monetary policy response to the credit-to-GDP gap ϕ_L are both estimated to be larger, in comparison with those of the benchmark model. In Variant 1, because recurrent stock bubbles cannot be facilitated under no firm turnover mechanism, the capital reallocation effect disappears in the transmission channel from the stock market through the supply-side to the real economy, inducing less intratemporal reallocation of capital from unproductive to productive firms and more price adjustment. In Variant 2, because individual consumption smoothing carries over in aggregate terms under no household turnover mechanism, the financial wealth effect vanishes in the propagation mechanism from the stock market via the demand-side to the real economy, inducing more intertemporal consumption smoothing and more price reoptimization.

To evaluate monetary policy response to the credit-to-GDP gap ϕ_L, the fifth column describes Variant 3 featuring no monetary policy response to credit market misalignments. The Calvo probability ξ_P and price indexation τ are both estimated to be smaller, whereas household replacement rate ξ_H, firm replacement rate ξ_W, interest rate inertia ρ_R, monetary policy responses to inflation gap ϕ_π and output gap ϕ_Y are all estimated to be larger, in comparison with those of the benchmark model. The changes reflect the missing specification of monetary policy responses to credit market misalignments and more frequent price adjustment due to more uncertainty.

The sixth to eighth columns examine monetary policy responses to the financial slack captured by the stock price gap, the confidence shock, and the financial shock. The sixth column displays Variant 4 featuring monetary policy response to the stock price gap s_t[27]:

$$rn_t = \rho_R rn_{t-1} + (1-\rho_R)\left(\phi_\pi \pi_t + \phi_Y y_t + \phi_S s_t\right) + \varepsilon_{R,t} \tag{41}$$

Zhang et al. (2019) document the role of confidence in China's monetary policy transmission mechanism. The seventh column displays Variant 5 featuring monetary policy response to excess stock market volatility captured by log-linearized confidence shock $v_{C,t}$[28]:

$$rn_t = \rho_R rn_{t-1} + (1-\rho_R)\left(\phi_\pi \pi_t + \phi_Y y_t + \phi_C v_{C,t}\right) + \varepsilon_{R,t} \tag{42}$$

The eighth column describes Variant 6 featuring monetary policy response to financial frictions represented by log-linearized financial shock $v_{F,t}$[29]:

$$rn_t = \rho_R rn_{t-1} + (1-\rho_R)\left(\phi_\pi \pi_t + \phi_Y y_t + \phi_F v_{F,t}\right) + \varepsilon_{R,t} \tag{43}$$

In all the three scenarios, household replacement rate ξ_H and firm replacement rate ξ_W both increase. Monetary policy responses to the stock price gap, the confidence shock, and the financial shock are all smaller than to the credit-to-GDP gap l_t in the

[26] Prior distributions $U[-\sqrt{3}, \sqrt{3}]$ and $N(0, 1^2)$ have the same mean 0 and standard deviation 1.
[27] Log-linearized stock price gap $s_t = lnS_t - ln\overline{S}$ is percentage deviation of real stock price S_t from its frictionless level $\overline{S}$.
[28] Log-linearized confidence shock $v_{C,t} = ln\varepsilon_{C,t} - ln\overline{\varepsilon_C} = ln\varepsilon_{C,t}$ is percentage deviation of the confidence shock $\varepsilon_{C,t}$ from its steady state $\overline{\varepsilon_C}$.
[29] Log-linearized financial shock $v_{F,t} = ln\varepsilon_{F,t} - ln\overline{\varepsilon_F} = ln\varepsilon_{F,t}$ is percentage deviation of the financial shock $\varepsilon_{F,t}$ from its steady state $\overline{\varepsilon_F}$.

Table 4
Model comparison between benchmark and variants.

Parameters	Benchmark	V 1	V 2	V 3	V 4	V 5	V 6	V 7
Firm replacement ξ_W	0.027[0.016, 0.038]	–	**0.043**	**0.051**	0.035	**0.043**	**0.045**	**0.039**
Household replacement ξ_H	0.095[0.052, 0.138]	0.104	–	0.107	0.114	0.127	0.132	0.119
Calvo probability ξ_P	0.806[0.779, 0.831]	0.787	0.735	0.786	**0.879**	**0.865**	**0.897**	0.828
Price indexation τ	0.361[0.194, 0.482]	0.336	0.301	0.325	0.421	0.443	0.424	0.375
Leisure weight ϱ	1.294[1.116, 1.457]	**1.708**	**1.532**	**1.724**	**1.795**	1.320	**1.598**	**1.512**
Interest rate inertia ρ_R	0.865[0.851, 0.880]	**0.894**	0.876	**0.883**	0.871	**0.845**	**0.822**	0.878
Response to inflation gap ϕ_π	1.791[1.464, 2.145]	1.604	1.763	1.823	**1.410**	1.500	**1.408**	1.758
Response to output gap ϕ_Y	0.587[0.368, 0.812]	0.562	0.585	0.741	0.546	0.452	0.497	0.569
Response to credit-to-GDP gap ϕ_L	0.092[0.037, 0.147]	0.118	0.127	–	–	–	–	–
Response to stock price gap ϕ_S	–	–	–	–	0.076	–	–	–
Response to confidence shock ϕ_C	–	–	–	–	–	0.074	–	–
Response to financial shock ϕ_F	–	–	–	–	–	–	0.081	–
Response to loan growth gap ϕ_G	–	–	–	–	–	–	–	0.083
Logmarginal likelihood	1112.6	1097.7	1030.7	1050.4	1073.4	1060.6	1066.5	1093.6

Note : Variant 1: Firm replacement rate $\xi_W = 0$. Variant 2: Household replacement rate $\xi_H = 0$.
Variant 3: No monetary policy response to the credit-to-GDP gap l_t.
Variant 4: Monetary policy response to the stock price gap s_t.
Variant 5: Monetary policy response to log-linearized confidence shock $v_{C,t}$.
Variant 6: Monetary policy response to log-linearized financial shock $v_{F,t}$.
Variant 7: Monetary policy response to the loan growth gap $g_{L,t}$.
Posterior means in bold face denote significant differences from those of the benchmark model. Variants use the same observed variables.

benchmark model. The monetary policy rule displays more sensitivity to credit market misalignments, in comparison with stock price misalignments and excess stock market volatility.

