Exchange Rate Regime and Optimal Policy:

The Case of China

Yujeong Cho† Yiping Huang‡ Changhua Yu§

Abstract

This study examines how financial friction in a situation with foreign currency-denominated debt could affect the Chinese economy and social welfare using a small open economy model with Chinese characteristics. We find that the financial channel, as well as the trade channel, operates well in response to various external shocks. In addition, macroeconomic variables are more stable and bring higher welfare under a floating exchange rate system than under a fixed exchange rate system. Finally, in an economy with macroprudential policies, such as a capital inflow tax and financial regulation, welfare is higher than in an economy without such policies, under either exchange rate regime. This analysis has important policy implications for the choice of exchange rate regime and for foreign debt management in China.

Keywords: China, Exchange rate regimes, Financial accelerator, Foreign currency denominated debts, Macroprudential policy, Optimal policy

JEL classification: F31, F32, E42, F41

† Bank of Korea, E-mail: petiteelf@bok.or.kr
‡ Peking University, E-mail: yhuang@nsd.pku.edu.cn
§ Peking University, E-mail: changhuay@gmail.com

1. Introduction

In traditional economic theory, a depreciation of the domestic currency brings positive effects to the economy by increasing exports and output. However, even though emerging countries' currencies depreciated during the Global Financial Crisis, the financial channel's negative effects, such as a decrease in investment and output due to capital outflows, overwhelmed the trade channel's positive effects such as an increase in exports. In addition to this, domestic currency depreciation accelerates global capital outflows and, as a result, further deepens domestic currency depreciation, producing a vicious cycle.

China has taken an export-driven growth policy, but intends to open financial markets only gradually. The exchange rate affects not only the real economy through exports and imports, but also the financial economy through global capital flows. Therefore, it is important to analyze how these offsetting effects of the exchange rate change the trade and financial channels and how they ultimately impact the whole Chinese domestic economy.

The key research questions of our study are as follows. What are the ultimate effects of various external shocks on the Chinese economy through capital flows and exchange rate change under the two kinds of exchange rate systems (a fixed exchange rate system and a floating exchange rate system), in a situation where there are foreign currency-denominated debts? This is the central research questions we intend to address in this paper. In addition, we also try to determine whether it is possible to improve welfare using macro-prudential policies against volatile capital flows and domestic currency value fluctuations.

In a situation with foreign currency-denominated debts, exchange rate fluctuations bring a change in the amounts of foreign borrowing. As shown in Figure 1, after 2008 when the yuan appreciated (an increase in the yuan/U.S. dollar exchange rates), Chinese corporate debts denominated in foreign currency increased rapidly. Starting in 2014, China's capital net outflow began and with RMB depreciation in 2015 and 2016, the amount of foreign borrowing turned to a decrease. Over two years, USD 640 billion flowed out because companies with dollar-denominated debts rushed to repay external liabilities due to the yuan's depreciation, as Chinese residents acquired foreign assets and deposited them in banks in expectation of further domestic currency depreciation. In tandem with this trend of foreign borrowing, the foreign currency denominated debt-to-GDP ratio increased after 2008, turning downward after recording a peak of 8.23% in 2014.

Figure 2 shows that the appreciation of the yuan has a positive relationship with foreign borrowing by Chinese financial institutions and corporations. Financial institutions play a key role in the overall domestic economy as an intermediary of funds, and thus can amplify

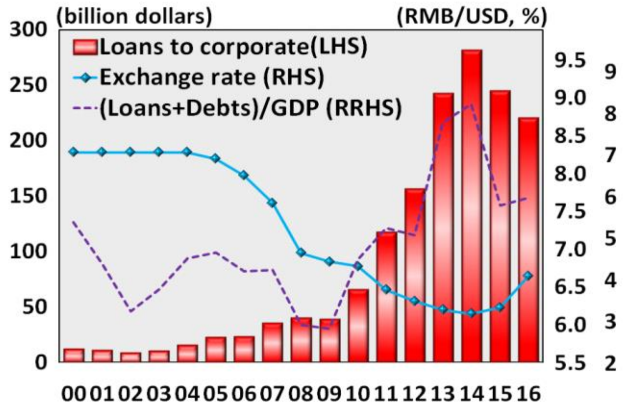

Fig. 1. Foreign Loans to China and Exchange Rate Loans to Corporations are cross-border loans from BIS-reporting banks to Chinese non-banks. Loans & Debts are cross-border loans to banks and non-banks, and international debt securities.
Source: BIS, World Bank, IMF

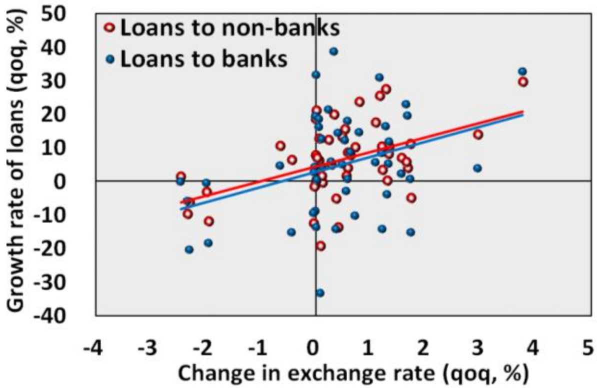

Fig. 2. Foreign Loans to China and Exchange Rate Loans are cross-border loans from BIS-reporting banks to Chinese banks (blue scatter) and non-banks (red scatter) from 2005Q1 to 2016Q4. Positive numbers of change in the exchange rate (RMB/USD) indicate an appreciation of the yuan.
Source: BIS, World Bank, IMF

their influence on the economy based on their borrowing and lending abilities. This suggests that, as financial institution foreign borrowing in China increases following the yuan's appreciation, spillover effects on the domestic economy can become bigger.

As Table 1 shows, the issuance of Chinese corporate bonds denominated in U.S. dollars is concentrated in industrial sectors with strong spillover effects on investment and production, such as the finance, real estate, and construction industries. Therefore, change of currency value can bring a bigger fluctuation in the size of foreign borrowing and subsequently in total output in China than in other countries.

