



# Gradual financial integration and macroeconomic fluctuations in emerging market economies: evidence from China

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## Abstract

This paper extends the conventional DSGE literature by developing a New Keynesian DSGE model featuring imperfect financial markets with various friction costs, which allows for the study of macroeconomic dynamics under different levels of financial integration. We conduct Bayesian estimation and draw implications on the macroeconomic effects of gradual financial integration using the Chinese economy as an example. We find that macroeconomic fluctuations vary with different levels of financial integration and the specific relationship depends on the nature of exogenous shocks. Variance decomposition analysis shows that as financial integration increases, the contribution of foreign exchange shocks declines while that of domestic shocks increases. We also find that there is a notable enhancement of welfare associated with improvement in financial integration, and the effectiveness of monetary policy in emerging market economies would be weakened as financial integration increases.

**Keywords** Financial integration · Emerging market · Macroeconomic fluctuations

**JEL Classification** E32 · E52 · F36

## 1 Introduction

Since the mid-1980s, the wave of financial integration has swept the globe and continues to shape the world economy. During the process, massive capital inflows and associated technology diffusion have greatly spurred the growth of emerging market

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economies (EMEs), accelerating their catch-up with developed countries. Nevertheless, the 1997 Asian Financial Crisis and the 2008 Global Financial Crisis had triggered debates on the volatility effects of financial integration. On the one hand, financial integration provides alternative opportunities of global portfolio diversification, risk sharing and consumption smoothing, which are helpful in stabilizing the economy. On the other hand, higher financial integration may bring more external shocks and incur financial co-movement since capital flows are highly mobile and pro-cyclical in nature, which is especially the case in EMEs due to their less developed financial systems.

In the present paper, we attempt to address the above debate by developing a small open economy dynamic stochastic general equilibrium (DSGE) model, which extends the model of Galí and Monacelli (2005) by allowing for imperfect financial integration with various friction costs. As in Sutherland (1996), we assume that there are adjustment costs when households transfer funds across borders to adjust their foreign assets. Thus, the process of financial integration is introduced as a reduction in adjustment costs. The modeling of gradual financial integration distinguishes our work from previous DSGE models, which treats financial markets either as closed (e.g., Badarau and Popescu 2014; Kulish et al. 2017; Gallegati et al. 2019) or fully open (e.g. Galí and Monacelli 2005; Poutineau and Vermandel 2015).

However, our model is not merely a rendition of that developed by Sutherland (1996). There are three modifications in our model. First, besides adjustment costs, we assume that there are transaction costs and other factors leading to deviations from the classic law of one price (LOP) condition. The introduction of these costs is due to the fact that with imperfect financial integration, the associated financial frictions (e.g., restrictive regulations, information asymmetries and nominal rigidities) would induce excess costs and result in deviations from the classic LOP condition (Sercu et al. 1995; Elberg 2016). Thus, financial integration can be captured by reductions in both adjustment costs and deviations of LOP condition, which leads to an explicit role of financial integration in the extended IS curve and the Phillips curves derived in our paper.

Second, instead of assuming an exogenous stochastic process of money supply, we introduce an endogenous monetary policy rule specified as the standard Taylor rule targeting output and inflation. The reason for this modification is twofold. On the one hand, the rapid development of shadow banking and financial innovation in the past three decades has posed great challenges to the central bank in monitoring and controlling the money aggregate, which eliminates the effectiveness of monetary policy that regulates money supply. This, along with interest rate marketization reform in China, prompts the People's Bank of China (PBoC, China's central bank) to switch to an alternative monetary policy that regulates nominal interest rate. On the other hand, the Taylor-type interest rule allows for richer model dynamics due to interactions between nominal interest rate and macroeconomic variables, which facilitates the subsequent analysis of monetary policy effects in the context of financial integration.

Finally, by incorporating an importers sector in the model, we show that the marginal costs of importers and the imported inflation are largely determined by real exchange rate and terms of trade. Since real exchange rate variations are closely related to financial integration, the introduction of importers sector allows us to investigate the

dynamics of CPI inflation under different levels of financial integration in a more tractable way.

This model is then used as a framework to investigate how macroeconomic fluctuations may vary during the process of financial integration. To gain implications for EMEs, we estimate the model by using data from the Chinese economy. China is identified by IMF as the largest emerging market economy in the world and had adopted a gradual and disciplined approach in promoting financial integration over the observation period of 2002–2019.

Several interesting results emerge from our analysis. Specifically, we find the impact of financial integration on macroeconomic fluctuations depends on the nature of exogenous shocks, where real exchange rate plays an important role by triggering a trade-off between households' consumption choices and investment decisions. This echoes the findings in Buch et al. (2005). We also find evidence that financial integration helps to stabilize real exchange rate fluctuations but leads to rapid pass-through to inflation due to lower friction costs. Variance decompositions further suggest that as financial integration increases, the contribution of foreign exchange (FX) shocks declines while that of domestic shocks increases. This delivers an important implication that policy-makers should devote to stabilizing domestic economy during the process of financial integration.

We then employ the model to analyze the influence of financial integration on the effectiveness of monetary policy. The results show that the optimal stance of monetary policy is dependent on the level of financial integration. In particular, monetary policy should have a weak preference for inflation control and a strong preference for output stabilization at early stages of financial integration. When financial integration improves to higher levels, however, a moderate reaction to inflation and an aggressive reaction to output would be optimal. Moreover, we also find that the effectiveness of monetary policy decreases at higher levels of financial integration.

This paper contributes to a large strand of literature that discusses the effects of financial integration on macroeconomic fluctuations. Based on the setup of Sutherland (1996), Ghazouani (2020) finds that financial integration mitigates the impacts of oil shocks. On the contrary, Faia (2011) and Pisani (2011) show that in the presence of financial frictions, financial integration would induce macroeconomic instability especially volatility in consumption. By introducing information asymmetry, Cakici (2011) finds financial integration amplifies the impact of monetary policy shock, but has little influence on technology shock. Different from these studies in which financial integration and financial frictions are modeled separately, it is assumed in our model that financial frictions decrease as financial integration improves. In this regard, Ma (2016) lays out a model where imperfect financial integration and financial frictions correlate inherently and result in a modified uncovered interest rate parity (UIP). The results share some similarities with our study in that the effects of financial integration on macroeconomic fluctuations vary under different shocks and the contribution of external shocks increases at higher levels of financial integration.

This paper is also related to studies that investigate the welfare effects of financial integration. In the early work of Obstfeld (1994), international risk sharing would bring welfare gains by increasing consumption growth. Lee and Shin (2012) find that financial integration improves consumption growth and thus the welfare gains of Asian

EMEs due to technology diffusion of FDI. Using the second-order Taylor approximation of households' utility as a welfare measure, Faia (2011) and Cakici (2011) find that financial integration reduces welfare. By constructing a welfare measure as the ratio of certainty-equivalent consumption to no-stochastic steady-state consumption, Devereux and Sutherland (2011) find that welfare is improved only when both bonds market and equity market are unified. In a similar vein, Ratanavararak (2018) finds that EMEs can hardly reap evident welfare gains from financial integration. By constructing a systemic Pareto criterion, Wang and Huang (2021) show that in the presence of unexpected shocks, perfect integration and risk sharing may endanger financial stability and reduce social welfare.

In contrast to the majority of the existing studies that use household consumption (utility) as welfare criteria, we adopt a different measure to quantify the welfare effects of financial integration, which focuses on macroeconomic stability by using output and inflation volatility to construct the welfare loss function, as in Woodford (2012). In this regard, Chang et al. (2015) have laid out a DSGE model which incorporates "Chinese Characteristics" (e.g., including strictly regulated capital account, pegged exchange rate and sterilized interventions) to investigate the implications of alternative liberalization policies. Their results show that either partially easing capital account or switching to floating exchange regime would give rise to welfare gains and macroeconomic stability, and the benefits are enhanced if the two liberalization policies are implemented simultaneously.

Moreover, our analysis also sheds new light on the optimal reaction of monetary policy under different levels of financial integration, which contributes to the choice of monetary policy strategy for economies that are in a gradual process of financial integration. In particular, while the existing literature pays more attention to the choice of alternative monetary policies, our study focuses primarily on the relative stances of output stabilization and inflation control within a stylized Taylor rule. To be more specific, Devereux and Sutherland (2008) find that price stability continues to be the optimal monetary policy in the presence of financial globalization and endogenous portfolio choices. Faia and Iliopoulos (2011) show that monetary policy should respond to exchange rate fluctuations at higher levels of financial integration. Pang (2013) claims that when there is no price distortion, inflation targeting monetary policy coped with flexible exchange rate is welfare-improving in the process of financial integration.

In a broader sense, our paper contributes to the large body of literature which investigates the nexus between financial sector and the real economy as well as their reciprocal effects on each other (e.g., Lengnick and Wohltmann 2013; Cavalli et al. 2022). Our paper also relates to the studies that explore the optimal policy configuration within the context of financial integration. For example, Zou et al. (2020) find that after the accession to European Union, the fiscal policy practice of the member states has been featured with more discretion as a result of the asymmetric institutional structure (i.e., a unified monetary policy and discrete fiscal policies outlined by each member state).

The remainder of the paper is organized as follows. Section 2 presents the model. Section 3 estimates the model. Section 4 analyzes how macroeconomic fluctuations vary under different levels of financial integration. Section 5 conducts welfare comparisons under alternative monetary policy rules. Section 6 concludes the paper.

## 2 The model

The conventional wisdom of modeling financial markets in DSGE models is to treat domestic financial markets as either autarky or perfect (fully integrated with international financial markets). However, financial integration in reality is usually a gradual process, which is particularly the case in EMEs. In order to provide a model with explicit considerations of the process of financial integration, in this section we develop a DSGE model with imperfect (partially integrated) financial markets, where various costs associated with different levels of financial integration affect both the demand and supply sides of the economy.

### 2.1 The households

We assume a continuum of identical households who seek to maximize their lifetime utility given by the following utility function:

$$\max_{C_t, N_t} E_0 \sum_{t=0}^{\infty} \beta^t \left[ \frac{1}{1-\sigma} (C_t - hC_{t-1})^{1-\sigma} - \frac{N_t^{1+\phi}}{1+\phi} \right] \tag{1}$$

where  $C_t$  denotes consumption,  $N_t$  denotes labor supply,  $\beta$  denotes discount factor,  $h$  denotes habit formation,  $\sigma$  denotes the inverse of elasticity of intertemporal substitution, and  $\phi$  denotes the inverse of elasticity of labor supply. In an open economy, household consumption consists of domestic products  $C_H$  and foreign imported products  $C_F$ , aggregated by the Dixit–Stiglitz function:  $C_t = \left[ (1-\omega)^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + \omega^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$ , where  $\eta$  measures the elasticity of substitution between domestic and imported products, and  $\omega$  is the portion of imports in the final consumption (i.e., the degree of trade openness).

It is assumed that households hold their financial wealth in two forms: domestic bonds and foreign bonds. The former is only traded in domestic financial markets with domestic currency, while the latter is only traded in foreign financial markets with foreign currencies. It is also assumed that households' holdings of domestic bonds can be freely adjusted, but the adjustment of foreign bonds would be subjected to adjustment costs, as in Sutherland (1996).

In each period, households invest  $I_t$  (in terms of domestic products) in foreign financial markets, thus the evolution of households' holdings of foreign bonds is given by:

$$FB_t = R_{t-1}^* FB_{t-1} + P_t^* I_t \tag{2}$$

where  $FB_t$  denotes foreign bonds denominated in foreign currency,  $R_t^*$  denotes gross interest rate of foreign bonds in period  $t$ , and  $P_t^*$  denotes the overall price index of the foreign economy.

Following Sutherland (1996), the adjustment in foreign bonds will induce the following quadratic costs:

$$\psi_t = \frac{1}{2}\gamma I_t^2 \tag{3}$$

where  $\psi_t$  denotes the adjustment costs (in terms of domestic products),  $\gamma \in [0, 1]$  measures the degree of financial integration. According to Eq. (3), a lower value of  $\gamma$  corresponds to less adjustment costs, which indicates less financial frictions and thus a higher level of financial integration. In the polar case of  $\gamma = 0$ , there are no adjustment costs and the domestic financial markets are perfectly integrated with the international financial markets.

Then, the budget constraint of households is given by:

$$P_t C_t + B_t + P_{H,t} I_t + P_{H,t} \psi_t = W_t N_t + R_{t-1} B_{t-1} + \Pi_t - T_t \tag{4}$$

where  $P_t$  denotes the overall price index of the domestic economy (i.e., the price of consumption basket  $C_t$ ),  $P_{H,t}$  denotes the price index of domestic products,  $W_t$  denotes the nominal wage,  $B_t$  denotes the domestic bonds denominated in domestic currency,  $R_t$  denotes gross interest rate of domestic bonds in period  $t$ ,  $\Pi_t$  denotes dividends received from imperfect competitive intermediate manufacturers, and  $T_t$  denotes the lump-sum tax.