To assess another measure of monetary policy response to credit market misalignments, the ninth column displays Variant 7 featuring monetary policy response to the loan growth gap $g_{L,t}$[30]:

$$rn_t = \rho_R rn_{t-1} + \left(1-\rho_R\right)\left(\phi_\pi \pi_t + \phi_Y y_t + \phi_G g_{L,t}\right) + \varepsilon_{R,t} \tag{44}$$

The household replacement rate ξ_H, firm replacement rate ξ_W, Calvo probability ξ_P, price indexation τ, and the interest rate inertia ρ_R all increase, monetary policy responses to inflation gap ϕ_π and output gap ϕ_Y both decrease, and the monetary policy response to the loan growth gap $g_{L,t}$ is smaller than to the credit-to-GDP gap l_t in the benchmark model. The monetary policy rule exhibits more responsiveness to misalignments in the loan-to-output ratio rather than to misalignments in the loan market.

Given that we estimate DSGE models using Bayesian methods, we can use log marginal likelihoods in Table 4 to construct twice the natural logarithms of Bayes factors for Bayesian model comparison with results reported in Table 5. Based on Kass and Raftery (1995)'s criterion, our benchmark DSGE model outperforms its variants with significant differences. Because our benchmark DSGE model is supported by the data and the associated monetary policy rule displays a positive response to the credit-to-GDP gap significantly, we deduce that a systematic component of China's monetary policy rule responds to the credit-to-GDP gap at business cycle frequencies.

3.5. Model validation

To investigate absolute performance in replicating data, we compute unconditional moments using simulated data over 1,000,000,000 periods from the estimated benchmark DSGE model and its variant counterparts specified using parameters' posterior means, and compare simulated moments generated by DSGE models with actual moments calculated using observed data. Table 6 and Table 8 in Appendix J compare model moments with data moments. Standard deviations and cross-correlations, which characterize distributions of observed variables, quantify the extent to which estimated models approximate the volatility and comovement of time series. Our benchmark DSGE model matches the data closely and its six variants reproduce the data reasonably well apart from three moments, namely, stock return volatility, consumer confidence growth volatility, and correlation between stock return and output growth. Moments for our benchmark DSGE model and its variants accord well with conventional wisdom. Based on standard deviations, consumption growth ΔlnC_t, investment growth ΔlnI_t, confidence growth $\Delta lnCI_t$, and stock return $\Delta lnSP_t$ all exhibit more volatility in comparison with output growth ΔlnY_t. According to cross-correlations, consumption growth ΔlnC_t, investment growth ΔlnI_t, capacity utilization rate KU_t, labor growth ΔlnH_t, stock return $\Delta lnSP_t$, loan growth ΔlnL_t, and inflation $\Delta lnPD_t$ are all procyclical in terms of exhibiting positive contemporaneous correlations with output growth ΔlnY_t, whereas interest rate R_t displays countercyclicality.

[30] The loan growth gap $g_{L,t}$ is the deviation of aggregate loan gross growth rate from its steady state.

Table 5
Bayesian model comparison.

Models	Twice the Logarithms of Bayes factor	Strength of evidence
Benchmark V.S. V1	$2\ln(BF_{B,V1}) = 2[\ln P(X\|\theta_B) - \ln P(X\|\theta_{V1})]$ $= 2(1112.6 - 1097.7) = 29.8 \in (10, +\infty)$	Benchmark is more supported by data than V1, strength of evidence is very strong
Benchmark V.S. V2	$2\ln(BF_{B,V2}) = 2[\ln P(X\|\theta_B) - \ln P(X\|\theta_{V2})]$ $= 2(1112.6 - 1030.7) = 163.8 \in (10, +\infty)$	Benchmark is more supported by data than V2, strength of evidence is very strong
Benchmark V.S. V3	$2\ln(BF_{B,V3}) = 2[\ln P(X\|\theta_B) - \ln P(X\|\theta_{V3})]$ $= 2(1112.6 - 1050.4) = 124.4 \in (10, +\infty)$	Benchmark is more supported by data than V3, strength of evidence is very strong
Benchmark V.S. V4	$2\ln(BF_{B,V4}) = 2[\ln P(X\|\theta_B) - \ln P(X\|\theta_{V4})]$ $= 2(1112.6 - 1073.4) = 78.4 \in (10, +\infty)$	Benchmark is more supported by data than V4, strength of evidence is very strong
Benchmark V.S. V5	$2\ln(BF_{B,V5}) = 2[\ln P(X\|\theta_B) - \ln P(X\|\theta_{V5})]$ $= 2(1112.6 - 1060.6) = 104 \in (10, +\infty)$	Benchmark is more supported by data than V5, strength of evidence is very strong
Benchmark V.S. V6	$2\ln(BF_{B,V6}) = 2[\ln P(X\|\theta_B) - \ln P(X\|\theta_{V6})]$ $= 2(1112.6 - 1066.5) = 92.2 \in (10, +\infty)$	Benchmark is more supported by data than V6, strength of evidence is very strong
Benchmark V.S. V7	$2\ln(BF_{B,V7}) = 2[\ln P(X\|\theta_B) - \ln P(X\|\theta_{V7})]$ $= 2(1112.6 - 1093.6) = 38 \in (10, +\infty)$	Benchmark is more supported by data than V7, strength of evidence is very strong