As such, we could confirm that exchange rate volatility plays an important role through the financial channel using empirical data, even in China which does not have a completely open capital market. This shows that the financial accelerator mechanism is working in a way so that any domestic currency appreciation improves company balance sheets, strengthens their foreign borrowing ability, and, accordingly, their foreign debt increases. The Chinese government did express concerns about excessive exchange rate movements in one-direction, like the depreciation of the yuan in 2016 and the appreciation of the yuan in 2017. Recently, the People's Bank of China (PBoC) has made efforts to prevent any sudden change in the exchange rate from having an amplified negative effect on the economy through the financial channel, such as removing counter-cyclical factors that could cause an appreciation in the yuan.[1]

1 In May 2017, the PBoC adopted a counter-cyclical adjustment factor as a device to mitigate exchange rate fluctuations in calculating the reference exchange rate, to prevent the yuan from tilting too much toward depreciation.

(billion dollar)

	Real estate& Construction	Finance	Technology	Oil & Gas	Utility	Other	Total
China	**68**	**67**	**23**	**47**	**16**	**44**	**265**
Brazil	7	28	2	34	0	31	102
Mexico	12	2	7	29	4	19	73
South Korea	1	25	3	6	11	4	50
India	0	18	5	8	2	11	44
Indonesia	2	2	1	7	4	4	20
Malaysia	1	6	1	5	0	2	15
Other	10	151	21	70	22	80	354
Total	101	299	63	206	59	195	923

Table 1. Emerging Market USD-Denominated Corporate Bond Issuance (2012M1‒2015M11).

Source: Dealogic, RBA

This study intends to specify this series of mechanisms through a small open economy dynamic stochastic general equilibrium (DSGE) model. China has a regulated domestic financial market, a still relatively rigid exchange rate regime, and its capital markets are not yet fully opened. Therefore, we need to consider a model with China's unique characteristics, instead of a standard framework.

Our model and analysis have the following features. First, this study intends to focus on better explaining China's actual economy by creating a model with Chinese characteristics. We set a theoretical model that reflects China's restrictions on bond capital flows and its sterilization policies. Second, by constructing a model that includes both a financial channel and a trade channel, we try to understand their relative influences. By assuming the financial channel, which contains entrepreneurs with foreign currency denominated debts, apart from the trade channel, we make a financial friction model in which the financial accelerator mechanism functions. Third, we analyze the results under both a fixed exchange rate system and a floating exchange rate system to learn how the effects are different by exchange rate regime. Lastly, we examine what policies are effective in mitigating volatile capital movements by conducting a welfare analysis under various financial policies, such as monetary policy and macroprudential policy.

In this study, the main finding is that the financial channel has already become significant in China. From the impulse response results to various external shocks, we can confirm that not only the trade channel but also the financial channel is functioning. Second,

However, as the yuan has appreciated continuously since, the PBoC has decided to exclude the counter-cyclical factor to mitigate tilting too much toward appreciation on Jan. 9, 2018. Since removing this device allows the range of fluctuation of the exchange rate in either direction, to become larger in the future, the market is expected to play a bigger role in determining exchange rates.

macroeconomic variables are more stable under the floating exchange rate system than under the fixed exchange rate system. This is because changes in the nominal exchange rate can absorb external shocks in a floating exchange rate regime. Lastly, macroprudential regulations are important in the process of opening financial markets. A capital inflows tax and financial regulations can increase welfare by alleviating volatile global capital flows.

The key contribution of our study lies in finding that the financial channel and macroprudential regulations are important in China by using a model with Chinese characteristics not dealt with by existing studies.

The remainder of the paper is organized as follows. In Section 2, we summarize the contents and results of existing studies, and in Section 3 we describe the details of our model. In Section 4 we present the calibration and simulation results. Section 5 discusses the welfare comparison results of monetary policy rules and macro-prudential policies. Section 6 concludes.

2. Related Literature

A convenient way to formalize financial frictions with a theoretical model is by introducing financial accelerators, which is adopted in Bernanke et al. (1999). The financial accelerator mechanism of Bernanke et al. (1999) was analyzed in more depth by balance sheet effects and by risk-taking channels. The balance sheet effects of Céspedes et al. (2004) show that domestic currency appreciation will have a positive impact on the balance sheet through a decrease in foreign currency denominated debts and an increase in net worth. This brings a reduction in risk premiums of firms and, in turn, ultimately raises production by increasing loans to firms. Bruno and Shin (2015) noted that if there were an expansionary monetary policy shock in advanced economies, an unexpected appreciation of the currencies in emerging economies that mainly hold dollar-denominated debts would bring a positive impact on their economies through the risk-taking channel. As such, the effect of "liability dollarization" on balance sheets has been discussed in many kinds of literature concerning emerging market financial conditions and exchange rate adjustments.[2] [3]

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2 The balance sheet effect and the risk-taking channel are similar concepts in that in case of domestic currency depreciation, company balance sheets become worse, resulting in a reduction in investment and production, but they have the following differences. In the balance sheet effect, fund borrowers are a key player and the effect of a change in company net worth (the balance sheet) on the real economy is important (the borrowers' balance sheet effects). Meanwhile, in the risk-taking channel, global financial intermediaries play a key role and therefore, it focuses on analyzing changes in the creditor's leverage ratio (the lenders' risk-taking capacity). For example, in the case of a U.S. interest rate decline shock, global banks tend to prefer more risk-taking lending due to falls in interest rates and VIX, and also increase further lending in expectation of borrowers' balance sheet improvements due to an appreciation in the currency.

3 Banerjee et al. (2016), Elekdag et al. (2006), and Christensen and Did (2008) showed that the financial

Gertler et al. (2007), Broda (2004) and Faia (2010) showed that flexible exchange rate regimes have a more mitigating effect on the economy in response to external shocks than fixed exchange rate regimes. Elekdag and Tchakarov (2007) identified leverage and debt to GDP ratios, above which a fixed exchange rate regime is welfare, superior to a flexible exchange rate regime. Kitano and Takaku (2018a) found that in an economy with a financial accelerator, an optimal capital control policy under a fixed exchange rate yields higher welfare.