Solving the households’ optimization problem leads to the following first-order conditions (FOCs, in log-linear form):

$$\hat{w}_t - \hat{p}_t = \frac{\sigma}{1-h} (\hat{c}_t - h\hat{c}_{t-1}) + \phi \hat{n}_t \tag{5}$$

$$\hat{c}_t = \frac{1}{1+h} E_t \hat{c}_{t+1} + \frac{h}{1+h} \hat{c}_{t-1} - \frac{1-h}{\sigma(1+h)} (\hat{r}_t - E_t \hat{\pi}_{t+1}) \tag{6}$$

$$\hat{r}_t - E_t \hat{\pi}_{H,t+1} = (\hat{r}_t^* - E_t \hat{\pi}_{t+1}^*) + \frac{\gamma I}{1+\gamma I} E_t (\hat{I}_{t+1} - \hat{I}_t) \tag{7}$$

where a letter without time subscript denotes the steady-state value of the respective variable, while a lowercase letter with a “hat” superscript represents log-deviation of the variable from its steady-state value (i.e.,  $\hat{x}_t \equiv \log X_t - \log X$ ),  $\hat{\pi}_t = \hat{p}_t - \hat{p}_{t-1}$  is CPI inflation,  $\hat{\pi}_{H,t} = \hat{p}_{H,t} - \hat{p}_{H,t-1}$  is domestic inflation, and  $\hat{\pi}_t^* = \hat{p}_t^* - \hat{p}_{t-1}^*$  is foreign inflation. As one can see, Eq. (5) corresponds to the optimal labor supply, Eq. (6) stands for the consumption Euler equation with habit formation, and Eq. (7) represents the optimal condition for cross-border financial investments.

### 2.2 The producers

The producers sector consists of numerous intermediate manufacturers and one final manufacturer who purchases intermediate products to produce domestic products  $Y_{H,t}$ .

The final manufacturer minimizes its costs under the following Dixit–Stiglitz-type aggregate production function:

$$Y_{H,t} = \left( \int_0^1 Y_{H,t}(j)^{\frac{\chi-1}{\chi}} dj \right)^{\frac{\chi}{\chi-1}} \tag{8}$$

where  $\chi$  denotes the elasticity of substitution between different intermediate products produced within the same economy. Cost minimization leads to the price index of

domestic products: 
$$P_{H,t} = \left( \int_0^1 P_{H,t}(j)^{1-\chi} dj \right)^{\frac{1}{1-\chi}} .$$

Assuming a similar market structure and aggregate technology employed by the importers, the price index of imported products can be written as  $P_{F,t} =$

$$\left( \int_0^1 P_{F,t}(j)^{1-\chi} dj \right)^{\frac{1}{1-\chi}} .$$
 Then, the overall price index is constructed as follows:

$$P_t = \left[ (1 - \omega)P_{H,t}^{1-\eta} + \omega P_{F,t}^{1-\eta} \right]^{\frac{1}{1-\eta}} . \tag{9}$$

As usual, intermediate manufacturers are assumed to produce intermediate products under monopolistic competition with a Cobb–Douglas (C–D) production function:  $Y_{H,t}(j) = A_t N_t(j)^{1-\alpha}$ , where  $A_t$  stands for the production technology commonly shared among intermediate manufacturers,  $N_t(j)$  denotes labor hired by firm  $j$ , and  $\alpha$  refers to the share of capital income in total output.

As in Calvo (1983), it is assumed that each intermediate manufacturer can reset its price with probability  $1 - \theta$  in each period. Then the objective of intermediate manufacturer  $j$  who can re-price its products is to maximize discounted expected nominal profits by setting price  $P_{H,t}(j)$ :

$$\max_{P_{H,t}(j)} E_t \sum_{k=0}^{\infty} \theta^k \Omega_{t,t+k} [Y_{H,t+k}(j) P_{H,t}(j) - W_{t+k} N_{t+k}(j)] \tag{10}$$

where  $\Omega_{t,t+k} = \Omega_{t,t+1} \Omega_{t+1,t+2} \dots \Omega_{t+k-1,t+k}$ ,  $\Omega_{t,t+1} = \frac{1}{R_t}$  denotes the stochastic discount factor,  $Y_{H,t+k}(j)$  denotes demand of firm  $j$  in period  $t+k$  after price had been set in period  $t$ ,  $W_{t+k}$  denotes unit wage in period  $t+k$ . Under the standard Calvo–Yun approach (Calvo 1983; Yun 1996), we obtain the following forward-looking New Keynesian Phillips curve of domestic inflation (domestic NKPC, in log-linear form):

$$\hat{\pi}_{H,t} = \beta E_t \hat{\pi}_{H,t+1} + \Phi \widehat{m}c_{H,t} \tag{11}$$

where  $\Phi = \frac{(1-\theta)(1-\beta\theta)}{\theta}$ ,  $\widehat{m}c_{H,t}$  denotes the real marginal cost of intermediate manufacturer in log-linear form.

### 2.3 The importers

The structure of the importers sector is analogous to the producers sector, which consists of numerous intermediate importers and one final importer. Similarly, intermediate importers are under monopolistic competition and subjected to sluggish price adjustment à la Calvo (1983). The probability for each intermediate importer to reset its price in each period is  $1 - \theta_F$ . The real marginal cost of intermediate importer is given by:

$$MC_{F,t} = \frac{\varepsilon_t P_t^*}{P_{F,t}} \tag{12}$$

where  $\varepsilon_t$  denotes the nominal exchange rate.

Profits maximization leads to the following standard New Keynesian Phillips curve of imported inflation (imported NKPC):

$$\hat{\pi}_{F,t} = \beta E_t \hat{\pi}_{F,t+1} + \Phi_F \widehat{mc}_{F,t} \tag{13}$$

where  $\Phi_F = \frac{(1-\theta_F)(1-\beta\theta_F)}{\theta_F}$ .

### 2.4 Gradual financial integration and the international financial markets

#### 2.4.1 Law of one price under imperfect financial integration

Under the assumption of perfect financial integration, domestic and foreign prices can achieve equilibrium instantly with perfect exchange rate pass-through, which leads to the classic law of one price (LOP) condition as follows:

$$P_{F,t} = \varepsilon_t P_t^* \tag{14}$$

However, in reality, domestic financial markets in many emerging market economies are not perfectly integrated with the international financial markets and there are in fact various restrictions on access to foreign financial markets. For example, to reduce the impact of external shocks on domestic financial markets, restrictive regulations are usually imposed to limit capital flows, international financial transactions and currency exchanges. These measures give rise to financial frictions and induce various types of costs, which lead to deviations from the classic LOP condition. In view of this, Eq. (14) can be modified as:

$$P_{F,t} = \varepsilon_t P_t^* (L_t Z_t)^\gamma \tag{15}$$

where  $L_t$  denotes transaction costs, and  $Z_t$  denotes the LOP gap which is assumed to follow an AR (1) process:  $\hat{z}_t = \rho_z \hat{z}_{t-1} + \varepsilon_t^z$ , where  $\varepsilon_t^z \sim i.i.d.N(0, \sigma_z^2)$  is an exogenous lop gap shock.



In addition, we assume that transaction costs are proportional to cross-border financial investments, i.e.,  $L_t = \xi P_{H,t} I_t$ , with its log-linear form given by:

$$\Delta \hat{l}_t = \hat{\pi}_{H,t} + \Delta \hat{I}_t + \varepsilon_t^l \tag{16}$$

where  $\Delta \hat{l}_t = \hat{l}_t - \hat{l}_{t-1}$ , and  $\varepsilon_t^z \sim i.i.d.N(0, \sigma_z^2)$  is an exogenous transaction cost shock.

As one can see from Eq. (15), the costs induced by financial frictions are closely associated with the level of financial integration  $\gamma$ . At higher levels of financial integration (i.e., lower values of  $\gamma$ ), there are less costs and smaller deviations from the classic LOP condition. Thus, Eq. (15) captures the notion that domestic and foreign prices converge at higher levels of financial integration due to less financial frictions. Note also that in the polar case of  $\gamma = 0$ , Eq. (15) collapses to the classic LOP condition for perfect financial integration.

The log-linear form of Eq. (15) is given by:

$$\hat{p}_{F,t} = \hat{\varepsilon}_t + \hat{p}_t^* + \gamma (\hat{l}_t + \hat{z}_t). \tag{17}$$

Meanwhile, as is standard in the literature, terms of trade is defined as:

$$S_t \equiv \frac{P_{F,t}}{P_{H,t}}. \tag{18}$$

The real exchange rate is defined as:

$$Q_t \equiv \frac{\varepsilon_t P_t^*}{P_t}. \tag{19}$$

Log-linearizing Eqs. (9), (18), (19) and rearranging these equations, we have:

$$\hat{\pi}_t = (1 - \omega)\hat{\pi}_{H,t} + \omega\hat{\pi}_{F,t} \tag{20}$$

$$\Delta \hat{s}_t = \hat{\pi}_{F,t} - \hat{\pi}_{H,t} \tag{21}$$

$$\hat{q}_t = (1 - \omega)\hat{s}_t - \gamma (\hat{l}_t + \hat{z}_t). \tag{22}$$

Equation (22) says that in an economy with imperfect financial integration ( $\gamma \in (0, 1]$ ), the real exchange rate is not only related to the terms of trade, but also related to the various costs arising from financial frictions, and the impact of the costs declines as financial integration improves. In the context of perfect financial integration ( $\gamma = 0$ ), Eq. (22) collapses to  $\hat{q}_t = (1 - \omega)\hat{s}_t$ , which is exactly the case under the assumption of perfect financial markets (see Galí and Monacelli 2005). Therefore, Eq. (22) can be viewed as a more general version of the model developed in Galí and Monacelli (2005) which allows for the role of financial integration.

### 2.4.2 UIP and risk sharing condition under imperfect financial integration

Under the assumption of perfect and fully integrated financial markets, the equilibrium price of foreign risk-free bonds denominated in domestic currencies is given by:  $\varepsilon_t (R_t^*)^{-1} = E_t \{ \Omega_{t,t+1} \varepsilon_{t+1} \}$ , while the pricing equation of domestic bonds is given by:  $(R_t)^{-1} = E_t \{ \Omega_{t,t+1} \}$ . Combining these two equations delivers the classic uncovered interest rate parity (UIP) as assumed in most open economy models:

$$E_t \left\{ \Omega_{t,t+1} \left[ R_t - R_t^* \frac{\varepsilon_{t+1}}{\varepsilon_t} \right] \right\} = 0. \tag{23}$$

Rearranging Eq. (23) we have:

$$\frac{1}{R_t} = \frac{1}{R_t^*} \frac{\varepsilon_t}{\varepsilon_{t+1}}. \tag{24}$$

Combining Eq. (24) with the consumption Euler equations for domestic and foreign households, we obtain:

$$\begin{aligned} \beta E_t \left\{ \left( \frac{C_{t+1} - hC_t}{C_t - hC_{t-1}} \right)^{-\sigma} \left( \frac{P_t}{P_{t+1}} \right) \right\} &= E_t \Omega_{t,t+1} \\ &= \beta E_t \left\{ \left( \frac{C_{t+1}^* - hC_t^*}{C_t^* - hC_{t-1}^*} \right)^{-\sigma} \left( \frac{P_t^*}{P_{t+1}^*} \right) \frac{\varepsilon_t}{\varepsilon_{t+1}} \right\}. \end{aligned} \tag{25}$$

Plugging Eq. (19) into Eq. (25), we have:

$$E_t \left( \frac{C_{t+1} - hC_t}{C_t - hC_{t-1}} \right) = E_t \left( \frac{C_{t+1}^* - hC_t^*}{C_t^* - hC_{t-1}^*} \right) \left( \frac{Q_{t+1}}{Q_t} \right)^{\frac{1}{\sigma}}. \tag{26}$$

As in Galí and Monacelli (2005), assuming the proportions of domestic and foreign consumption are fixed in the process of optimization, Eq. (26) can be written into the following one-period form:

$$C_t - hC_{t-1} = \nu (C_t^* - hC_{t-1}^*) Q_t^{\frac{1}{\sigma}} \tag{27}$$

where  $\nu$  is certain constant that depends on the initial relative assets holdings of domestic and foreign households.