Note: 'BF' denotes 'Bayes Factor'. 'X' denotes actual observations. 'ln' denotes natural logarithm. θ_B, θ_{V1}, θ_{V2}, θ_{V3}, θ_{V4}, θ_{V5}, θ_{V6}, and θ_{V7} denote structural parameter vectors of Benchmark, Variant 1, Variant 2, Variant 3, Variant 4, Variant 5, Variant 6, and Variant 7 models, respectively.
Kass and Raftery (1995) suggest twice the natural logarithms of Bayes Factor criterion:
2lnBF$\in (0, 2)$: Strength of evidence is not worth more than a bare mention.
2lnBF$\in (2, 6)$: Strength of evidence is positive.
2lnBF$\in (6, 10)$: Strength of evidence is strong.
2lnBF$\in (10, +\infty)$: Strength of evidence is very strong.

Table 6
Model moments.

Observables	ΔlnY_t	ΔlnC_t	ΔlnI_t	KU_t	$\Delta lnCI_t$	$\Delta lnSP_t$	ΔlnW_t	ΔlnL_t	$\Delta lnPD_t$	R_t
Models	*Standard deviations* (%)									
Data	1.61	1.62	3.24	6.75	2.54	12.40	1.45	1.09	0.93	1.15
Benchmark	1.64	1.60	3.67	6.57	2.87	13.23	1.48	1.14	0.91	1.17
Models	*Correlation with* ΔlnY_t									
Data	1	0.78	0.46	0.25	0.01	0.12	0.04	0.15	0.07	−0.18
Benchmark	1	0.82	0.50	0.29	0.03	0.22	0.06	0.21	0.05	−0.16

Note: Observed real per capita growth rates ΔlnY_t, ΔlnC_t, ΔlnI_t, ΔlnW_t, $\Delta lnCI_t$, $\Delta lnSP_t$, and ΔlnL_t refer, respectively, to GDP growth, household consumption growth, business investment growth, wage growth, Consumer Confidence Index growth, SSE Composite Index return, and total loan growth. Observed rates $\Delta lnPD_t$, KU_t, and R_t refer, respectively, to inflation, capacity utilization rate, and 7-Day Interbank Repo Rate. Simulated observed values are not percentualized.

4. Dynamic and cyclical patterns

4.1. Impulse response analysis

Impulse responses trace out percentage divergences of endogenous variables from steady state values in response to structural shocks. Fig. 2 and Fig.6 in Appendix K report dynamic reactions of endogenous variables to structural shocks. The impulse responses depict expected future paths of endogenous variables for specific sizes of structural shocks over a 20-quarter horizon. The thick black lines are benchmark DSGE impulse responses, with Bayesian 90% posterior intervals depicted by the grey regions surrounding them.

The first row presents impulse responses of key endogenous variables, which include the interest rate, output, consumption, investment, capacity utilization, stock price gap, confidence, total loan, and inflation, to the monetary policy shock. We set the magnitude of the monetary policy shock so that it produces an unexpected rise in the interest rate, whose quarterly size equals a 25-basis point hike in the annualized interest rate. By simulating impulse responses to an unanticipated 25-basis point contractionary monetary policy shock, we find that the stock price gap and total loan react significantly, with initial responses of about −0.25% and −0.75%, respectively. Aggregate stock price is influenced by the preference shocks through equilibrium stochastic discount factor, driven by the financial shocks through the evolution of aggregate marginal capital value, and controlled by the confidence shocks via the evolution of aggregate stock bubble. Stock price fluctuations are also affected by the total factor productivity and investment efficiency shocks, via production and capital accumulation, respectively. In the second, third, fourth, fifth, sixth, and seventh rows, we set sizes of the total factor productivity, preference, labor intensity, investment efficiency, financial, and confidence shocks, respectively, such that each of them triggers a 1% increase in the stock price gap, then simulate impulse responses of endogenous variables to these structural shocks. We focus on the second to seventh rows in Fig. 2.

In the first column, we simulate percentage responses of the interest rate to structural shocks, each of which induces a 1% stock price increment in the sixth column and stimulates a loan growth in the eighth column. Positive total factor productivity, preference, labor intensity, investment efficiency, financial, and confidence shocks lead to increases, respectively, in production, demand, labor utilization, investment, collateral value, and borrowing capacity, entailing a boom in the stock market and a rise in the credit-to-GDP gap, as total loan grows more than output. To stabilize stock price misalignments and tame excess credit cycles, the monetary authority exhibits positive and significant responses to these structural shocks, each of which triggers an increase in the credit-to-GDP gap.

In the third, fourth, and second columns, we simulate percentage responses of consumption, investment, and output to structural shocks, each of which produces a 1% stock price increment in the sixth column and a loan growth in the eighth column. A stock market boom transmits to the economy not only directly through financial wealth effect on consumption and capital reallocation effect on investment, but also indirectly via induced interest rate variations, which affect intertemporal substitution of consumption and intratemporal reallocation of capital. The financial wealth effect boosts consumption, capital reallocation effect improves capital allocation and spurs productive investment, leading to expansionary impacts on output. Nevertheless, upsurges in the interest rate, which is triggered by increases in the credit-to-GDP gap, cause households to postpone consumption and firms to delay investment, resulting in contractionary impacts on output. Expansionary effects dominate contractionary impacts. Given relatively high estimated monetary policy inertia, the interest rate is neither influential enough to persuade households to substitute more current consumption for future consumption, nor prominent enough to induce firms to defer more investment. Impulse responses of consumption, investment, and output to the preference, labor intensity, financial, confidence, and total factor productivity shocks are all positive and significant with corresponding posterior bands beyond zero. The estimated monetary policy response to the credit-to-GDP gap does not offset the propagation of stock market booms' effects on consumption, investment, and output.