A growing body of literature investigates the role of macroprudential policies in small open economies.[4] Devereux and Yu (2017) showed that macroeconomic outcomes are far worse under a pegged exchange rate regime during a crisis with the presence of pecuniary externalities in asset prices. Devereux and Yu (2018) also found that macroprudential policy is used aggressively as part of an optimal policy framework under a pegged exchange rate regime. Kitano and Takaku (2018b) found that the welfare improving effect of capital controls (a tax on the bank's foreign borrowings) is larger than that of macroprudential regulations (a tax on the bank's asset holdings) in a situation with a higher degree of financial friction. The evaluation of Liu and Spiegel (2015) is that there are welfare implications to the use of capital account policies, such as sterilization interventions, which are normally used in China, and to taxing capital inflows for macroeconomic stabilization in response to fluctuations in capital flows. Their results suggested that optimal sterilization and capital controls are complementary policies. Huang et al. (2019) proposed that when exchange rate flexibility is relatively low, a two-pillar macroregulation, such as both monetary policy and macro-prudential policy, has a greater stabilization effect on the macro-economy and a larger benefit on social welfare in China.

Our paper differs from previous analyses in several respects, in addition to many differences in the modeling structure. First, we construct both a trade channel and a financial channel. While existing literature using the financial friction model focuses on analyzing the financial sector only, our model is different in that it tries to find which channel has a bigger

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accelerator magnified the impact of shocks on real and financial volatilities through balance sheets in situations where there were foreign currency denominated debts. Ueda (2012) showed the net worths of financial intermediaries, as well as of entrepreneurs, which were credit constrained. They revealed that negative shocks that hit one country due to the globalization of financial intermediaries affect other countries, yielding business cycle synchronization. Regarding the empirical analyses, Aizenman et al. (2017) found that having a higher weight in dollar debts makes the response of a financial variable in the peripheral economies more sensitive to any changes in key variables in the central economies, such as policy interest rates or exchange rates.

4 Davis and Presno (2014, 2017) explored temporary capital controls that allow an optimal monetary policy to focus more on domestic variables and less on foreign interest rates, and which lead to a significant welfare improvement. Aoki et al. (2016) found that a cyclical tax on foreign currency borrowing by banks was beneficial for the welfare gain. Unsal (2013) also showed that a macroprudential policy was a useful complementary instrument for monetary policy during a financial shock that triggers capital inflows. Farhi and Werning (2012, 2014) found that capital controls are used to restore monetary autonomy in a fixed exchange rate regime, and that they work as terms of trade manipulation in a flexible exchange rate regime.

effect by analyzing both the trade channel and the financial channel. Second, we consider a model with Chinese characteristics, such as a fixed exchange rate system, restrictions on bond capital flows, and a sterilization policy.[5] There has been very little effort at analyzing the financial accelerator mechanism in China with a theoretical model. Therefore, our study is meaningful in that it uses a model with Chinese characteristics. Third, we consider an exchange rate shock as well as a foreign interest rate shock and an export demand shock. Considering a shock that directly affects exchange rates, we accurately identify spillover effects caused by exchange rates that other shocks fail to capture in the existing literature. Lastly, our study uses specific macroprudential policies to evaluate welfare. Our model differs from Chang et al. (2015) and from Liu and Spiegel (2015) which simply adjusted the capital control parameters or considered only the capital inflow tax in their welfare analysis. Instead, we investigate the effects of macroprudential policies by adjusting the tax rates on capital inflows and the leverage ratio, and then solve the Ramsey problem.

3. Model

In this section we examine how various external shocks would affect China's economy in cases where there are foreign-currency denominated debts by using a DSGE model with added Chinese characteristics.

3.1 Overview of the Model[6]

We construct a small open economy model by combining the model of Céspedes et al. (2004) and the model of Chang et al. (2015), which can include both a financial accelerator and Chinese characteristics.

This model reflects China's actual economic situation where the capital market is not fully open and where the household sector has a relatively high adjustment cost parameter in the form of a quadratic function between domestic and foreign currency bond portfolios. It also

5 Our model mainly follows the model of Chang et al. (2015) in that it contains Chinese characteristics. However, our study has several differences parts from theirs. First, our model has international financial transactions. Therefore, we can explore the financial accelerator mechanism through entrepreneurs' foreign debt, which affects physical capital and investment, but they don't have this mechanism. Second, we focus on the effect of the exchange rate change. Our main goal is to determine how the effects on the Chinese economy change depending on the amount of foreign debts. For this, we add the exchange rate shock according to Itskhoki and Mukhin (2017), and try to conduct an analysis based on the different types of exchange rate regimes and the presence of the financial channel together. In contrast, Chang et al. (2015) focus on the domestic transaction mechanisms, like a sterilization policy and interest rate changes. Lastly, we use specific macroprudential policies by using tax rates on capital inflows and the leverage ratio for a welfare evaluation, and solve the Ramsey problem. However, Chang et al. (2015) didn't consider macroprudential policies and simply adjusted the capital control parameter in their welfare analysis.

6 The overall model structure is presented in Appendix A: Model Structure (Small Open Economy Model).

reflects a People's Bank of China policy to stabilize exchange rates.[7] [8] Our model is different from the model used in Chang et al. (2015) in that it contains investment dynamics as an important channel for international financial transactions. As foreign borrowing is on the rise in China, by adding entrepreneurs with foreign currency denominated debts, which are linked to an endogenous risk premium, we intend to see how the change in exchange rates affects the domestic economy through the financial channel, in addition to the trade channel. Our study examines whether the financial accelerator mechanism is operated through entrepreneurs' balance sheet effects and whether or not it amplifies the effects on China's domestic economy in cases where there is a shock related to exchange rates.[9]

This model consists of households, entrepreneurs, intermediate goods firms, final goods firms, and the central bank.

The household chooses a portfolio consisting of domestic and foreign bonds, and when this portfolio combination changes, a quadratic portfolio adjustment cost occurs. This adjustment cost restricts the domestic private sector's approach to foreign assets and reflects China's current economic situation where there exist bond capital controls in the financial sector.