Log-linearizing Eq. (27) leads to:

$$\hat{c}_t - h\hat{c}_{t-1} = \hat{c}_t^* - h\hat{c}_{t-1}^* + \frac{1-h}{\sigma} \hat{q}_t. \tag{28}$$

Plugging Eq. (22) into Eq. (28), we have:

$$\hat{c}_t - h\hat{c}_{t-1} = \hat{c}_t^* - h\hat{c}_{t-1}^* + \frac{1-h}{\sigma} \left[ (1-\omega)\hat{s}_t - \gamma(\hat{l}_t + \hat{z}_t) \right]. \tag{29}$$

Again, Eq. (29) can be viewed as a more general form of the classic risk sharing condition obtained under the assumption of perfect and fully integrated financial markets (corresponding to the polar case of  $\gamma = 0$ ). However, as long as domestic financial markets are not perfectly integrated with the international financial markets ( $\gamma \in (0, 1]$ ), the level of financial integration and the associated costs would play a role in international risk sharing, as suggested by Eq. (29).

### 2.5 Monetary policy

Monetary policy is set by the central bank according to the following standard Taylor rule:

$$\hat{r}_t = \rho_r \hat{r}_{t-1} + (1 - \rho_r)(r_\pi \hat{\pi}_t + r_y \hat{y}_{H,t}) + \varepsilon_t^r \tag{30}$$

where  $\rho_r$  denotes policy smoothing,  $r_\pi$  and  $r_y$  are the reaction coefficients of monetary policy to inflation and output gap, respectively, and  $\varepsilon_t^r \sim i.i.d.N(0, \sigma_r^2)$  is an exogenous interest rate shock.

### 2.6 The government

The government purchases domestic products and finances its expenditure by lump-sum taxation:

$$P_{H,t}G_t = T_t. \tag{31}$$

As usual, for simplicity we assume that government expenditure is a constant proportion of the aggregate demand for domestic products:  $G_t = \delta_3 Y_{H,t}$ , with its log-linear form given by:

$$\hat{g}_t = \hat{y}_{H,t}. \tag{32}$$

### 2.7 Equilibriums

#### 2.7.1 Aggregate demand and the extended IS curve

The market clearing condition of domestic products requires that aggregate demand equals to aggregate supply:

$$Y_{H,t} = C_{H,t} + C_{H,t}^* + G_t + I_t + \psi_t \tag{33}$$

where  $C_{H,t}^*$  denotes foreign households' consumption on domestic products.

With some subsequent computations, the extended IS curve (in log-linear form) is given by:

$$\hat{y}_{H,t} = \delta_1 \hat{c}_t + \delta_2 \hat{c}_t^* + (\delta_1 + \delta_2)\eta\omega\hat{s}_t + \delta_2\eta\left[\hat{q}_t + \gamma\left(\hat{l}_t + \hat{z}_t\right)\right] + \delta_3\hat{g}_t + \delta_4\hat{l}_t + \delta_5\hat{\psi}_t \quad (34)$$

where  $\delta_1 = \frac{C_H}{Y_H}$  is the proportion of domestic households' consumption on domestic products in aggregate demand at steady state. Similarly,  $\delta_2 = \frac{C_H^*}{Y_H}$ ,  $\delta_3 = \frac{G}{Y_H}$ ,  $\delta_4 = \frac{I}{Y_H}$ ,  $\delta_5 = \frac{\psi}{Y_H}$ .

From Eq. (34), we can see that, by relaxing the assumption of perfect (fully integrated with international financial markets) financial markets, the aggregate demand is now influenced by the level of financial integration ( $\gamma$ ).

### 2.7.2 Aggregate supply and the extended Phillips curve

According to the production function defined in the producers sector,  $Y_{H,t}(j) = A_t N_t(j)^{1-\alpha}$ , the real marginal cost of intermediate manufacturers is derived as (in log-linear form):  $\widehat{mc}_{H,t} = \hat{w}_t + \hat{n}_t - \hat{p}_{H,t} - \hat{y}_{H,t}$ . Plugging Eq. (5) into it, we have:

$$\widehat{mc}_{H,t} = \frac{\phi + \alpha}{1 - \alpha} \hat{y}_{H,t} - \frac{\phi + 1}{1 - \alpha} \hat{a}_t + \omega\hat{s}_t + \frac{\sigma}{1 - h} (\hat{c}_t - h\hat{c}_{t-1}) \quad (35)$$

where the production technology  $\hat{a}_t$  is assumed to follow an AR(1) process:  $\hat{a}_t = \rho_a \hat{a}_{t-1} + \varepsilon_t^a$ ,  $\varepsilon_t^a \sim i.i.d.N(0, \sigma_a^2)$  is an exogenous technology shock.

Combining Eqs. (11), (29) and (35) yields the following extended New Keynesian Phillips Curve (NKPC) for domestic inflation:

$$\begin{aligned} \hat{\pi}_{H,t} &= \beta E_t \hat{\pi}_{H,t+1} \\ &+ \Phi \left[ \frac{\phi + \alpha}{1 - \alpha} \hat{y}_{H,t} - \frac{\phi + 1}{1 - \alpha} \hat{a}_t + \frac{\sigma}{(1 - h)} (\hat{c}_t^* - h\hat{c}_{t-1}^*) + \hat{s}_t - \gamma (\hat{l}_t + \hat{z}_t) \right]. \end{aligned} \quad (36)$$

An examination of Eq. (36) immediately reveals that, the domestic NKPC we derived deviates from the standard literature in that financial integration can have an impact on domestic inflation via the real marginal cost channel. Specifically, an increase in financial integration would mitigate the impact of financial friction costs on domestic inflation.

According to Eq. (12), the log-linearized real marginal cost of intermediate importers is derived as:  $\widehat{mc}_{F,t} = \hat{\varepsilon}_t + \hat{p}_t^* - \hat{p}_{F,t}$ . Combining Eq. (19), we have:

$$\widehat{mc}_{F,t} = \hat{q}_t - (1 - \omega)\hat{s}_t. \quad (37)$$

Plugging Eq. (37) into Eq. (13), we have the following New Keynesian Phillips curve for imported inflation:

$$\hat{\pi}_{F,t} = \beta E_t \hat{\pi}_{F,t+1} + \frac{(1 - \beta\theta_F)(1 - \theta_F)}{\theta_F} [\hat{q}_t - (1 - \omega)\hat{s}_t]. \tag{38}$$

Again, as  $\hat{q}_t = (1 - \omega)\hat{s} - \gamma(\hat{l}_t + \hat{z}_t)$ , the dynamics of imported inflation would also be affected by the level of financial integration.

### 2.8 Foreign economy

As is standard in the literature (e.g., Galí and Monacelli 2005), the clearing condition for the foreign economy is given by  $\hat{y}_t^* = \hat{c}_t^*$ . Foreign output, CPI inflation and foreign nominal interest rate are all assumed to follow AR (1) processes:

$$\hat{y}_t^* = \rho_{y^*} \hat{y}_{t-1}^* + \varepsilon_t^{y^*} \tag{39}$$

$$\hat{\pi}_t^* = \rho_{\pi^*} \hat{\pi}_{t-1}^* + \varepsilon_t^{\pi^*} \tag{40}$$

$$\hat{r}_t^* = \rho_{r^*} \hat{r}_{t-1}^* + \varepsilon_t^{r^*} \tag{41}$$

where  $\varepsilon_t^{y^*}$ ,  $\varepsilon_t^{\pi^*}$ ,  $\varepsilon_t^{r^*}$  denote exogenous foreign output shock, foreign inflation shock and foreign interest rate shock, respectively.

## 3 Estimation results

### 3.1 Estimation methodology

We employ Bayesian technique to estimate the DSGE model constructed in Sect. 2. Compared with other estimation methodologies, Bayesian technique can better deal with problems of misspecification and outperforms alternative methods such as generalized moment estimation (GMM) and maximum likelihood estimation (MLE) in small samples, as noted by Lubik and Schorfheide (2006). These advantages not only enable Bayesian technique to yield more accurate and reasonable estimates, but also make it a more universal technique for estimating DSGE models (Smets and Wouters 2003, 2007).

### 3.2 Data and prior distributions

To estimate the model, we use data from the Chinese economy. The gradualist approach adopted by the Chinese government in financial integration makes the Chinese economy an ideal example for studying the main issues of our paper.

China's financial integration with the world could date back to the historic decision of "Reform and Opening-up" in 1978. Since then China's financial integration has been characterized as a disciplined and gradual process. In 1994, the dual exchange rate system merged into one single "managed floating exchange rate system based on market supply and demand," marked as a significant step forward. In 1996, China realized full convertibility under current account and prepared for further integration. However, the process was interrupted by the 1997 Asian Financial Crisis, from which China drew on important experiences from its neighbors that the process of financial integration should be matched with the fundamentals of the economy. Having in mind that there were still distortions and deficiencies in the real economy and the financial system, Chinese policymakers have been holding a firm stance in promoting financial integration in a gradual manner.

The landmark of China's financial integration was the accession to the World Trade Organization (WTO) at the end of 2001, when China made its commitment to weaving its financial system more closely into the global market. Since then, the integration process has been fueled, and the "basket-peg managed floating exchange rate system" was adopted in 2005. Caution still pervaded the whole process, which is believed to be a key element of China's success in safeguarding its financial system during the 2008 international financial crisis. Despite the lingering impact of 2008 crisis, China has been pushing ahead with internationalization of RMB and succeeded in the RMB's inclusion in the SDR basket in 2015.

Overall, China has made great strides in financial integration in the past two decades. Nevertheless, the degree of China's financial integration is still thought to have lagged behind its economic integration with the global economy, hence there is a long way to go beyond in the future. In general, China's gradual financial integration is centered on three pillars (see Table 1): (i) gradually moving toward a more market-based exchange rate regime, (ii) gradual liberalization of the capital account and (iii) the gradual bidirectional opening up of financial services.

In estimating the model, we use data over the period of 2002Q1-2019Q3. Inasmuch as China's accession to WTO is widely regarded as a milestone for China's financial integration with the world economy, we take 2002Q1 as our starting point. The sample period ends in 2019Q3 before the breakout of the COVID-19 crisis.

There are seven exogenous shocks in our model: technology shock, interest rate shock, transaction cost shock, log gap shock, foreign output shock, foreign inflation shock and foreign interest rate shock. In Bayesian estimation, as the number of observable variables should not exceed the number of shocks, six macroeconomic variables are used as observables: domestic output, domestic overall inflation (China's CPI inflation), domestic nominal interest rate (7-day interbank market interest rate in China), foreign output (real GDP of the USA), foreign overall inflation (CPI inflation of the USA) and foreign nominal interest rate (federal funds rate in the USA). Domestic macroeconomic data are obtained from National Bureau of Statistics of China and People's Bank of China (PBoC). As usual, since the USA is used as a proxy for the foreign economy, foreign macroeconomic data used in estimation are obtained from Federal Reserve Economic Data (FRED). In line with the log-deviation definition of the model variables, all of the raw data are logged on a seasonally adjusted basis and then de-trended using one-side HP filter (Stock and Watson 1999).

**Table 1** Memorabilia of China's financial integration process

Time	Events
	<i>Reform of exchange rate system</i>
1994	Switch to market-based managed floating exchange rate system
2005	Switch to basket-peg managed floating exchange rate system
2014	Widen daily exchange rate margin to 2%
2015	Reform RMB exchange rate formation mechanism
2017	Introduction of counter-cyclical factor to RMB exchange rate formation mechanism
	<i>Liberalization of capital account</i>
1996	Realization of full convertibility under current account
2002	Introduction of Qualified Foreign Institutional Investor (QFII) system
2007	Introduction of Qualified Domestic Institutional Investor (QDII) system
2011	Introduction of RMB Qualified Foreign Institutional Investor (RQFII) system
2014	Introduction of RMB Qualified Domestic Institutional Investor (RQDII) system
2014	Opening Shanghai-Hong Kong stock connect
2015	RMB's inclusion in the SDR basket
2016	Opening Shenzhen-Hong Kong stock connect
2017	Announcement of opening Bond connect
2019	Abolishment of investment limit on QFII and RQFII
	<i>Bidirectional opening of financial services</i>
2002	Relaxation of entry barriers to securities for foreign institutions
2004	Abolishment of various restrictions on insurance for foreign investors
2006	Abolishment of various restrictions on banking for foreign investors
Since 2003	The Joint-stock Reforms, Overseas listings, acquisitions and establishment of branches overseas of State-owned enterprises

In Bayesian estimation, some parameters must be calibrated before estimation to avoid identification problems. The discount factor,  $\beta$ , is calibrated at 0.99, indicating an annual interest rate of 4%. The elasticity of substitution between domestic and foreign goods,  $\eta$ , is set to be 1, as in Lubik and Schorfheide (2007). The degree of trade openness,  $\omega$ , is set to 0.21 to be in line with the average proportion of imports in the final consumption over the sample period. The proportion of domestic households' consumption on domestic products in domestic output ( $\delta_1$ ) is calibrated at 0.313 to match the historical average over the sample period. Analogously, we calibrate the proportion of foreign households' consumption on domestic products in domestic output ( $\delta_2$ ) at 0.205, the proportion of government purchase in domestic output ( $\delta_3$ ) at 0.128 and the proportion of foreign financial investment in domestic output ( $\delta_4$ ) at 0.024. Finally, the proportion of adjustment costs in domestic output ( $\delta_5$ ) is calculated to be 0.33 using the steady-state relationship as implied by Eq. (33).