In the sixth, eighth, and ninth columns, we simulate percentage responses of inflation and total loan to a 1% stock price increment. When a stock market boom emerges, financial wealth and capital reallocation effects trigger inflation, however, the increase in inflation is partially offset by a rise in the interest rate, and inflation's responses to the financial and confidence shocks are insignificant with corresponding posterior bands comprising zero. Monetary policy responses to the credit-to-GDP gap induced by the financial and confidence shocks offset the propagation of stock market booms' effects on inflation. The preference and investment efficiency shocks provoke stock market booms, which translate into inflation, through consumption and investment, respectively, as well as raising the interest rate via the monetary policy rule. The preference and investment efficiency shocks exert significant impacts on inflation with corresponding posterior bands above zero. Monetary policy responses to the credit-to-GDP gap provoked by the preference and investment efficiency shocks do not fully offset the propagation of stock market booms' effects on inflation.

4.2. Historical decomposition

By applying the Kalman smoother algorithm to our DSGE model's state space form, we can calculate historical decompositions in order to provide a structural interpretation of the smoothed observed dynamics, which are linear combinations of the smoothed initial states and estimated structural shocks. In Figs. 3 to 5, black lines depict percentage deviations of observed variables from steady state values, color bars and grey bars, which are added vertically to yield black lines, capture observed variability attributable to structural shocks and initial states, respectively.

In Fig. 3, output growth rate declines during the 2008 Global Financial Crisis and plunges during the 2020 COVID-19 Pandemic, these downtrends are primarily attributable to the preference, investment efficiency, labor intensity, and financial shocks.

In Fig. 4, the Consumer Confidence Index growth rate exhibits massive slumps during the 2003 SARS Coronavirus Outbreak, the 2008 Global Financial Crisis, and the 2020 COVID-19 Pandemic, with these downturns mostly explained by the confidence, financial, preference, investment efficiency, and price markup shocks.

In Fig. 5, the SSE Composite Index return displays large jumps during the 2008 Global Financial Crisis, and falls slightly during the 2003 SARS coronavirus outbreak, as well as the 2020 COVID-19 Pandemic. Downswings are mainly captured by the investment efficiency, financial, confidence, and preference shocks, whereas upswings are generally explained by the total factor productivity, investment efficiency, financial, and fiscal policy shocks.

4.3. Forecast error variance decomposition

DSGE forecasts at the infinite horizon provide anchors for observed variables' evolution from initial values absent structural shocks, and the realized combinations of structural shocks contribute to observed deviations from forecasts. Table 7 presents unconditional forecast error variance decompositions of observed variables in terms of structural shocks. SSE Composite Index return fluctuations are primarily induced by the financial, confidence, investment efficiency, total factor productivity, and preference shocks, all of which influence stock wealth and stock market capitalization. Output growth fluctuations are mainly explained by the preference, investment efficiency, total factor productivity, labor intensity, and fiscal policy shocks, the moderate contributions of the financial and confidence shocks capture the influence of financial frictions and stock bubbles on the long-term dynamics of output growth. Inflation variations are mostly captured by the price markup, inflation target, investment efficiency, preference, and financial shocks, because these shocks influence stock wealth, consumption, and consumption good price, as well as affecting credit limit, investment, and investment good price.

Unconditional forecast error variance decompositions capture proportions of observed deviations attributable to structural shocks in the long run, as well as gauging relative contributions of structural shocks. The confidence shocks explain about 14.8%, 23.6%, 7.6%, 5.8%, 7.9%, and 5.6% of fluctuations in the SSE Composite Index return, the consumer confidence index growth, investment growth, capacity utilization rate, output growth, and inflation, respectively. The financial shocks account for around 18.5%, 13.6%, 12.2%, 11.1%, 11.6%, and 9.3% of fluctuations in the SSE Composite Index return, the consumer confidence index growth, investment growth, capacity utilization rate, output growth, and inflation, respectively.