Entrepreneurs are the key players in our model. Entrepreneurs raise funds by borrowing from abroad. This foreign borrowing is subject to financial frictions. The easier fundraising by entrepreneurs is, investments into capital increase, and this ultimately contributes to economic growth. As exchange rates fluctuate, foreign currency denominated debts also change. Then, even though foreign debts denominated in dollars are the same, the value of foreign debts denominated in the domestic currency decrease where there is domestic currency appreciation. In turn, an entrepreneur's balance sheet becomes stronger, their borrowing capacity increases, and their access to loans becomes easier. This leads to an increase in investment and in GDP.

The central bank purchases foreign currencies from private sectors at the prevailing level of the exchange rate, with money creation or bond issuance to stabilize the exchange rate. In addition, these foreign currency reserves are used as a resource to buy overseas government

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7 China's exchange rate regime was converted from a peg exchange rate system to a managed floating exchange rate system on July 21, 2005. The trading band around the daily fixed rate is ±2% as of January 2021.

8 Under both fixed and managed floating exchange rate systems, if foreign currencies flow in due to an increase in net exports or an increase in foreign borrowings, the central bank issues money and absorbs foreign currencies to reduce the extent of any exchange rate fluctuation. Since the domestic price level increases by the creation of money, the central bank absorbs money by issuing domestic bonds again. This intervention is called a sterilization policy. Our model doesn't consider lump-sum taxes as resources for raising funds by a central bank, in order to focus on analyzing the effects of the sterilization policy, as in Chang et al. (2015).

9 In order to simplify the model and clarify the effect of financial friction, we assume that there are no domestic financial institutions, and that entrepreneurs only borrow funds in foreign currencies through global financial institutions.

securities.

3.2 Model Agents

3.2.1 Households

The representative household maximizes its utility function by choosing consumption C_t, money balance M_t, and labor hours L_t. The expected utility function of a representative household is as follows:

$$E_t \sum_{t=0}^{\infty} \beta^t \left[lnC_t + \Phi_m ln \frac{M_t}{P_t} - \Phi_l \frac{L_t^{1+\eta}}{1+\eta} \right] \tag{1}$$

subject to the budget constraints as follows.

$$C_t + \frac{M_t}{P_t} + I_t + \frac{B_t + e_t B_{pt}^*}{P_t} \left[1 + \frac{\Omega_b}{2} \left(\frac{B_t}{B_t + e_t B_{pt}^*} - \overline{\psi} \right)^2 \right] \leq w_t L_t + \frac{M_{t-1}}{P_t} + r_{t-1}^k \frac{Q_{Kt-1}}{P_t} K_t + \frac{R_{t-1} B_{t-1} + e_t R_{t-1}^* B_{pt-1}^*}{P_t} + \frac{\prod_t}{P_t} \tag{2}$$

where, the term E_t represents an expectation operator conditional on information available at time t, $\beta \in (0,1)$ is a subjective utility discount factor and $\eta > 0$ is the inverse Frisch elasticity of labor supply. $\Phi_m > 0$ denotes the utility weight for the real money balance and $\Phi_l > 0$ is the utility weight for leisure.

I_t represents capital investment, B_t and B_{pt}^* denote nominal domestic and foreign bonds held by households, respectively. P_t is the domestic price level and e_t is the nominal exchange rate.[10] w_t denotes real labor income, r_t^k is the real return on capital for households, K_t is capital, Q_{Kt} is the price of one unit of capital, and $\prod_t$ is the nominal dividend income from owning firms. R_t and R_t^* represent the nominal interest rates for domestic and foreign bonds, respectively. The parameter Ω_b measures the size of the portfolio adjustment costs of domestic and foreign bond holdings and the parameter $\overline{\psi}$ denotes the steady-state portfolio share of domestic bonds as part of the total value of household bond holdings. Therefore, the equation $\frac{\Omega_b}{2} \left(\frac{B_t}{B_t + e_t B_{pt}^*} - \overline{\psi} \right)^2 \frac{B_t + e_t B_{pt}^*}{P_t}$ becomes the portfolio adjustment costs due to capital controls.

The stock of capital evolves according to the following law of motion

10 Asterisks indicate foreign variables.

$$K_{t+1} = \left[\frac{I_t}{K_t} - \frac{\Omega_k}{2}\left(\frac{I_t}{K_t} - (\lambda_z - 1 + \delta)\right)^2\right] K_t + (1-\delta)K_t \tag{3}$$

where δ is the capital depreciation rate, λ_z is the growth rate of technology, and the parameter Ω_k measures the degree of capital investment adjustment cost. Therefore, the equation $\frac{\Omega_k}{2}\left(\frac{I_t}{K_t} - (\lambda_z - 1 + \delta)\right)^2 K_t$ becomes the capital investment adjustment costs.[11]

From the profit-maximization problem of capital producers, the capital price Q_{Kt} is given by

$$Q_{Kt} = P_t\left[1 - \Omega_k\left(\frac{I_t}{K_t} - (\lambda_z - 1 + \delta)\right)\right]^{-1} \tag{4}$$

The representative household maximizes its utility function Equation (1) subject to the constraints in equations (2) and (3). That yields first-order conditions concerning a consumption Euler equation, the optimal demand for real money balances, labor supply, investment, and domestic and foreign bond holdings as below.

$$\Lambda_t = \frac{1}{C_t} \tag{5}$$

$$\frac{\Phi_m}{\Lambda_t m_t} = 1 - E_t \frac{\beta\Lambda_{t+1}}{\Lambda_t}\frac{1}{\pi_{t+1}} \tag{6}$$

$$w_t = \frac{\Phi_l L_t^{\eta}}{\Lambda_t} \tag{7}$$

$$E_t \frac{\beta\Lambda_{t+1}}{\Lambda_t} r_t^k \frac{1}{\pi_{t+1}} = 1 \tag{8}$$

$$E_t \frac{\beta\Lambda_{t+1}}{\Lambda_t}\frac{R_t}{\pi_{t+1}} = 1 + \frac{\Omega_b}{2}\left(\psi_t - \overline{\psi}\right)^2 + \Omega_b(\psi_t - \overline{\psi})(1 - \psi_t) \tag{9}$$

$$E_t \frac{\beta\Lambda_{t+1}}{\Lambda_t}\frac{e_{t+1}}{e_t}\frac{R_t^*}{\pi_{t+1}} = 1 + \frac{\Omega_b}{2}\left(\psi_t - \overline{\psi}\right)^2 - \Omega_b\psi_t\left(\psi_t - \overline{\psi}\right) \tag{10}$$

where Λ_t is the Lagrangian multiplier for the budget constraint, $m_t \equiv M_t/P_t$ is the quantity of the real money balance, and $\pi_{t+1} \equiv P_{t+1}/P_t$ is the inflation rate from period t to t+1. $\psi_t = B_t/(B_t + e_t B_{pt}^*)$ denotes the portfolio share of domestic bonds as part of the total value of household bond holdings.