The rest parameters of the model are all estimated with Bayesian technique, with their prior distributions presented in first two columns of Table 2. The inverse of elasticity of intertemporal substitution,  $\sigma$ , is assumed to follow gamma distribution

**Table 2** Prior and posterior distributions of parameters

Parameter	Prior distribution	Posterior mean	Posterior standard error	90% Confidence interval
$\sigma$	Gamma[1.5, 0.1]	1.487	0.097	[1.324, 1.640]
$\phi$	Gamma[2, 0.5]	2.284	0.538	[1.385, 3.099]
$h$	Beta[0.5, 0.1]	0.403	0.091	[0.252, 0.551]
$\alpha$	Beta[0.5, 0.1]	0.578	0.098	[0.420, 0.742]
$\theta$	Beta[0.75, 0.15]	0.860	0.022	[0.824, 0.897]
$\theta_F$	Beta[0.75, 0.15]	0.844	0.044	[0.771, 0.912]
$\gamma$	Beta[0.5, 0.1]	0.509	0.100	[0.338, 0.668]
$\rho_r$	Beta[0.75, 0.15]	0.728	0.038	[0.667, 0.791]
$r_y$	Beta[0.5, 0.1]	0.565	0.092	[0.415, 0.717]
$r_\pi$	Gamma[1.5, 0.1]	1.348	0.094	[1.196, 1.503]
$\rho_a$	Beta[0.75, 0.15]	0.939	0.039	[0.885, 0.997]
$\rho_z$	Beta[0.75, 0.15]	0.755	0.148	[0.533, 0.983]
$\rho_{y^*}$	Beta[0.75, 0.15]	0.909	0.037	[0.849, 0.970]
$\rho_{\pi^*}$	Beta[0.75, 0.15]	0.446	0.064	[0.343, 0.552]
$\rho_{r^*}$	Beta[0.75, 0.15]	0.904	0.025	[0.863, 0.943]
$\sigma_a$	Inv gamma[0.01, $\infty$ ]	0.017	0.007	[0.007, 0.027]
$\sigma_r$	Inv gamma[0.01, $\infty$ ]	0.009	0.001	[0.008, 0.010]
$\sigma_z$	Inv gamma[0.01, $\infty$ ]	0.008	0.006	[0.002, 0.016]
$\sigma_l$	Inv gamma[0.01, $\infty$ ]	0.068	0.018	[0.040, 0.094]
$\sigma_{y^*}$	Inv gamma[0.01, $\infty$ ]	0.004	0.0004	[0.004, 0.005]
$\sigma_{\pi^*}$	Inv gamma[0.01, $\infty$ ]	0.008	0.0007	[0.007, 0.009]
$\sigma_{r^*}$	Inv gamma[0.01, $\infty$ ]	0.003	0.0002	[0.002, 0.003]

(1) This table presents the prior and posterior distributions of the parameters in the model; (2) Numbers in the square brackets of the prior distribution are prior means and standard errors; (3) Numbers in the square brackets of the confidence interval are the lower and upper bounds of the posterior estimates at the 90% confidence interval

with prior mean 1.5 and standard error 0.1, and the inverse of elasticity of labor supply,  $\phi$ , is assumed to follow gamma distribution with prior mean 2 and standard error 0.5. The persistence of consumption habit,  $h$ , as well as the share of capital income,  $\alpha$ , is assumed to follow beta distribution with prior mean 0.5 and standard error 0.1. The Calvo pricing parameters for domestic producers  $\theta$  and importers  $\theta_F$  are both assumed to follow beta distribution with mean 0.75 and standard error 0.15. For the parameter of financial integration,  $\gamma$ , since its theoretical boundary is  $[0, 1]$ , a beta distribution with mean 0.5 and standard error 0.1 is assumed.

Turning to monetary policy parameters, the persistence parameter  $\rho_r$  is assumed to follow beta distribution with prior mean 0.75 and standard error 0.15. Meanwhile, the reaction coefficient to output gap,  $r_y$ , is assumed to follow beta distribution with mean 0.5 and standard error 0.1, and the reaction coefficient to inflation gap,  $r_\pi$ , is assumed to follow gamma distribution with mean 1.5 and standard error 0.1. Finally, for all AR



(1) processes, the persistence parameters are all assumed to be beta distributed with prior mean 0.75 and standard error 0.15, and all exogenous shocks are assumed to follow inverted gamma distribution with standard error 0.01.

### 3.3 Parameter estimates

The posterior estimates for model parameters, which are obtained based on 100,000 draws with 90% confidence intervals, are reported in the last three columns of Table 2. As one can see, the inverse of elasticity of intertemporal substitution  $\sigma$  is estimated to be 1.487, indicating that the Chinese households exhibit strong risk aversion and prefer current consumption to future consumption, with 1 percent increase in interest rate leading to only 0.672 percent increase in future consumption. The estimate of the inverse of elasticity of labor supply  $\phi$  is 2.284, indicating a relatively low sensitivity of labor supply to wage changes. The persistence of consumption habit  $h$  is estimated to be 0.403, which is much lower than those estimated for advanced economies (e.g., Christiano et al. 2005; Hohberger et al. 2019; Aursland et al. 2020), suggesting a relatively low consumption persistence in China. For parameters of the producers, the share of capital income  $\alpha$  is estimated to be 0.578, which is higher than those found in advanced economies (e.g., Smets and Wouters 2007; Kulish et al. 2017; Giri 2018). The estimate of Calvo parameter  $\theta$  is 0.860, suggesting that only 14% of the intermediate manufacturers can re-optimize their prices in each period. However, the price adjustment of importers shows slightly more flexibility, with the Calvo parameter  $\theta_F$  estimated at 0.844, indicating an average delay of 6.5 quarters between price adjustments.

Turning to the estimates of monetary policy parameters, the policy smoothing parameter  $\rho_r$  is estimated to be 0.728, indicating a relatively high degree of policy smoothing. The reaction parameters of interest rate to inflation and output gap ( $r_\pi$  and  $r_y$ ) are estimated to be 1.348 and 0.565, respectively, indicating that the PBoC has a stronger preference for output stabilization but a weaker preference for inflation control as compared with advanced economies. Regarding the financial integration parameter,  $\gamma$ , which is a main focus of our study, its posterior mean is 0.509, indicating a medium level of financial integration for the Chinese economy over the sample period. According to the model presented in Sect. 2, when  $\gamma = 0.509$ , the LOP condition deviates from the classic one as there are friction costs associated with imperfect financial integration, and this is largely in line with the “managed floating exchange rate system” implemented in China over this period. Finally, for parameters that are related to exogenous shocks, all the autoregressive parameters show considerable degrees of persistence.

## 4 Implications for macroeconomic fluctuations

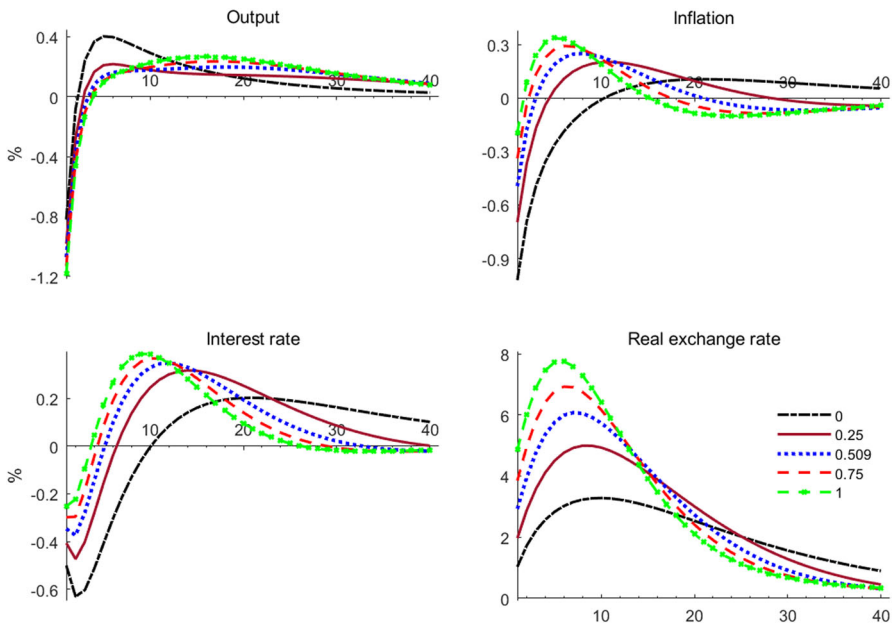
In this section, we investigate how macroeconomic fluctuations vary at different levels of financial integration. To do so, a data set of {0, 0.25, 0.509, 0.75, 1} is assigned to  $\gamma$  to represent different levels of financial integration, where a smaller value of  $\gamma$

corresponds to a higher level of financial integration, and  $\gamma = 0.509$  is the estimated value of China's financial integration obtained in Sect. 3.3 and thus is used as the baseline scenario.

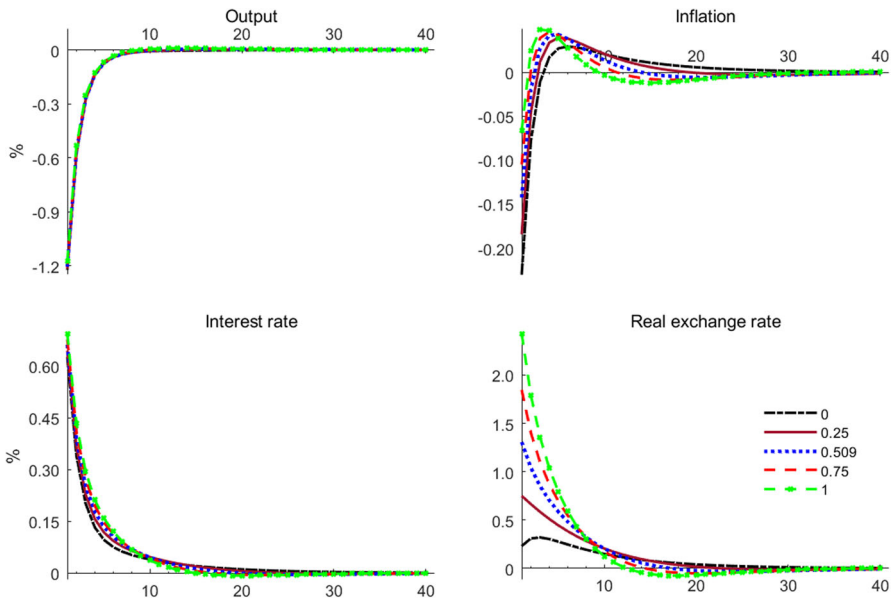
#### 4.1 Impulse response analysis

There are four main macroeconomic variables (i.e., domestic output, inflation, interest rate and real exchange rate) and seven exogenous shocks in our model. The shocks can be divided into three categories: (i) the technology shock and the interest rate shock, which originate from the domestic economy; (ii) the transaction cost shock and the log gap shock, which affect foreign exchange transactions; (iii) the foreign output shock, the foreign inflation shock and the foreign interest rate shock, which originate from the foreign economy. To see how macroeconomic fluctuations vary at different levels of financial integration, the impulse responses of these four variables under each exogenous shock are plotted in Figs. 1, 2, 3, 4, 5, 6 and 7.