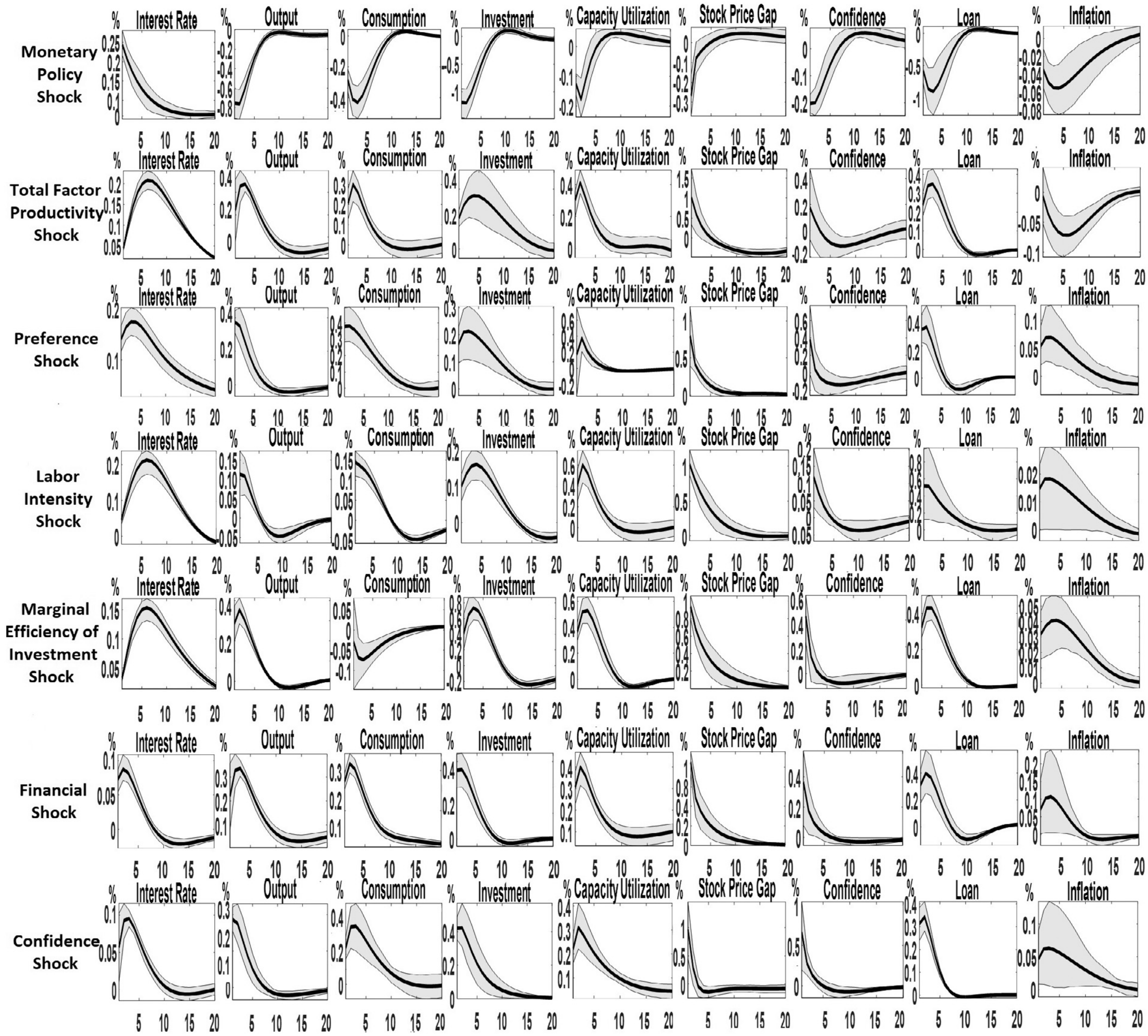

Fig. 2. Impulse responses of endogenous variables to structural shocks.

Table 7
Forecast error variance decomposition.

Observed variable (%)	ε_A	ε_P	ε_H	ε_μ	ε_Y	ε_F	ε_C	ε_π	ε_G	ε_R
Output growth rate ΔlnY_t	10.2	15.7	9.2	14.7	9.2	11.6	7.9	4.1	9.6	7.8
Consumption growth rate ΔlnC_t	6.5	27.9	13.8	12.6	7.2	7.4	6.7	4.2	6.5	7.2
Investment growth rate ΔlnI_t	7.7	9.4	10.7	25.3	5.2	12.2	7.6	4.7	5.9	11.3
Capacity utilization KU_t	8.5	8.1	20.2	23.6	5.4	11.1	5.8	5.3	4.7	7.3
Wage growth rate ΔlnW_t	5.1	9.1	23.3	12.9	19.6	6.8	5.5	7.3	4.8	5.6
Confidence growth rate $\Delta lnCI_t$	6.1	16.5	5.4	11.6	4.1	13.6	23.6	5.8	6.1	7.2
SSE Composite index return $\Delta lnSP_t$	12.3	10.3	5.3	16.6	6.2	18.5	14.8	4.1	6.3	5.6
Loan growth rate ΔlnL_t	8.7	7.8	6.4	21.7	5.6	15.8	8.2	6.3	5.6	13.9
Inflation $\Delta lnPD_t$	5.8	12.3	4.2	11.1	21.7	9.3	5.6	15.8	5.3	8.9
Interest rate R_t	5.9	12.2	6.8	13.5	5.7	6.7	5.2	14.7	7.5	21.8

Note: Structural shocks ε_A, ε_P, ε_H, ε_μ, ε_Y, ε_F, ε_C, ε_π, ε_G, and ε_R refer, respectively, to the total factor productivity, preference, labor intensity, investment efficiency, price markup, financial, confidence, inflation target, fiscal, and monetary policy shocks.

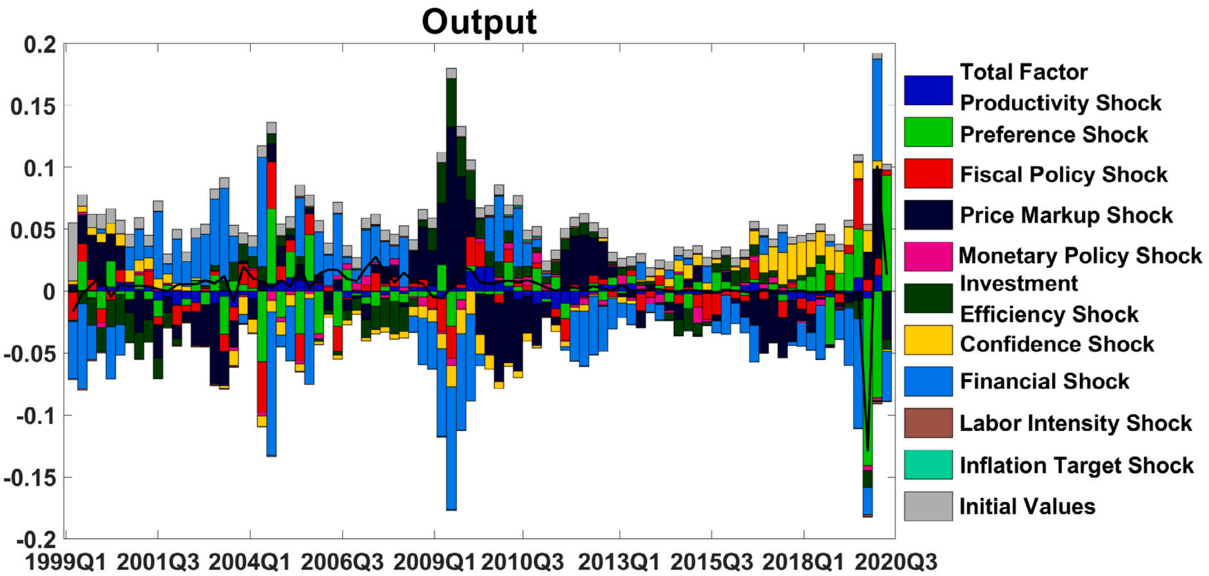

Fig. 3. Historical decomposition of output growth rate. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