Combining equations (9) and (10), which represent the optimal choices for B_t and B_{pt}^*,

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11 The standard capital investment adjustment cost is $\frac{\Omega_k}{2}\left(\frac{I_t}{K_t} - \delta\right)^2 K_t$. However, since our model contains the productivity growth rate, this equation form is used in order to make it easier to calculate a steady-state investment.

generates an equation that corresponds to the general UIP condition, as below. For example, a decrease in the price of domestic bonds (an increase in the domestic interest rate) brings about an increase in the right side of the Equation (11), and it expresses an increase of ψ_t in the left side of the equation, that is, an increase in the portfolio share of domestic bond holdings.

$$\Omega_b\left(\psi_t - \overline{\psi}\right) = E_t \frac{\beta\Lambda_{t+1}}{\Lambda_t}\frac{1}{\pi_{t+1}}\left[R_t - R_t^* \frac{e_{t+1}}{e_t}\right] \qquad (11)$$

This equation deviates from the standard UIP condition in which a difference in interest rates between two countries is adjusted through appreciation and depreciation of the currency, and this comes from imperfect substitutions between domestic and foreign bonds due to portfolio adjustment costs.[12] Therefore, this generates a new form of UIP condition that depends on ψ_t, the portfolio share of domestic bond holdings.

3.2.2 Entrepreneurs

Adopting the model of Céspedes et al. (2004), entrepreneurs can invest with foreign borrowing linked to the value of their net worth denominated in the domestic currency. Therefore, investment that engages in capital accumulation in the next period $(t+1)$ is financed partly with net worth and partly with foreign currency-denominated debt.[13] Hence, the entrepreneurs' budget constraint is

$$P_t N_t + e_t D_t^* = Q_{Kt} K_{t+1} \qquad (12)$$

where N_t denotes net worth, and D_t^* is the amount borrowed abroad.

The demand for foreign borrowing is determined by the equality of the expected return on investment to the cost of borrowing foreign funds.

$$E_t\, r_{t+1}^k \frac{e_t}{e_{t+1}} = R_{et}^* \Phi_{t+1} \qquad (13)$$

The interest rate when borrowing abroad is not R_{et}^*, a nominal safe interest rate on overseas funds, but $R_{et}^*\Phi_{t+1}$, where Φ_t is a risk premium.[14] Following Bernanke et al. (1999), we

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12 The standard UIP condition is $0 = E_t \frac{\beta\Lambda_{t+1}}{\Lambda_t}\frac{1}{\pi_{t+1}}\left[R_t - R_t^* \frac{e_{t+1}}{e_t}\right]$.

13 Some studies, such as Kiyotaki and Moore (1997), use a model with entrepreneurs' collateral constraints for debt, which limit their borrowing capacity. In order to focus sharply on the balance sheet effect, we assume that entrepreneurs do not have collateral constraints.

14 R_e^*, the nominal interest rate on foreign loans used in calculating interest rates on loans to entrepreneurs was set at a higher level than R^*, the nominal foreign interest rate or treasury yield used elsewhere in our model. We set R_e^*= 1.0075R^*, considering that the annual loan margin of U.S. banks is about 3% during our sample periods.

assume the risk premium is given by

$$\Phi_{t+1} = F\left(\frac{Q_{Kt}K_{t+1}}{P_t N_t}\right), \qquad \text{with } F(1) = 1,\ \ F'(\cdot) > 0 \tag{14}$$

The risk premium is an increasing function of the value of the investment relative to net worth. We assume that this function takes the form of F as below:

$$F(g) = g^{\varsigma} \tag{15}$$

where ς is the elasticity of the external finance premium, and represents the degree of financial imperfection. From the two equations above, we know that the risk premium increases as the value of net worth relative to investment decreases, and, in turn, leads to rising interest rates on foreign borrowing. A risk premium means that there is financial friction, which is a key characteristic of this model, and this is due to the asymmetric information between domestic entrepreneurs and foreign creditors.

The dynamic of the net worth is as follows:

$$P_t N_t = \omega(r_t^k Q_{Kt-1} K_t - R_{et-1}^* \Phi_t e_t D_{t-1}^*) \tag{16}$$

where ω is an entrepreneur's survival probability. An unexpected change that causes an appreciation of the domestic currency (a decrease in foreign exchange rates), *ceteris paribus*, gives a positive impact on net worth through a decrease in the value of foreign currency denominated debts, and reduces the risk premium. As a result, the borrowing interest rate, which is a cost for borrowing in foreign funds, decreases, and this generates a balance sheet effect for entrepreneurs, such as activating the financial accelerator mechanism that reduces the burden on an entrepreneur's borrowing, and results in more overseas borrowing.

The return on capital for entrepreneurs r_t^k depends on the rental rate of capital r_t and the rate of capital depreciation, which is adjusted for capital price valuation effects.

$$E_t\, r_{t+1}^k = \frac{r_{t+1}}{Q_{Kt}} + \frac{Q_{Kt+1}}{Q_{Kt}} \times \left[(1-\delta) + \Omega_k\left(\frac{I_{t+1}}{K_{t+1}} - (\lambda_z - 1 + \delta)\right)\frac{I_{t+1}}{K_{t+1}} - \frac{\Omega_k}{2}\left(\frac{I_{t+1}}{K_{t+1}} - (\lambda_z - 1 + \delta)\right)^2\right] \tag{17}$$

3.2.3 Final Goods Firms

This is to reflect a real economic situation where interest rates on foreign loans are usually higher than general interest rates applied in creditor countries, apart from any risk premium, depending on the net worth.