Figure 1 shows the impulse responses under a positive technology shock. We start by considering the baseline scenario. The price of domestic products falls due to



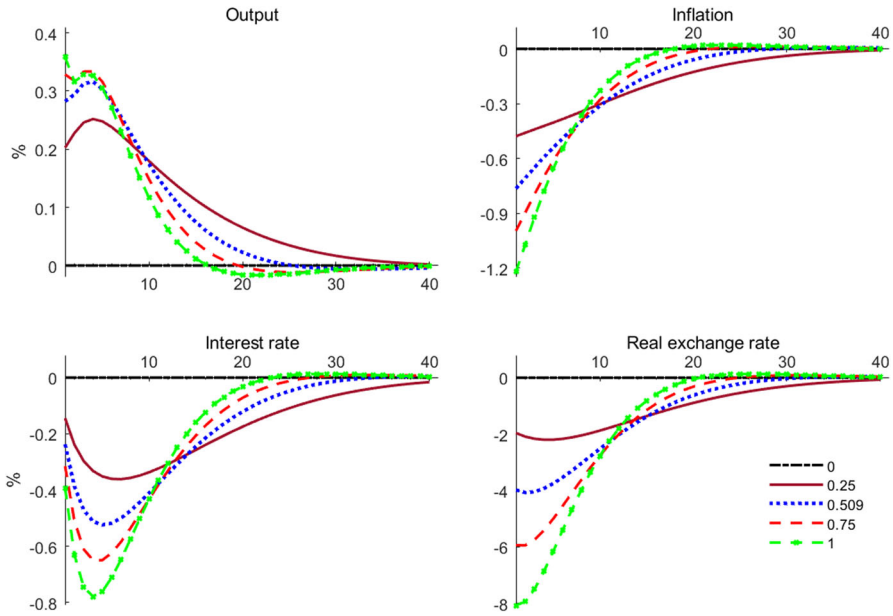
**Fig. 1** Macroeconomic dynamics under different levels of financial integration: the case of a positive technology shock. *Notes* (1) This figure shows the impulse responses of output, inflation, nominal interest rate and real exchange rate under a positive technology shock with different levels of financial integration; (2) The impulse responses are computed under different levels of financial integration while other parameters of the model are kept fixed at their calibrated or estimated values in Sect. 3.3; (3) Five representative values (i.e., 0, 0.25, 0.509, 0.75 and 1) are assigned to the financial integration parameter  $\gamma$ , with a smaller value of  $\gamma$  indicating a higher level of financial integration; (4)  $\gamma = 0.509$  is the estimate of China's actual financial integration over the sample period of 2002Q1–2019Q3, which is used as the baseline scenario



**Fig. 2** Macroeconomic dynamics under different levels of financial integration: the case of a positive interest rate shock. *Notes* (1) This figure shows the impulse responses of output, inflation, nominal interest rate and real exchange rate under a positive interest rate shock with different levels of financial integration; (2) The impulse responses are computed under different levels of financial integration while other parameters of the model are kept fixed at their calibrated or estimated values in Sect. 3.3; (3) Five representative values (i.e., 0, 0.25, 0.509, 0.75 and 1) are assigned to the financial integration parameter  $\gamma$ , with a smaller value of  $\gamma$  indicating a higher level of financial integration; (4)  $\gamma = 0.509$  is the estimate of China’s actual financial integration over the sample period of 2002Q1–2019Q3, which is used as the baseline scenario

lower marginal costs brought by technical advances (via the domestic NPKC), which decreases the overall inflation. Facing lower domestic inflation, households reduce foreign financial investments as implied by Eq. (7), resulting in a contraction in aggregate demand. To stimulate the shrinking economy, the central bank cuts nominal interest rate according to the Taylor rule. However, falling domestic prices cause real exchange rate to depreciate and raise the competitiveness of domestic products. This boosts aggregate demand and drives manufacturers to expand production at incremental marginal costs, which offsets the decrease in output and inflation. Therefore, output and inflation exhibit an increasing trend, which decline sharply in period 1 and rise above the steady state thereafter. As the central bank adjusts interest rate at discretion and manufacturers renew domestic prices, the economy gradually moves back to steady state.

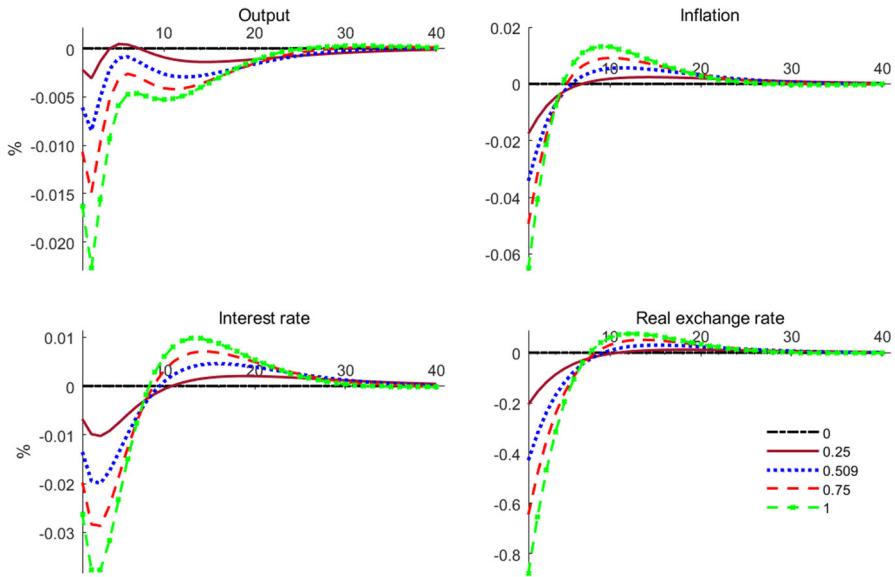
As financial integration increases (i.e.,  $\gamma$  decreases from 1 to 0), the deviations of output and real exchange rate from their steady states become smaller, while those of inflation and interest rate become larger. This is not difficult to understand. According to Eq. (22), the effect of costs arising from imperfect financial integration on real exchange rate weakens as financial integration improves. Therefore, the real exchange rate depreciates to a lesser extent, resulting in a reduction in the real marginal costs



**Fig. 3** Macroeconomic dynamics under different levels of financial integration: the case of a positive transaction cost shock. *Notes* (1) This figure shows the impulse responses of output, inflation, nominal interest rate and real exchange rate under a positive transaction cost shock with different levels of financial integration; (2) The impulse responses are computed under different levels of financial integration while other parameters of the model are kept fixed at their calibrated or estimated values in Sect. 3.3; (3) Five representative values (i.e., 0, 0.25, 0.509, 0.75 and 1) are assigned to the financial integration parameter  $\gamma$ , with a smaller value of  $\gamma$  indicating a higher level of financial integration; (4)  $\gamma = 0.509$  is the estimate of China's actual financial integration over the sample period of 2002Q1–2019Q3, which is used as the baseline scenario

of importers, as implied by the NPKC of the foreign economy. As imported inflation starts to decline, the overall inflation is brought down further. As for output, on the one hand, falling import prices reduce the competitiveness of domestic products and intensify output shrinkage. On the other hand, the decreased adjustment costs as well as increased purchasing power of domestic currency encourage households to cut foreign financial investments to a lesser extent, which offsets the decline in output. Since the second effect outweighs the first one, output fluctuations become smaller. Given the estimated Taylor rule, interest rate exhibits greater fluctuations due to the corresponding variations in output and inflation.

Figure 2 shows that, in the baseline scenario, following a positive interest rate shock, nominal interest rate responds with an immediate increase. This leads to an increase in real interest rate, encouraging households to reduce investment in foreign bonds and to postpone current consumption to the future. As a result, equilibrium aggregate demand falls (via the IS curve). Facing shrinking demand, manufacturers curtail their productions and the real marginal costs start to decrease, causing a fall in domestic inflation (via the domestic NPKC) and thus the overall inflation. Nevertheless, lower relative price of domestic products results in depreciation in real exchange rate, which induces households to shift consumption from imported to domestic goods and drives

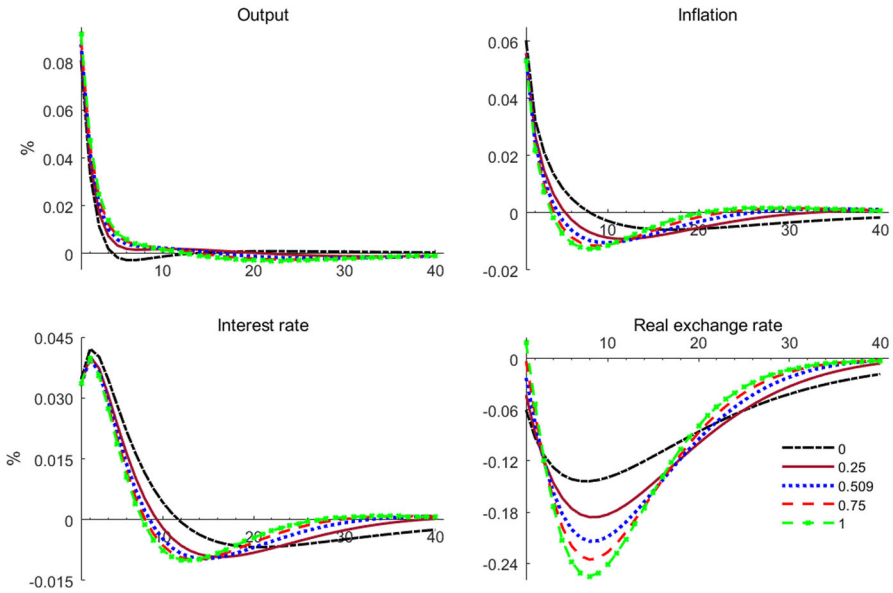


**Fig. 4** Macroeconomic dynamics under different levels of financial integration: the case of a positive log gap shock. *Notes* (1) This figure shows the impulse responses of output, inflation, nominal interest rate and real exchange rate under a positive log gap shock with different levels of financial integration; (2) The impulse responses are computed under different levels of financial integration while other parameters of the model are kept fixed at their calibrated or estimated values in Sect. 3.3; (3) Five representative values (i.e., 0, 0.25, 0.509, 0.75 and 1) are assigned to the financial integration parameter  $\gamma$ , with a smaller value of  $\gamma$  indicating a higher level of financial integration; (4)  $\gamma = 0.509$  is the estimate of China’s actual financial integration over the sample period of 2002Q1–2019Q3, which is used as the baseline scenario

manufacturers to expand production at incremental marginal costs. As a result, both inflation and output show an upward trend.

With higher financial integration, real exchange rate depreciates to a lesser extent due to less costs arising from financial frictions, which brings down imported inflation (via the foreign NPKC) and leads to lower overall inflation. The declined import prices reduce the competitiveness of domestic products and therefore intensify output contraction. To prevent severe deflation, the central bank cuts interest rate. However, to avoid disturbances caused by sudden policy reverse, the adjustment is implemented in a gradual manner. Thus, as financial integration increases, interest rate and real exchange rate exhibit smaller fluctuations, with a mild exacerbation of inflation and output fluctuations.

Figure 3 shows the impulse responses under a positive transaction cost shock. In the baseline scenario, real exchange rate appreciates since transaction costs raise the relative position of domestic overall prices to foreign overall prices, as implied by Eq. (22). This drives down imported inflation by reducing the real marginal costs of importers (via the foreign NPKC). With respect to the producers sector, the results are elusive since there are two opposing forces at work. On the one hand, the appreciation in real exchange rate creates an incentive for households to cut consumption on domestic products as suggested by the risk sharing condition, which causes output and domestic

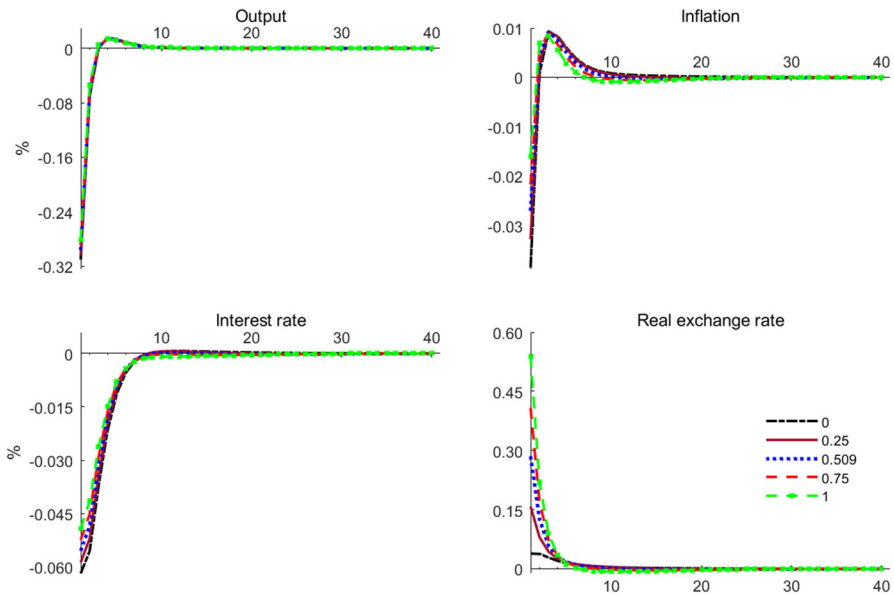


**Fig. 5** Macroeconomic dynamics under different levels of financial integration: the case of a positive foreign output shock. *Notes* (1) This figure shows the impulse responses of output, inflation, nominal interest rate and real exchange rate under a positive foreign output shock with different levels of financial integration; (2) The impulse responses are computed under different levels of financial integration while other parameters of the model are kept fixed at their calibrated or estimated values in Sect. 3.3; (3) Five representative values (i.e., 0, 0.25, 0.509, 0.75 and 1) are assigned to the financial integration parameter  $\gamma$ , with a smaller value of  $\gamma$  indicating a higher level of financial integration; (4)  $\gamma = 0.509$  is the estimate of China's actual financial integration over the sample period of 2002Q1–2019Q3, which is used as the baseline scenario

inflation to decrease (via the domestic NPKC). On the other hand, the appreciated real exchange rate induces households to invest in foreign bonds, which forces up output and domestic inflation. The latter one outweighs the former, and therefore output starts to increase. Combining the responses of imported and domestic inflation, the overall inflation decreases, and the central bank lowers interest rate as a response (according to the estimated Taylor rule).