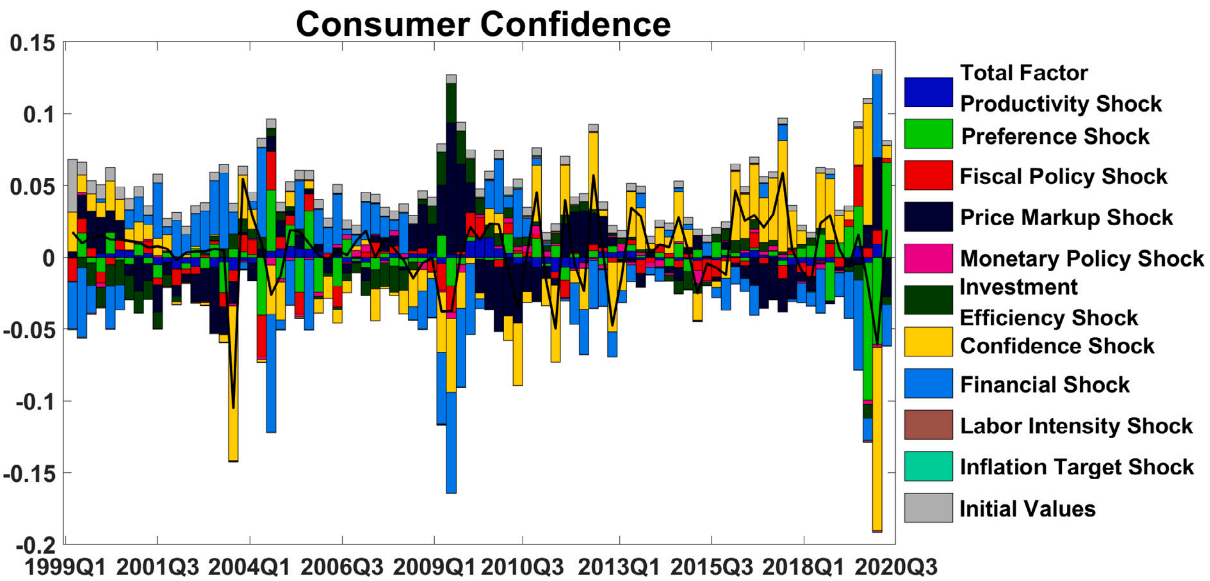

Fig. 4. Historical decomposition of consumer confidence index growth rate. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

5. Conclusions

To dig into China's financial wealth and capital reallocation effects, we incorporate stock wealth as an essential component of household wealth and include equity financing as a crucial channel of corporate financing in a DSGE model, by specifying both household replacement and firm replacement mechanisms. Because stock price swings convey expectations about future stock wealth and stock market capitalization, we not only examine the influence of stock market booms on household consumption through stock wealth and consumption smoothing, but also scrutinize impacts of stock market booms upon firm investment and capacity utilization via stock bubbles and borrowing capacity.

On the demand-side, a discrepancy between individual and aggregate consumption smoothing arises due to the household turnover mechanism. When a stock market boom emerges, all current households increase current consumption, however, in

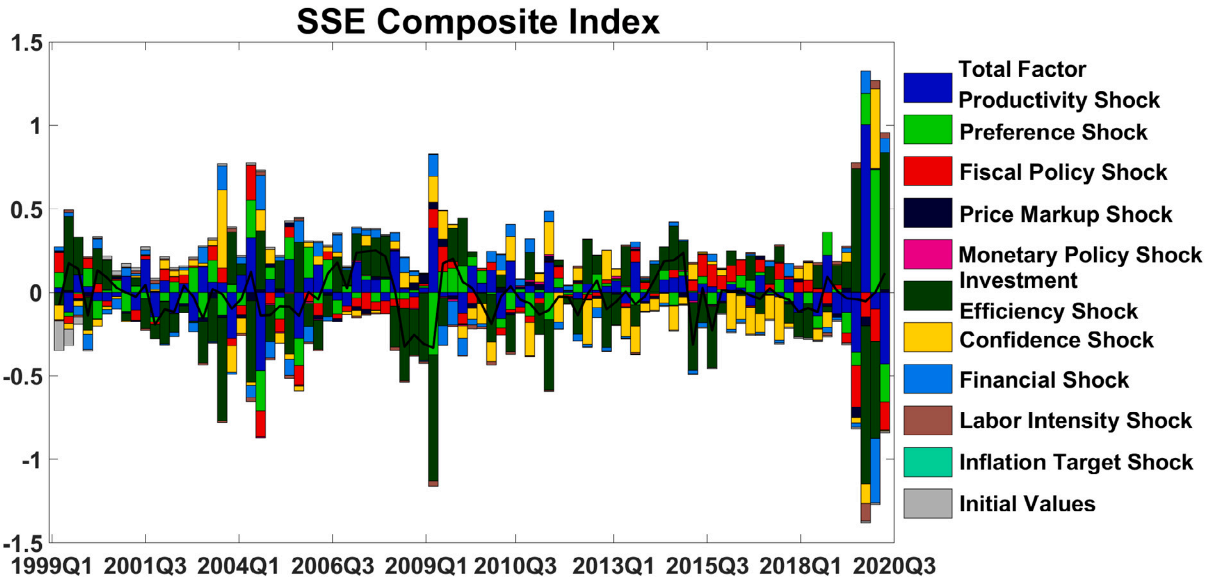

Fig. 5. Historical decomposition of SSE Composite index return. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