Next, there is a continuum of final goods firms, and each firm produces $Y_t(j)$, a differentiated product indexed by $j \in (0,1)$ through a production function as below using the inputs of intermediate goods $\Gamma_t(j)$, labor $L_t(j)$ and capital $K_t(j)$:

$$Y_t(j) = \mathrm{A}_t \Gamma_t(j)^{\phi} [(Z_t L_t(j))^{1-\alpha} K_t(j)^{\alpha}]^{1-\phi} \tag{18}$$

where Z_t is a labor-augmenting technology, the parameter $\phi \in (0,1)$ is the cost share of intermediate inputs, and $\alpha \in (0,1)$ is the share of capital relative to labor in production. Technology is assumed to grow at a rate of $\lambda_z \equiv Z_t / Z_{t-1}$.

Firms take input prices as given and produce based on the cost minimization principle using the production function, Equation (18), and this implies the following equation:

$$mc_t = \frac{1}{\mathrm{A}_t} \tilde{\phi} \tilde{\alpha} q_{mt}^{\phi} \left(\frac{w_t}{Z_t}\right)^{(1-\alpha)(1-\phi)} r_t^{\alpha(1-\phi)} \tag{19}$$

where $\mathrm{mc_t}$ represents a firm's real marginal cost, $\mathrm{q_{mt}}$ denotes the relative price of intermediate inputs, and r_t is the real rental rate on capital. $\tilde{\phi} \equiv \phi^{-\phi}(1-\phi)^{\phi-1}$ and $\tilde{\alpha} \equiv \alpha^{\alpha(\phi-1)}(1-\alpha)^{(1-\alpha)(\phi-1)}$ are constants.

Cost-minimizing behavior implies the following optimal factor demand conditions:

$$w_t L_t = (1-\alpha)(1-\phi)\, mc_t Y_t \tag{20}$$

$$r_t K_t = \alpha(1-\phi)\, mc_t Y_t \tag{21}$$

$$q_{mt} \Gamma_t = \phi\, mc_t Y_t \tag{22}$$

These equations represent the implicit demand curves of labor, capital and intermediate goods, respectively.

Final goods firms take their prices from competitive input markets as given, but can set a price in production as they produce monopolistically competitive products. That is, a retailer j takes the price of input goods w_t, r_t, q_{mt} and the price level P_t as given, but can have the market power to set the price for its own differentiated good $P_t(j)$, and in case they adjust the price, they face a quadratic price adjustment cost $\frac{\Omega_p}{2}\left(\frac{P_t(j)}{\pi P_{t-1}(j)} - 1\right)^2 C_t$, as in Rotemberg (1982). Ω_p represents the size of the price adjustment costs, and π represents the steady-state inflation rate.

The retailer solves the following problem:

$$Max_{P_t(j)}\, E_t \sum_{k=0}^{\infty} \beta^k \frac{\Lambda_{t+k}}{\Lambda_t} \left[\left(\frac{P_{t+k}(j)}{P_{t+k}} - mc_{t+k} \right) Y_{t+k}^d(j) - \frac{\Omega_p}{2} \left(\frac{P_{t+k}(j)}{\pi P_{t+k-1}(j)} - 1 \right)^2 C_{t+k} \right] \quad (23)$$

where $Y_t^d(j)$ is the downward sloping demand curve given by

$$Y_t^d(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\theta_p} Y_t \quad (24)$$

and the price level P_t is determined by individual firms' prices as in the equation $P_t = \left[\int_0^1 P_t(j)^{1-\theta_p} dj \right]^{1/(1-\theta_p)}$, with $\theta_p > 1$ representing the elasticity of substitution between differentiated final products.

In a symmetric equilibrium with $P_t(j) = P_t$ for all j, the optimal pricing decision is as in the following equation, which means the Phillips curve:

$$mc_t = \frac{\theta_p - 1}{\theta_p} + \frac{\Omega_p}{\theta_p} \frac{C_t}{Y_t} \left[\left(\frac{\pi_t}{\pi} - 1 \right) \frac{\pi_t}{\pi} - \beta E_t \left(\frac{\pi_{t+1}}{\pi} - 1 \right) \frac{\pi_{t+1}}{\pi} \right] \quad (25)$$

3.2.4 Intermediate Goods Firms

Intermediate goods firms produce intermediate goods using domestically produced final goods and imported goods as inputs, with the production function as below:

$$\Gamma_t = \Gamma_{ht}^{\lambda_\Gamma} \Gamma_{ft}^{1-\lambda_\Gamma} \quad (26)$$

where Γ_{ht} and Γ_{ft} denote the input of domestic production goods and foreign imports respectively, and $\lambda_\Gamma \in (0,1)$ is the expenditure share of domestic input.

Cost-minimizing implies the following equation:

$$q_t = \frac{(1 - \lambda_\Gamma)\Gamma_{ht}}{\lambda_\Gamma \Gamma_{ft}} \quad (27)$$

where $q_t \equiv e_t P_t^* / P_t$ is the real exchange rate and P_t^*, as the foreign price level, is taken as given in a small open economy. The cost minimization also implies the following relationship:

$$q_{mt} = \tilde{\lambda}_\Gamma q_t^{1-\lambda}, \qquad \text{with } \tilde{\lambda}_\Gamma \equiv {\lambda_\Gamma}^{-\lambda_\Gamma} (1 - \lambda_\Gamma)^{\lambda_\Gamma - 1} \quad (28)$$

3.2.5 International Sector

The international sector includes both the trade and financial channels, and in the trade part, the trade balance is derived using imported goods and exported final goods:

$$tb_t = X_t - \ q_t \Gamma_{ft} \tag{29}$$

where X_t represents the quantity of exported final goods, which is given by

$$X_t = \left(\frac{e_t P_t^*}{P_t}\right)^{\theta_x} X_t^* = q_t^{\theta_x} X_t^* \tag{30}$$

where θ_x denotes the export demand elasticity, and X_t^*, as the export demand, is deemed to have been given in a small open economy. This export demand curve shows an export demand schedule, such as exports decreasing with the relative price of final export goods rising and in turn, real exchange rates decreasing (an appreciation of the domestic currency) and exports increasing with export demand rising.