As one can see, under the transaction cost shock, when financial integration increases, all of the four macroeconomic variables exhibit smaller fluctuations. This is mainly attributed to the fact that there are less frictions and transaction costs in more integrated financial markets, which weakens the impact of transaction cost shock on all variables. In particular, in the polar case of  $\gamma = 0$ , the influence of transaction cost shock no longer exists and all of the four variables stay at their steady state. Overall, under the transaction cost shock, macroeconomic fluctuations decrease at higher levels of financial integration.

The general picture under a positive log gap shock (as shown in Fig. 4) is similar to that under the transaction cost shock, but exhibits some noteworthy differences. According to Eq. (22), real exchange rate appreciates in response to a log gap hike, which brings down imported inflation through the real marginal cost channel. As for

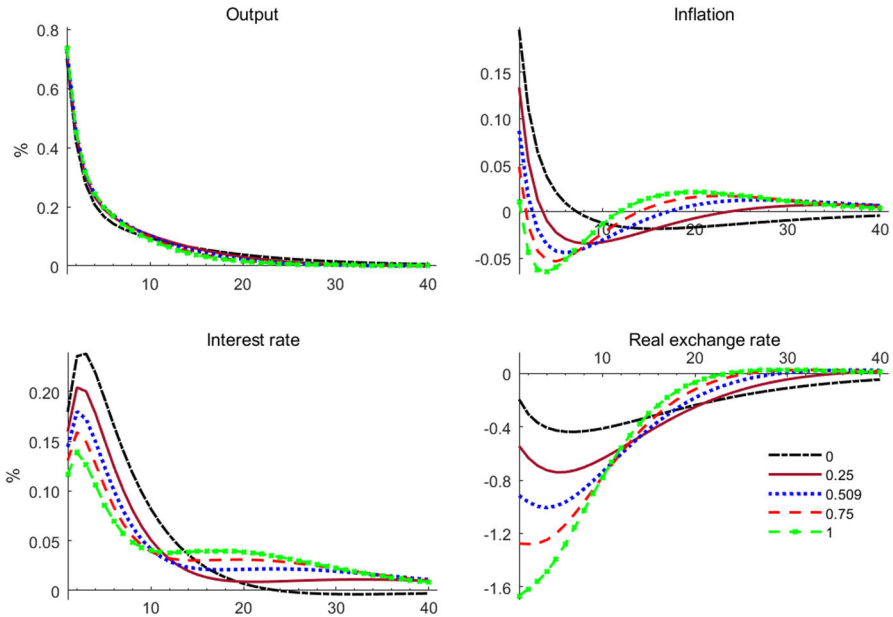


**Fig. 6** Macroeconomic dynamics under different levels of financial integration: the case of a positive foreign inflation shock. *Notes* (1) This figure shows the impulse responses of output, inflation, nominal interest rate and real exchange rate under a positive foreign inflation shock with different levels of financial integration; (2) The impulse responses are computed under different levels of financial integration while other parameters of the model are kept fixed at their calibrated or estimated values in Sect. 3.3; (3) Five representative values (i.e., 0, 0.25, 0.509, 0.75 and 1) are assigned to the financial integration parameter  $\gamma$ , with a smaller value of  $\gamma$  indicating a higher level of financial integration; (4)  $\gamma = 0.509$  is the estimate of China's actual financial integration over the sample period of 2002Q1–2019Q3, which is used as the baseline scenario

the producers sector, facing appreciated real exchange rate, the contraction effect of households' reduced consumption outweighs the expansion effect of the increase in foreign financial investments, leading to a decline in output and overall inflation. The interest rate falls as implied by the Taylor rule. However, since the real marginal costs of manufacturers decrease under shrinking demand, domestic prices decline gradually, which raises the competitiveness of domestic products. The price advantages in turn lead to a depreciation in real exchange rate and generate impetus for domestic output. As a result, all of the four macroeconomic variables decline first and rise thereafter, exhibiting an upward trend.

Analogously, in more integrated financial markets with less frictions, there are less financial friction costs affecting the LOP condition, which leads to a diminishing impact of the lop gap shock on all macroeconomic variables. In this way, increasing financial integration is helpful in mitigating macroeconomic fluctuations under the lop gap shock.

Turning to the case of a positive foreign output shock (as shown in Fig. 5), the increase in foreign output directly raises foreign consumption demand. As a result, output grows. The booming demand prompts manufacturers to expand production at incremental marginal costs, which increases the price of domestic products and thus



**Fig. 7** Macroeconomic dynamics under different levels of financial integration: the case of a positive foreign interest rate shock. *Notes* (1) This figure shows the impulse responses of output, inflation, nominal interest rate and real exchange rate under a positive foreign interest rate shock with different levels of financial integration; (2) The impulse responses are computed under different levels of financial integration while other parameters of the model are kept fixed at their calibrated or estimated values in Sect. 3.3; (3) Five representative values (i.e., 0, 0.25, 0.509, 0.75 and 1) are assigned to the financial integration parameter  $\gamma$ , with a smaller value of  $\gamma$  indicating a higher level of financial integration; (4)  $\gamma = 0.509$  is the estimate of China's actual financial integration over the sample period of 2002Q1–2019Q3, which is used as the baseline scenario

the overall inflation. To cool down the economy, the central bank raises interest rate. As trade competitiveness gradually declines because of increasing domestic prices, real exchange rate appreciates. In face of appreciated real exchange rate, households cut consumption on domestic products and consume more imported products. As a result, the demand for domestic goods declines quickly. Descending demand forces manufacturers to cut down production, and the overall inflation decreases due to lower marginal costs.

From Fig. 5, we can also see that, as financial integration increases, inflation and interest rate exhibit greater fluctuations, while output and real exchange rate show smaller fluctuations. In more integrated financial markets, real exchange rate becomes less volatile due to less financial friction costs and therefore appreciates to a lesser extent. This raises real marginal costs of the importers and leads to higher imported inflation (via the imported NKPC). The less appreciated real exchange rate encourages households to consume more as implied by the risk sharing condition, which induces manufacturers to expand production and leads to a higher level of domestic inflation (via the domestic NPKC). As a result, the overall inflation increases. However, the less appreciated real exchange rate also drives households to invest less in foreign



financial markets, which reduces aggregate demand and offsets the increase in output. According to the estimated Taylor rule, the central bank raises the interest rate to a much higher level to cool down the economy.

Figure 6 shows the impulse responses under a positive foreign inflation shock. According to Eq. (7), the increase in foreign inflation cuts down the real rate of return of foreign bonds, which generates incentives for households to reduce the investment in foreign bonds and thus the demand for domestic products. Manufacturers reduce productions at descending real marginal costs, which drives down domestic inflation (via the domestic NPKC). As a result, output and overall inflation decline sharply. The central bank lowers the interest rate to restore the economy as suggested by the Taylor rule. Nevertheless, real exchange rate depreciates because of the falling domestic prices, which creates extra demand for domestic products and offsets the contraction in output and inflation.

As financial integration improves, the fluctuations of output, inflation and interest rate become greater with the only exception of real exchange rate. This is because at higher levels of financial integration, real exchange rate is less influenced by the various costs associated with financial frictions and therefore depreciates to a lesser extent. This indicates that the price advantage of domestic products would gradually lose as financial integration improves, which weakens the associated expansion effect. As a result, output and inflation exhibit larger negative fluctuations, and interest rate decreases to a much lower level according to the Taylor rule. Overall, following a foreign inflation shock, macroeconomic fluctuations are exacerbated at higher levels of financial integration.

The results of a positive foreign interest rate shock are shown in Fig. 7. In the baseline scenario, the increase in foreign interest rate raises the return of foreign bonds, which induces households to increase investment in foreign bonds and thus the demand for domestic products. Higher domestic demand encourages manufacturers to expand production at incremental marginal costs, which leads to an increase in output and overall inflation. Then, interest rate increases as Taylor rule suggests. However, increased domestic inflation leads to an appreciation in real exchange rate and a reduction in aggregate demand. In addition, the increase in domestic real interest rate drives households to reduce foreign financial investments and to postpone current consumption to the future, which exacerbates the reduction in demand. As a result, output and inflation decline after a sharp rise in period 1.

As financial integration improves, real exchange rate appreciates to a lesser extent and exhibits smaller fluctuations as implied by Eq. (22), which raises imported inflation (via foreign NPKC) and pushes up overall inflation further. According to the risk sharing condition, households can make better use of the opportunities of smoothing consumption in more integrated financial markets, which leads to less reductions in consumption and output. However, due to less appreciation in real exchange rate, foreign financial investments increase to a lesser extent, which offsets the increase in output. Since the second effect outweighs the first, output shows smaller positive fluctuations. Due to the variations in output and inflation, interest rate exhibits greater positive fluctuations according to the Taylor rule. Above all, under a positive foreign

interest rate shock, an increase in financial integration would intensify the fluctuations of inflation and interest rate while mitigating the fluctuations of output and real exchange rate.

Overall, there are two main conclusions that can be summarized from the above analysis. First, macroeconomic fluctuations vary under different exogenous shocks. Second, the dynamics of real exchange rate play an important role in macroeconomic fluctuations during the process of financial integration, and there are two main channels identified. On the one hand, real exchange rate affects households' consumption choices of domestic and imported products by altering their relative prices. On the other hand, real exchange rate influences households' investment decisions on foreign bonds because of its close relationship with the purchasing power of domestic currency.

## 4.2 Standard deviations of impulse responses

In Sect. 4.1, we have provided a preliminary analysis of the relationship between financial integration and macroeconomic fluctuations by comparing the impulse responses of main variables under different levels of financial integration. To have a quantitative assessment, in this subsection we proceed to calculate the volatility (standard deviation) for each of the four macroeconomic variables under different shocks with different levels of financial integration. For easy comparison, the representative values denoting different levels of financial integration are the same as those specified in Sect. 4.1. The results are displayed in Table 3.

From the results in Table 3, we can see that as financial integration increases ( $\gamma$  decreases from 1 to 0): (i) under the technology shock, the standard deviations of inflation and interest rate increase from 14.80 and 16.62 to 23.82 and 24.46, respectively, while those of output and real exchange rate decrease from 24.81 and 269.01 to 19.58 and 80.98, respectively; (ii) under the interest rate shock, the standard deviations of output and inflation increase from 20.51 and 1.86 to 21.38 and 4.08, respectively, while those of interest rate and real exchange rate decrease from 13.84 and 54.82 to 11.35 and 10.00, respectively; (iii) under the transaction cost shock and the log gap shock, the standard deviations of all variables decrease dramatically to 0; (iv) under the foreign output shock, the standard deviations of inflation and interest rate increase from 1.07 and 1.22 to 1.24 and 1.43, respectively, while those of output and real exchange rate decrease from 1.69 and 9.13 to 1.38 and 4.31, respectively; (v) under the foreign inflation shock, the standard deviations of output, inflation and interest rate increase from 4.56, 0.33 and 1.08 to 5.04, 0.66 and 1.43, respectively, with the only exception of real exchange rate, whose standard deviation decreases from 9.22 to 0.96; (vi) under the foreign interest rate shock, the standard deviations of inflation and interest rate increase from 2.56 and 3.16 to 3.98 and 7.64, respectively, while the standard deviations of output and real exchange rate decrease from 14.47 and 56.77 to 13.03 and 13.53, respectively.