the next period, new household entrants, who hold no financial wealth to smooth consumption and consume relatively less, replace a fraction of incumbent household traders, who hold financial wealth to smooth consumption and consume relatively more, leading to less expected future aggregate consumption than otherwise. The wedge between current and expected future aggregate consumption enlarges, influencing equilibrium stochastic discount factor and creating a financial wealth effect. On the supply-side, recurrent stock bubbles supported by the firm turnover mechanism enhance firm borrowing capacity and relax credit constraints, boosting firm investment and improving capacity utilization. Higher demand for investment goods induces a rise in investment good price, a stimulus in capital accumulation, and a contraction in Tobin's marginal Q, increasing the idiosyncratic investment productivity shock's threshold. Firms should reach a higher investment productivity level in order to produce, redirecting capital from unproductive to productive firms and creating a capital reallocation effect. The capital reallocation effect discourages unproductive investment, but turns savings from unproductive firms into loans granted to productive firms via commercial banks, stimulating productive investment. Stock bubbles' intensive positive impacts on productive investment typically exceeds extensive negative impacts on unproductive investment, generating positive net impacts on aggregate investment. China's financial wealth effect and capital reallocation effect exert expansionary impacts on consumption and investment, respectively, and the contractionary impacts imposed by rises in the interest rate do not offset the expansionary effects.

We identifies a significant, counteractive, and systematic reaction of China's monetary policy rule to the credit-to-GDP gap. The estimated monetary policy response to the credit-to-GDP gap is 0.092 with 90% posterior bands [0.037, 0.147], which is significantly above zero. Bayesian model comparison indicates that China's data supports the benchmark DSGE model featuring a monetary policy response to the credit-to-GDP gap. The impulse responses of the interest rate to positive financial and confidence shocks, both of which capture financial frictions and convey excess credit, increase substantially and significantly. These results suggest a crucial role of China's monetary policy rule in taming excess financial cycles and stabilizing credit markets.

The household turnover mechanism perturbs aggregate consumption smoothing and makes stock prices relevant for consumption fluctuations. A higher household replacement rate amplifies the difference between current and expected future aggregate consumption, stimulating aggregate demand. The firm turnover mechanism facilitates recurrent stock bubbles and ensures stationarity of aggregate stock bubble. When the firm replacement rate increases and expected future aggregate stock bubble return exceeds a certain threshold, new wholesale firms are more likely to contain stock bubbles than incumbent counterparts. More stock bubbles lessen credit constraints, enhance borrowing capacity, and stimulate productive investment. As investment may crowd out consumption, a higher firm replacement rate may contaminate the financial wealth effect. In consistency with Castelnuovo and Nisticò (2010)'s analysis, we find that a higher household replacement rate is associated with a larger financial wealth effect based on China's data.

The estimated household replacement rate 0.095, which indicates that Chinese households trade in financial markets for 3 years on average, is smaller than that of Castelnuovo and Nisticò (2010)'s DSGE model with neither a firm replacement mechanism nor a capital reallocation effect using U.S. data. A lower estimated household replacement rate indicates a smaller financial wealth effect in China. The estimated firm replacement rate 0.027, which implies that Chinese firms trade in the stock market for 10 years on average, is marginally higher than that of Miao et al. (2015)'s DSGE model with neither a household replacement mechanism nor a financial wealth effect based on U.S. data. According to impulse responses, output, investment, and capacity utilization all display positive and significant impulse responses to the financial, confidence, investment efficiency, and labor intensity shocks, all of which are normalized in scale to induce a 1% stock market boom, and the concurrent rises in the interest rate do not fully offset these positive impacts. Impulse responses of inflation to the financial and confidence shocks, both of which are normalized to trigger a 1% stock market boom, are positive but insignificant, implying that monetary policy responses to credit-to-GDP gaps associated with stock market booms offset these positive effects.

Last but not least, our DSGE model elucidates the propagation mechanism of key structural shocks, which include the financial, confidence, investment efficiency, preference, and labor intensity shocks, from China's stock market to macroeconomy. The financial shock captures external financing frictions, and the confidence shock drives aggregate stock bubble evolution. Based on the model structure and impulse responses, the financial and confidence shocks influence sizeable fractions of stock price swings and macroeconomic fluctuations, mainly via external financing frictions and corporate borrowing capacity. According to forecast error variance decompositions, the financial shocks account for about 18.5%, 12.2%, 11.1%, and 11.6% of forecasted fluctuations in stock return, investment growth, capacity utilization rate, and output growth, respectively, while the confidence shocks explain around 14.8%, 7.6%, 5.8%, and 7.9% of forecasted fluctuations in stock return, investment growth, capacity utilization rate, and output growth, respectively.

Policy implications include understanding propagation mechanisms of shocks between China's stock market and macroeconomy, developing monetary policy tools to ensure financial stability, and evaluating financial frictions and confidence in shaping financial cycles and macroeconomic fluctuations. The following aspects provide avenues for future research. Chinese firms could be categorized into state-owned and private enterprises to reflect financial heterogeneity. China's money supply rules could be examined in addition to interest rate rules. An open economy model could be explored to delve into international trade. Correlated or non-normal structural shocks with stochastic volatility could be included to capture fat tail behavior, intra-dependence, and inter-dependence.

CRediT authorship contribution statement

Tao Jin: Funding acquisition, Supervision, Conceptualization, Investigation, Resources, Formal analysis, Writing – review & editing. **Simon Kwok:** Supervision, Conceptualization, Investigation, Resources, Formal analysis, Writing – review & editing. **Xin Zheng:** Project administration, Writing – original draft, Resources, Data curation, Methodology, Software, Validation, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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References

Auernheimer, L., & Trupkin, D. (2014). The role of inventories and capacity utilization as shock absorbers. *Review of Economic Dynamics*, *17*(1), 70–85. http://dx.doi.org/10.1016/j.red.2013.04.003.