The current account balance equals the sum of the trade balance and the net interest income from foreign bond holdings minus the net interest cost from foreign borrowing, as in the following:

$$ca_t = tb_t + \frac{e_t(R_{t-1}^* - 1)B_{t-1}^*}{P_t} - \frac{e_t(R_{et-1}^* \Phi_t - 1)D_{t-1}^*}{P_t} \tag{31}$$

and, B_{t-1}^* is the aggregate amount of foreign bonds held by households (B_{pt-1}^*) and the government (B_{gt-1}^*), which is the total size of foreign currency denominated bonds held by a country in period $t-1$. As capital inflows due to a surplus in the trade balance are used to purchase foreign assets, a current account surplus (deficit) means an increase (decrease) in foreign assets. That is, the current balance can be represented as changes in the balance of the total amount of foreign assets, as below:

$$ca_t = \frac{e_t(B_t^* - B_{t-1}^*)}{P_t} - \frac{e_t(D_t^* - D_{t-1}^*)}{P_t} \tag{32}$$

3.2.6 Central Bank

The central bank purchases foreign currencies by issuing domestic bonds and domestic currency. When concerned about inflation due to money creation, the central bank conducts a sterilization policy by absorbing liquidity through the issuance of domestic-currency bonds. The budget constraint of the central bank is defined as follows:

$$e_t(B_{gt}^* - R_{t-1}^* B_{gt-1}^*) \leq B_t^s - R_{t-1} B_{t-1}^s + M_t^s - M_{t-1}^s \tag{33}$$

where B_t^s and M_t^s represent the volume of domestic bonds issued and currency issued, respectively.

3.2.7 Market Clearing and Equilibrium[15]

An equilibrium in this economy is a sequence of prices $\{P_t, w_t, r_t, r_t^k, Q_{Kt}, R_t, e_t, q_t, q_{mt}\}$ and aggregate quantities $\{C_t, I_t, Y_t, \Gamma_{ht}, \Gamma_{ft}, X_t, L_t, K_t, M_t, M_t^s, B_t, B_{pt}^*, B_{gt}^*, B_t^*\}$, as well as the prices $P_t(j)$ and quantities $\{Y_t(j), L_t(j), \Gamma_t(j)\}$ for each retailer j, such that: (i) taking all prices as given, the allocations solve the household's utility maximizing problem; (ii) taking all prices but its own product as given, the prices and allocations for each final goods firm solve for their profit maximizing problem; and, (iii) markets for the final goods, intermediate goods, labor, capital, money balances, and bond holdings all clear. The market-clearing conditions are summarized below:

$$Y_t = C_t + I_t + \Gamma_{ht} + X_t + \frac{\Omega_p}{2}\left(\frac{\pi_t}{\pi} - 1\right)^2 C_t + \frac{B_t + e_t B_{pt}^*}{P_t}\frac{\Omega_b}{2}\left(\psi_t - \overline{\psi}\right)^2 \tag{34}$$

$$\Gamma_t = \int_0^1 \Gamma_t(j)dj \tag{35}$$

$$L_t = \int_0^1 L_t(j)dj \tag{36}$$

$$K_t = \int_0^1 K_t(j)dj \tag{37}$$

$$M_t = M_t^s \tag{38}$$

$$B_t = B_t^s \tag{39}$$

Real GDP consists of the sum of consumption, investment and net exports, which is given by:

$$GDP_t = C_t + I_t + X_t - q_t\Gamma_{ft} \tag{40}$$

A steady-state can be defined in the usual way and is the same regardless of assumptions about price rigidities. All shocks are absent and all stationary variables are constant.[16]

4. Calibration

4.1 Monetary Policy

The monetary authority conducts monetary policy by following Taylor-type interest rate

15 The stationary equilibrium model equations are presented in Appendix B: Summary of Equilibrium Conditions.

16 The steady-state equilibrium is presented in Appendix C: The Steady-State Equilibrium Conditions.

rule as in Taylor (1993).

$$\hat{R}_t = \psi_r \hat{R}_{t-1} + (1-\psi_r)\left[\psi_p \hat{\pi}_t + \psi_y G\widehat{D}P_t + \psi_s \hat{S}_t\right] \tag{41}$$

where the variables $\hat{R}_t$, $\hat{\pi}_t$, $G\widehat{D}P_t$, and $\hat{S}_t$ denote the log-deviations of the nominal interest rate, the inflation rate, real GDP, and the nominal exchange rate growth, respectively, from the steady-state. The term ψ_r represents the degree of interest rate smoothing. The parameters ψ_p, ψ_y and ψ_s measure the responsiveness of the policy interest rate to changes in exchange rate growth, inflation, and real GDP growth.

According to Kollmann (2004) and Elekdag et al. (2006), when $\psi_s \to \infty$ in Equation (41), the monetary authority is implementing a fixed exchange rate regime. In other words, under the fixed exchange rate system, the nominal exchange rates growth is 1, and the central bank has to give up an independent monetary policy to defend exchange rates.[17] [18]

4.2 Shock Process

According to Itskhoki and Mukhin (2017), we use an equation for the exchange rate shock as below.[19] [20]

$$q'_t = \left(\frac{e_t P_t^*}{P_t}\right) e^{\xi_t} = q_t e^{\xi_t} \tag{42}$$

ξ_t is the law of one price shock, and follows the stochastic process:

$$ln\xi_t = (1-\rho_\xi) ln\xi + \rho_\xi ln\xi_{t-1} + \sigma_\xi \varepsilon_{\xi_t} \tag{43}$$

where $\rho_\xi \in (0,1)$ is a persistence parameter, σ_ξ is the standard deviation of the shock, and ε_{ξ_t} is the i.i.d. standard normal process.

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17 The People's Bank of China has gradually widened the trading band around the daily fixed rate (0% → ±0.5% (2007.5) → ±1% (2012.4) → ±2% (2014.3)).

18 From the perspective of the impossible trinity theorem, with free capital mobility, independent monetary policies are feasible if and only if exchange rates are floating.