To sum up, the above results suggest that as financial integration increases: (i) output volatility decreases most under the transaction cost shock and the log gap shock (by 100%) and increases most under the foreign inflation shock (by 11%); (ii)

**Table 3** Volatility of main variables under different levels of financial integration

Financial integration	Standard deviations of output ( $\times 10^{-2}$ )						
	$\varepsilon_t^a$	$\varepsilon_t^r$	$\varepsilon_t^l$	$\varepsilon_t^z$	$\varepsilon_t^{y*}$	$\varepsilon_t^{\pi*}$	$\varepsilon_t^{r*}$
$\gamma = 0$	19.58	21.38	0.00	0.00	1.38	5.04	13.03
$\gamma = 0.25$	19.12	21.34	8.70	0.07	1.48	4.93	13.97
$\gamma = 0.509$	21.41	21.14	11.47	0.18	1.56	4.81	14.35
$\gamma = 0.75$	23.28	20.86	12.27	0.32	1.63	4.69	14.47
$\gamma = 1$	24.81	20.51	12.19	0.50	1.69	4.56	14.47
Financial integration	Standard deviations of inflation ( $\times 10^{-2}$ )						
	$\varepsilon_t^a$	$\varepsilon_t^r$	$\varepsilon_t^l$	$\varepsilon_t^z$	$\varepsilon_t^{y*}$	$\varepsilon_t^{\pi*}$	$\varepsilon_t^{r*}$
$\gamma = 0$	23.82	4.08	0.00	0.00	1.24	0.66	3.98
$\gamma = 0.25$	16.44	3.37	15.12	0.40	1.13	0.58	2.84
$\gamma = 0.509$	14.48	2.74	23.03	0.76	1.09	0.49	2.40
$\gamma = 0.75$	14.25	2.23	28.26	1.08	1.08	0.41	2.35
$\gamma = 1$	14.80	1.86	32.80	1.41	1.07	0.33	2.56
Financial integration	Standard deviations of interest rate ( $\times 10^{-2}$ )						
	$\varepsilon_t^a$	$\varepsilon_t^r$	$\varepsilon_t^l$	$\varepsilon_t^z$	$\varepsilon_t^{y*}$	$\varepsilon_t^{\pi*}$	$\varepsilon_t^{r*}$
$\gamma = 0$	24.46	11.35	0.00	0.00	1.43	1.43	7.64
$\gamma = 0.25$	20.19	12.06	12.10	0.36	1.33	1.34	5.88
$\gamma = 0.509$	18.24	12.71	18.88	0.68	1.27	1.25	4.69
$\gamma = 0.75$	17.23	13.27	23.35	0.96	1.24	1.17	3.85
$\gamma = 1$	16.62	13.84	27.21	1.24	1.22	1.08	3.16
Financial integration	Standard deviations of real exchange rate ( $\times 10^{-2}$ )						
	$\varepsilon_t^a$	$\varepsilon_t^r$	$\varepsilon_t^l$	$\varepsilon_t^z$	$\varepsilon_t^{y*}$	$\varepsilon_t^{\pi*}$	$\varepsilon_t^{r*}$
$\gamma = 0$	80.98	10.00	0.00	0.00	4.31	0.96	13.53
$\gamma = 0.25$	157.58	20.94	77.19	4.81	6.32	2.83	27.68
$\gamma = 0.509$	205.73	32.35	145.99	9.86	7.59	4.95	38.67
$\gamma = 0.75$	239.32	43.19	203.58	14.65	8.43	7.01	47.72
$\gamma = 1$	269.01	54.82	261.11	19.78	9.13	9.22	56.77

(1) This table reports the volatility of main variables under representative levels of financial integration; (2) Volatility is calculated as the standard deviation of each variable over a horizon of 40 periods; (3)  $\varepsilon_t^a$ ,  $\varepsilon_t^r$ ,  $\varepsilon_t^l$ ,  $\varepsilon_t^z$ ,  $\varepsilon_t^{y*}$ ,  $\varepsilon_t^{\pi*}$  and  $\varepsilon_t^{r*}$  denote technology shock, interest rate shock, transaction cost shock, log gap shock, foreign output shock, foreign inflation shock and foreign interest rate shock, respectively.

inflation volatility decreases most under the transaction cost shock and the lop gap shock (by 100%) and increases most under the interest rate shock (by 119%); (iii) interest rate volatility decreases most under the transaction cost shock and the lop gap shock (by 100%) and increases most under the foreign interest rate shock (by 142%); (iv) real exchange rate volatility decreases under all exogenous shocks, with the greatest reduction under the transaction cost shock and the lop gap shock (by 100%).

Overall, four main conclusions can be drawn from the results in Table 3. First, the effect of financial integration on macroeconomic volatility varies under different exogenous shocks. Second, real exchange rate becomes less volatile at higher levels of financial integration under all of the seven exogenous shocks, implying a notable stabilizing effect of financial integration on real exchange rate. Third, inflation becomes more volatile in more integrated financial markets under all shocks except for the transaction cost shock and the lop gap shock. This stems from the fact that the costs arising from financial frictions combined with the inertia in nominal prices act as buffers preventing the relative price of domestic and foreign products from adjusting too quickly in response to exogenous shocks. But financial integration would lead to a reduction of such friction costs. At last, as financial integration increases, the volatility of domestic macroeconomic variables (i.e., output, inflation and interest rate) decreases under the transaction cost shock and the lop gap shock, but increases under the foreign inflation shock. This indicates that while financial integration can reduce the impact of foreign exchange shocks on domestic variables, it also brings the risk of amplifying the impact of foreign inflation shock on these variables. This is straightforward to understand. As explained in Sect. 4.1, in more integrated financial markets, there are less friction costs, which weakens the impact of transaction cost shock and the lop gap shock on the domestic economy. However, the reduction in these costs would also lead to a smaller deviation from the classic LOP condition, which means that the foreign price shock can be transmitted to the domestic economy more quickly and more thoroughly, which in turn leads to greater fluctuations in domestic macroeconomic variables.

### 4.3 Variance decomposition

To explore the contributions of exogenous shocks to the forecast error variance of main variables of interest (i.e., output, inflation, interest rate and real exchange rate) and how these contributions vary with financial integration, we conduct variance decomposition analysis over infinite horizons. The results are presented in Table 4.

First, we focus on the variance decomposition of output. Technology shock and interest rate shock together account for over 65% of the variations in output. As financial integration increases from 0.1 to 1, the contribution of technology shock has decreased by 4%, while that of interest rate shock has increased by 12%. Turning to inflation, when financial market is not perfectly integrated with the world, transaction cost shock plays a dominant role, accounting for over 60% of inflation variations. However, as financial integration increases, the contribution of transaction cost shock rapidly diminishes to zero, while the contribution of technology shock

**Table 4** Variance decomposition under different levels of financial integration

Financial integration	Output decomposition (%)						
	$\varepsilon_t^a$	$\varepsilon_t^r$	$\varepsilon_t^l$	$\varepsilon_t^z$	$\varepsilon_t^{y*}$	$\varepsilon_t^{\pi*}$	$\varepsilon_t^{r*}$
$\gamma = 0$	41.36	38.08	0.00	0.00	0.15	2.01	18.40
$\gamma = 0.25$	33.92	34.20	11.54	0.00	0.16	1.74	18.44
$\gamma = 0.509$	37.86	30.35	12.94	0.00	0.16	1.50	17.18
$\gamma = 0.75$	41.75	27.93	12.48	0.01	0.17	1.35	16.32
$\gamma = 1$	45.58	26.12	11.20	0.02	0.18	1.24	15.67
Financial integration	Inflation decomposition (%)						
	$\varepsilon_t^a$	$\varepsilon_t^r$	$\varepsilon_t^l$	$\varepsilon_t^z$	$\varepsilon_t^{y*}$	$\varepsilon_t^{\pi*}$	$\varepsilon_t^{r*}$
$\gamma = 0$	94.36	2.72	0.00	0.00	0.25	0.07	2.59
$\gamma = 0.25$	34.33	1.37	63.10	0.02	0.15	0.04	0.99
$\gamma = 0.509$	20.66	0.70	77.90	0.05	0.11	0.02	0.55
$\gamma = 0.75$	15.95	0.38	83.07	0.09	0.09	0.01	0.42
$\gamma = 1$	13.96	0.22	85.21	0.12	0.07	0.01	0.41
Financial integration	Interest rate decomposition (%)						
	$\varepsilon_t^a$	$\varepsilon_t^r$	$\varepsilon_t^l$	$\varepsilon_t^z$	$\varepsilon_t^{y*}$	$\varepsilon_t^{\pi*}$	$\varepsilon_t^{r*}$
$\gamma = 0$	72.49	17.58	0.00	0.00	0.24	0.26	9.43
$\gamma = 0.25$	41.94	14.41	38.84	0.01	0.15	0.17	4.48
$\gamma = 0.509$	31.06	13.88	51.77	0.03	0.12	0.13	3.00
$\gamma = 0.75$	25.01	13.31	59.24	0.06	0.10	0.10	2.17
$\gamma = 1$	20.92	12.70	64.52	0.09	0.09	0.08	1.60
Financial integration	Exchange rate decomposition (%)						
	$\varepsilon_t^a$	$\varepsilon_t^r$	$\varepsilon_t^l$	$\varepsilon_t^z$	$\varepsilon_t^{y*}$	$\varepsilon_t^{\pi*}$	$\varepsilon_t^{r*}$
$\gamma = 0$	98.25	0.30	0.00	0.00	0.15	0.00	1.30
$\gamma = 0.25$	84.01	0.50	13.91	0.02	0.10	0.01	1.45
$\gamma = 0.509$	75.16	0.76	22.33	0.06	0.09	0.02	1.59
$\gamma = 0.75$	68.26	1.01	28.84	0.10	0.07	0.02	1.68
$\gamma = 1$	62.13	1.26	34.60	0.15	0.06	0.03	1.76

(1) This table reports the variance decomposition of main variables under representative levels of financial integration; (2) Variance decomposition is conducted over an infinite time horizon; (3)  $\varepsilon_t^a, \varepsilon_t^r, \varepsilon_t^l, \varepsilon_t^z, \varepsilon_t^{y*}, \varepsilon_t^{\pi*}$  and  $\varepsilon_t^{r*}$  denote technology shock, interest rate shock, transaction cost shock, log gap shock, foreign output shock, foreign inflation shock and foreign interest rate shock, respectively.

increases dramatically by 80%. With regard to interest rate decomposition, when financial integration is at lower-middle levels, transaction cost shock is the main determinant of interest rate variations, accounting for over 50%. As financial integration increases, technology shock takes the place, whose contribution has increased by 50%. As for real exchange rate, technology shock dominates its variation and accounts for over 60%. As financial integration increases, the contribution of technology shock increases by 26%, while that of transaction cost shock decreases by about 35%.

Overall, the above results deliver three interesting implications. As financial integration increases: (i) shocks that originate from domestic economy (i.e., technology shock and interest rate shock) have greater impacts on the variations of macroeconomic variables and dominate their dynamics at higher levels of financial integration; (ii) the contribution of foreign exchange shocks (i.e., transaction cost shock and log gap shock) to macroeconomic fluctuations decreases, of which the underlying mechanisms have been discussed in Sects. 4.1 and 4.2; (iii) except for real exchange rate, macroeconomic variables are more prone to shocks that originate from the foreign economy (i.e., foreign output shock, foreign inflation shock and foreign interest rate shock), which can be attributed to the fact that with the reduction in transaction barriers and financial frictions, domestic and international financial markets converge and face the same shocks, so that foreign shocks tend to have greater impacts on domestic macroeconomic dynamics. This has the implication that policymakers should pay more attention to external shocks during the process of financial integration.

## 5 Implications for monetary policy

After analyzing the relationship between financial integration and macroeconomic fluctuations, a natural policy question is how the effects of monetary policy are related to different levels of financial integration. In this section, we attempt to answer this question by conducting welfare analysis.

As the most important objective for policymakers is to stabilize inflation and output, we use the following welfare loss function proposed by Woodford (2012):

$$W = \frac{1}{2} E_0 \sum_{t=0}^{\infty} \beta^t (\hat{\pi}_t^2 + \lambda_1 \hat{y}_{H,t}^2) \quad (42)$$

where inflation and output are regarded as target variables of the central bank,  $\lambda_1$  measures the central bank's relative preference on output stability, compared with its preference on stabilizing inflation (which is normalized to 1), and  $\beta$  is the discount factor as specified before. For simplicity, we assume the central bank has equal preference on each of the two target variables ( $\Omega_1 : \{\lambda_1 = 1\}$ ) in the following analysis.