Barsky, R., & Sims, E. (2012). Information, animal spirits, and the meaning of innovations in consumer confidence. *American Economic Review*, *102*(4), 1343–1377. http://dx.doi.org/10.1257/aer.102.4.1343.

Brandt, L., Hsieh, C., & Zhu, X. (2008). *Growth and structural transformation in china: china's great economic transformation* (pp. 683–728). Cambridge University Press, http://dx.doi.org/10.1017/CBO9780511754234.018.

Calvo, G. (1983). Staggered prices in a utility-maximising framework. *Journal of Monetary Economics*, *12*(3), 383–398. http://dx.doi.org/10.1016/0304-3932(83)90060-0.

Castelnuovo, E., & Nisticò, S. (2010). Stock market conditions and monetary policy in a DSGE model for the U.S.. *Journal of Economic Dynamics and Control*, *34*(9), 1700–1731. http://dx.doi.org/10.1016/j.jedc.2010.06.028.

Cecchetti, C., Genberg, H., Lipsky, J., & Wadhwani, S. (2011). *Asset prices and central bank policy*. International Center for Monetary and Banking Studies.

Chang, C., Chen, K., Wagoner, D., & Zha, T. (2016). Trends and cycles in China's macroeconomy. *NBER Macroeconomics Annual*, *30*(1), 1–84. http://dx.doi.org/10.1086/685949.

Chang, C., Liu, Z., Spiegel, M., & Zhang, J. (2019). Reserve requirements and optimal Chinese stabilization policy. *Journal of Monetary Economics*, *103*(2019), 33–51. http://dx.doi.org/10.1016/j.jmoneco.2018.08.005.

Chen, H., Funke, H., Lozev, I., & Tsang, A. (2020). To guide or not to guide? Quantitative monetary policy tools and macroeconomic dynamics in China. *International Journal of Central Banking*, *16*(5), 49–94.

Chen, K., Higgins, P., Waggoner, D., & Zha, T. (2016). *Impacts of monetary stimulus on credit allocation and macroeconomy: evidence from china*: *NBER working papers 22650*.

Dai, L., Minford, P., & Zhou, P. (2015). A DSGE model of China. *Applied Economics*, *47*(59), 6438–6460. http://dx.doi.org/10.1080/00036846.2015.1071477.

Del Negro, M., & Schorfheide, F. (2006). How good is what you've got? DGSE-VAR as a toolkit for evaluating DSGE models. *Economic Review*, *91*(2), 21–37.

Funke, M., Paetz, M., & Pytlarczyk, E. (2011). Stock market wealth effects in an estimated DSGE model for Hong Kong. *Economic Modelling*, *28*(1–2), 316–334. http://dx.doi.org/10.1016/j.econmod.2010.08.016.

He, Q., Liu, F., Qian, Z., & Chong, T. (2017). Housing prices and business cycle in China: A DSGE analysis. *International Review of Economics and Finance*, *52*, 246–256. http://dx.doi.org/10.1016/j.iref.2017.01.012.

Ikeda, D. (2013). Monetary policy and inflation dynamics in asset price bubbles. *Bank of Japan Working Paper Series*, *13*(4), 1–40.

Justiniano, A., Primiceri, G., & Tambalotti, A. (2010). Investment shocks and business cycles. *Journal of Monetary Economics*, *57*(2), 132–145. http://dx.doi.org/10.1016/j.jmoneco.2009.12.008.

Kass, R., & Raftery, A. (1995). Bayes factors. *Journal of the American Statistical Association*, *90*(430), 773–795. http://dx.doi.org/10.2307/2291091.

Kocherlakota, N. (2009). *Bursting bubbles: consequences and cures*: *University of minnesota working paper*, (pp. 603–605).

Koivu, T. (2009). Has the Chinese economy become more sensitive to interest rates? Studying credit demand in China. *China Economic Review*, *20*(3), 455–470. http://dx.doi.org/10.1016/j.chieco.2008.03.001.

Liu, Z., & Wang, P. (2014). Credit constraints and self-fulfilling business cycles. *American Economic Journal: Macroeconomics*, *6*(15), 32–69. http://dx.doi.org/10.1257/mac.6.1.32.

Miao, J., Wang, P., & Xu, Z. (2015). A Bayesian dynamic stochastic general equilibrium model of stock market bubbles and business cycles. *Quantitative Economics*, *6*(2015), 599–635. http://dx.doi.org/10.3982/QE505.

Nisticò, S. (2012). Monetary policy and stock-price dynamics in a DSGE framework. *Journal of Macroeconomics*, *34*(1), 17–146. http://dx.doi.org/10.1016/j.jmacro.2011.09.008.

Wang, C., Le, V., Matthews, K., & Zhou, P. (2020). Shadow banking activity and entrusted loans in a DSGE model of China. *The Manchester School*, *2020*, 1–25. http://dx.doi.org/10.1111/manc.12319.

Zhang, W. (2009). China's monetary policy: quantity versus price rules. *Journal of Macroeconomics*, *31*(3), 473–484. http://dx.doi.org/10.1016/j.jmacro.2008.09.003.

Zhang, C., Sun, Y., & Tang, D. (2019). Whose confidence matters in Chinese monetary policy? *International Review of Economics and Finance*, *60*, 188–202. http://dx.doi.org/10.1016/j.iref.2018.11.003.

Zhu, X. (2012). Understanding China's growth: past, present, and future. *Journal of Economic Perspectives*, *26*(4), 103–124. http://dx.doi.org/10.1257/jep.26.4.103.