Based on these assumptions, we then calculate the welfare losses under different levels of financial integration with different monetary policy parameters. Specifically, we investigate how the policy effects (as indicated by the associated welfare losses) vary with the values of the financial integration parameter ( $\gamma$ ) and the reaction coefficients of monetary policy ( $r_y$  and  $r_\pi$ ) while keeping other parameters of the model

**Table 5** Welfare analysis for alternative monetary policy rules

Output reaction coefficient	Welfare losses under different levels of financial integration ( $\times 10^{-4}$ )				
	$\gamma = 0$	$\gamma = 0.1$	$\gamma = 0.509$	$\gamma = 0.8$	$\gamma = 1$
$r_y = 0.1$	7.94	9.83	10.95	11.26	11.41
$r_y = 0.565$	3.61	3.81	4.92	5.71	6.23
$r_y = 1$	2.85	2.85	3.68	4.44	4.99
$r_y = 1.5$	2.45	2.37	3.06	3.77	4.30
$r_y = 2$	2.23	2.11	2.74	3.42	3.93
Inflation reaction coefficient	Welfare losses under different levels of financial integration ( $\times 10^{-4}$ )				
	$\gamma = 0$	$\gamma = 0.1$	$\gamma = 0.509$	$\gamma = 0.8$	$\gamma = 1$
$r_\pi = 1$	4.11	4.01	4.50	5.05	5.46
$r_\pi = 1.348$	3.61	3.81	4.92	5.71	6.23
$r_\pi = 1.75$	3.30	4.15	6.37	7.55	8.25
$r_\pi = 2$	3.24	4.70	7.85	9.32	10.14
$r_\pi = 2.25$	3.29	5.54	9.80	11.60	12.55

(1) Welfare losses in this table are calculated under the assumption that the central bank has equal preference for the stability of inflation and output; (2) Welfare losses are calculated over a ten-year (40 periods) horizon; (3) The parameter sets of  $\{\gamma = 0.509, r_y = 0.565\}$  and  $\{\gamma = 0.509, r_\pi = 1.348\}$  are the estimates obtained in Sect. 3.3, which can be referred to as the baseline scenario for the Chinese economy

unchanged. For the purpose of illustration, 25 representative parameter combinations are displayed in Table 5, where the set of  $\{0, 0.1, 0.509, 0.8, 1\}$  is assigned to financial integration ( $\gamma$ ), and the sets of  $\{0.1, 0.565, 1, 1.5, 2\}$  and  $\{1, 1.348, 1.75, 2, 2.25\}$  are assigned to the output reaction coefficient ( $r_y$ ) and the inflation reaction coefficient ( $r_\pi$ ), respectively. One thing worth noting is that to avoid the problem of indeterminacy in computing the model equilibrium, output reaction coefficient ( $r_y$ ) should be greater than 0 and inflation reaction coefficient ( $r_\pi$ ) should be greater than 1, so we use  $r_y = 0.1$  to denote tiny response to output gap and do not experiment on values less than 1 for  $r_\pi$ . In addition, the parameter sets of  $\{\gamma = 0.509, r_y = 0.565\}$  and  $\{\gamma = 0.509, r_\pi = 1.348\}$  are the estimates obtained from the Chinese economy (see Sect. 3.3), which are used as the baseline scenarios in the subsequent analysis.

From the upper section of Table 5, we can see that, there are significant welfare gains as output reaction coefficient ( $r_y$ ) increases. But the welfare effects associated with different levels of financial integration ( $\gamma$ ) are dependent on the value of the output reaction coefficient. When  $r_y$  is no more than 1, welfare loss decreases as financial integration improves. When  $r_y$  is greater than 1, however, welfare loss first decreases and then increases as financial integration improves, with the turning point occurring at  $\gamma = 0.1$ .

The result is somewhat different when financial integration ( $\gamma$ ) and inflation reaction coefficient ( $r_\pi$ ) vary simultaneously, as shown in the lower section of Table 5. Welfare loss generally declines as financial integration increases, but the welfare loss associated with changes in inflation reaction coefficient ( $r_\pi$ ) is dependent on the level of financial integration. In particular, at middle or lower levels of financial integration, welfare loss increases as  $r_\pi$  increases; but at higher degrees of financial integration, welfare loss first decreases and then increases as  $r_\pi$  becomes greater, with the turning point being larger at higher levels of financial integration.

To investigate how the marginal welfare effect of monetary policy may vary with increasing financial integration, one can compare the results in Table 6. From the upper section of Table 6, we can see that, as financial integration improves, the marginal reduction in welfare loss arising from increasing output reaction coefficient first rises and then falls when the output reaction coefficient is no more than 1. In contrast, the marginal reduction in welfare loss decreases at higher levels of financial integration when output reaction coefficient is larger than 1. From the lower section of Table 6, we can see that, the marginal increase in welfare loss incurred by increasing inflation reaction coefficient falls as financial integration improves.

To further confirm the results in Tables 5 and 6, we proceed to experiment with continuous values for  $\gamma$  over its theoretical interval  $[0, 1]$ , and for  $r_y$  and  $r_\pi$  over their

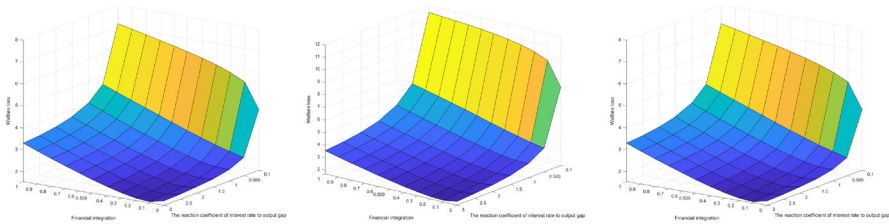
**Table 6** Marginal welfare effects under alternative monetary policy rules

Output reaction coefficient	Marginal welfare effects under different degrees of financial integration ( $\times 10^{-4}$ )				
	$\gamma = 0$	$\gamma = 0.1$	$\gamma = 0.509$	$\gamma = 0.8$	$\gamma = 1$
$r_y = 0.1$	–	–	–	–	–
$r_y = 0.565$	– 4.33	– 6.02	– 6.04	– 5.55	– 5.17
$r_y = 1$	– 0.77	– 0.96	– 1.23	– 1.27	– 1.25
$r_y = 1.5$	– 0.39	– 0.48	– 0.62	– 0.67	– 0.68
$r_y = 2$	– 0.22	– 0.26	– 0.33	– 0.35	– 0.37
Inflation reaction coefficient	Marginal welfare effects under different degrees of financial integration ( $\times 10^{-4}$ )				
	$\gamma = 0$	$\gamma = 0.1$	$\gamma = 0.509$	$\gamma = 0.8$	$\gamma = 1$
$r_\pi = 1$	–	–	–	–	–
$r_\pi = 1.348$	– 0.49	– 0.20	0.41	0.66	0.77
$r_\pi = 1.75$	– 0.32	0.34	1.45	1.84	2.01
$r_\pi = 2$	– 0.05	0.55	1.48	1.77	1.89
$r_\pi = 2.25$	0.05	0.84	1.95	2.28	2.41

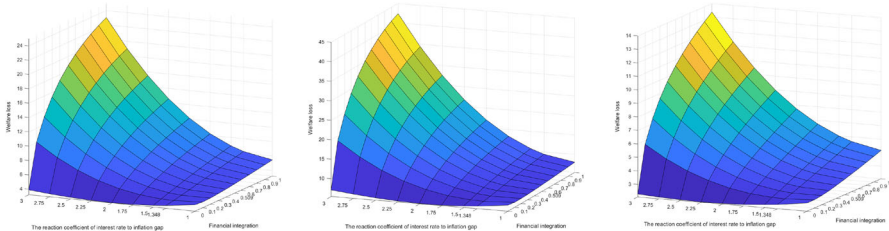
- (1) Welfare losses in this table are calculated under the assumption that the central bank has equal preference for the stability of inflation and output; (2) Welfare losses are calculated over a ten-year (40 periods) horizon; (3) The parameter sets of  $\{\gamma = 0.509, r_y = 0.565\}$  and  $\{\gamma = 0.509, r_\pi = 1.348\}$  are the estimates for the Chinese economy over the sample period of 2002Q1–2019Q3, which is used as the baseline scenario.



reasonable intervals  $[0.1, 3]$  and  $[1, 3]$ , respectively. Taking into account the potential differences in policy preference, we experiment on three alternative preference structures: (1)  $\Omega_1 : \{\lambda_1 = 1\}$ , for equal preference on the two target variables in Eq. (42); (2)  $\Omega_2 : \{\lambda_1 = 2\}$ , for greater preference on output stability; (3)  $\Omega_3 : \{\lambda_1 = 0.5\}$ , for greater preference on inflation stability. By calculating the welfare losses using the same method as before, we obtain the results in Figs. 8 and 9. As one can see, the results in Figs. 8 and 9 confirm our previous analysis over broader intervals for the three parameters. In addition, welfare losses under the three preference structures exhibit similar patterns, which gives additional supports to our main conclusions.



**Fig. 8** Welfare losses under different values of financial integration ( $\gamma$ ) and output reaction coefficient ( $r_y$ ) of monetary policy. *Notes:* (1) The welfare losses illustrated in this figure are calculated under the following three preference structures for Eq. (42): equal preference for the two target variables ( $\Omega_1$ , the left), greater preference for output stability ( $\Omega_2$ , the middle) and greater preference for inflation stability ( $\Omega_3$ , the right); (2) The welfare losses are calculated based on 40-period impulse responses, which is adequate to ensure the convergence of the variables; (3) The welfare losses shown at the Z-axis in each diagram are multiplied by  $10^{-4}$  for easy illustration; (4) The parameter of financial integration ( $\gamma$ ) is allowed to vary within its theoretical interval  $[0, 1]$  and the output reaction coefficient ( $r_y$ ) is assumed to vary within a reasonable interval of  $[0.1, 3]$ ; (5)  $\gamma = 0.509$  and  $r_y = 0.565$  are the estimated values for the Chinese economy over the sample period of 2002Q1–2019Q3



**Fig. 9** Welfare losses under different values of financial integration ( $\gamma$ ) and inflation reaction coefficient ( $r_\pi$ ) of monetary policy. *Notes:* (1) The welfare losses illustrated in this figure are calculated under the following three preference structures for Eq. (42): equal preference for the two target variables ( $\Omega_1$ , the left), greater preference for output stability ( $\Omega_2$ , the middle) and greater preference for inflation stability ( $\Omega_3$ , the right); (2) The welfare losses are calculated based on 40-period impulse responses, which is adequate to ensure the convergence of the variables; (3) The welfare losses shown at the Z-axis in each diagram are multiplied by  $10^{-4}$  for easy illustration; (4) The parameter of financial integration ( $\gamma$ ) is allowed to vary within its theoretical interval  $[0, 1]$  and the output reaction coefficient ( $r_\pi$ ) is assumed to vary within a reasonable interval of  $[0, 3]$ ; (5)  $\gamma = 0.509$  and  $r_\pi = 1.348$  are the estimated values for the Chinese economy over the sample period of 2002Q1–2019Q3

To sum up the results in Tables 5 and 6 and those in Figs. 8 and 9, we arrive at three main conclusions. First, there are in general notable welfare gains associated with financial integration. The only exception is that when the output reaction coefficient is high, there would be some welfare loss during the process of moving from high financial integration toward perfect financial integration. Second, for economies that are at early stages of financial integration, a more aggressive reaction of monetary policy to output gap or a mild reaction to inflation gap is beneficial for improving social welfare; but for economies at higher levels of financial integration, a more aggressive reaction to output gap or a moderate reaction to inflation gap would be optimal. Third, the marginal welfare effects brought by larger reaction to inflation and output gap are less pronounced at higher levels of financial integration, indicating that the effectiveness of monetary policy would be weakened as financial integration increases. As an application of these conclusions, the estimates for financial integration and monetary policy parameters in China (see Table 2) imply that the Chinese government can benefit from further promoting financial integration and the PBoC may pursue a more aggressive monetary policy stance to improve policy performance.

## 6 Concluding remarks

This paper extends the conventional DSGE literature by developing a New Keynesian DSGE model featuring imperfect financial markets with costs arising from financial frictions, which allows for the study of macroeconomic dynamics under different levels of financial integration. We conduct Bayesian estimation and draw implications on the macroeconomic effects of gradual financial integration using the Chinese economy as an example.

Several interesting findings emerge from our analysis. First, we find that the relationship between financial integration and macroeconomic fluctuations depends on the nature of underlying shocks. In particular, macroeconomic fluctuations decrease with financial integration under foreign exchange shocks. However, under shocks originating from other sources of the economy, the results are mixed and dependent on the type of shocks considered. Second, variance decomposition analysis suggests that shocks originating from the domestic economy account for a major portion of the variations in macroeconomic variables at higher levels of financial integration. Meanwhile, the contribution of foreign exchange shocks to macroeconomic fluctuations decreases as financial integration increases, and the reverse is true for shocks that originate from domestic and foreign economies. Third, there are in general notable welfare gains associated with financial integration, although some of the macroeconomic variables may exhibit greater volatility under certain exogenous shocks.

From a policy perspective, we find that monetary policy should hold a weak preference for inflation control and a strong preference for output stabilization at early stages of financial integration. When financial integration improves to higher levels, however, a moderate reaction to inflation and an aggressive reaction to output would be optimal. In addition, there is also evidence suggesting that the effectiveness of monetary policy in emerging market economies would be weakened as financial integration increases. Nevertheless, during the process of financial integration, policymakers should also take

necessary actions to insure against external shocks arising from international financial markets to reduce the adverse effects of these shocks on the domestic economy.

## Declarations

**Conflict of interest** The authors declare that they have no conflict of interest.

**Research Involving Human Participants and Animals** No human participants or animals were involved in this study.

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