19 In Itskhoki and Mukhin (2017), the strategic complementarity elasticity parameter $\gamma \in (0,1)$ was included in $q'_t = (e_t P_t^*/P_t)^\gamma e^{\xi_t} = q_t^\gamma e^{\xi_t}$. The bigger γ means that firms have a tendency to set product prices similar to local competitors. To simplify the model, we don't consider this parameter.

20 As a shock with a similar concept to our model, Alp and Elekdag (2011) used the sudden stop shock $(R_t = R_t^* E_t(e_{t+1}/e_t)\xi_t)$, and Kollmann (2002) used a UIP shock $(1 = \xi_t(1+R_t^*)E_t[\beta(C_t/C_{t+1})(P_t/P_{t+1})(e_{t+1}/e_t)])$. Devereux et al. (2006) used trade goods price shocks $(\Delta\widehat{P}_{XM_t} = 0.55\Delta\widehat{P}_{XM_{t-1}} + \varepsilon_t)$ and terms of trade shocks $(\Delta\widehat{P}_{TOT_t} = 0.32\Delta\widehat{P}_{TOT_{t-1}} + \varepsilon_t)$ for Thailand. Besides, there are trade cost shocks in Eaton et al. (2015) and Reyes-Heroles (2016), and terms of trade shocks in Broda (2004). In other studies, these shocks all play a key role and are referred to as exchange rate shocks, risk premia shocks, etc.

Both the foreign interest rate R_t^* and foreign export demand X_t^* are exogenous and follow the stochastic process.

$$lnR_t^* = (1-\rho_r)lnR^* + \rho_r lnR_{t-1}^* + \sigma_r \varepsilon_{r_t} \tag{44}$$

$$lnX_t^* = (1-\rho_x)lnX^* + \rho_x lnX_{t-1}^* + \sigma_x \varepsilon_{x_t} \tag{45}$$

where $\rho_r \in (0,1)$ and $\rho_x \in (0,1)$ are persistence parameters, σ_r and σ_x are the standard deviations of the shocks, and ε_{r_t} and ε_{x_t} are the i.i.d. standard normal processes.

4.3 Calibration

For the parameters, we mostly follow Chang et al. (2015). At the same time, the quarterly data from 1995Q1 to 2016Q4 for 20 years in China is used for the calibration, and these values are summarized in Table 2.[21]

In the household sector, we set the subjective discount factor $\beta = 0.982$ and the utility weight for real money balance $\Phi_m = 0.06$. The inverse Frisch elasticity of labor supply η is set at 2, implying a Frisch elasticity of labor supply of 0.5. The utility weight for leisure Φ_l is calibrated to use 40 % of the total time endowment of individuals in a steady-state to labor. The portfolio adjustment cost $\Omega_b = 0.6$ is at a higher level than other emerging countries to reflect the policy effects of capital controls by applying a higher cost to foreign bond holdings by China's household sector. By setting the steady-state share of domestic bonds $\overline{\psi} = 0.9$, it reflects reality where a domestic bonds home bias exists.

For an investment function of entrepreneurs, depreciation rate δ is set at 0.035, considering that China's annual depreciation rate is 14% according to Chang et al. (2017). The elasticity of risk premium ς is set at 0.61, which is the value for the elasticity of the external finance premium in China's non-tradable sector in Zhang (2011).[22]

We use $\Omega_k = 2$, which lies within the range of the empirical estimates of previous studies. An entrepreneur's survival probability ω is set at 0.9933, which was used for emerging countries in Ozkan and Unsal (2012).[23]

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21 In the case of the parameters where we don't explain the specific estimation method, we follow Chang et al. (2015).

22 Though this parameter is bigger than values used in existing studies, such as 0.07 in the tradable sector and 0.048 in Elekdag et al. (2006), we use a value of non-tradable sectors, considering that there are many restrictions on foreign borrowing in China. Portfolio inward investment in China is channeled through Qualified Foreign Institutional Investors (QFII), and has an aggregate ceiling of USD $150 billion (since July 2013). Regarding other inward investments, foreign borrowing is subject to a ceiling (for short-term borrowing) or approval requirements (for long-term borrowing), but lending abroad is largely unrestricted (Bayoumi and Ohnsorge, 2013).

23 There is a wide range of estimates for investment adjustment cost parameter Ω_k. Elekdag and Tchakarov

The cost share of intermediated goods ϕ is set at 0.5 and the capital income share α at 0.5, as in Chang et al. (2017). Average technology growth rate λ_z is calibrated at 1.023 reflecting that the average annual real GDP grows at a rate of 9.3%. The elasticity of substitution between differentiated products parameter θ_p is set at 10, implying a steady-state price markup of about 11%. Price adjustment cost parameter Ω_p is set at 60.

For the parameters in the international sector, the share of domestic intermediate inputs λ_Γ is set to 0.7556 to match the import to GDP ratio of 20% in the sample period. Export demand elasticity $\theta_x = 1.5$.

According to previous studies of the Chinese economy, under the flexible exchange regime, the interest rate follows the Taylor rule in Equation (43), with $\psi_r = 0.85$, $\psi_p = 1.2$ and $\psi_y = 0.5$ fixed.

For a shock parameter, the persistence of exchange rate shock ρ_ξ and foreign export demand shock ρ_x are set at 0.95 and the standard deviations of shock σ_ξ and shock σ_x are set to 0.1%. The persistence of foreign interest rate shock ρ_r is set at 0.98 to capture the relatively persistent trend in foreign interest rates and in risk premiums during and after the global financial crisis, and the standard deviation of shock σ_r is set to 0.1%.

5. Impulse Response Analysis

We examine how different the effects of external shocks on the domestic economy are depending on the presence of financial friction and exchange rate systems by classifying them into three scenarios: (i) a fixed exchange rate regime with financial frictions; (ii) a fixed exchange rate regime with no financial friction; and, (iii) a flexible exchange rate regime with financial frictions.

First of all, the benchmark model is a model that includes entrepreneurs that borrow funds from abroad in a fixed exchange rate system. In this model we tried to see how external shocks affect the domestic economy through financial channels apart from trade channels. We assumed a fixed exchange rate system in this case, and this is represented as the dotted line that is indexed as the “Base” line in Figures 3, 4 and 5.

The second model is a model that focuses on trade channels with no financial accelerator effects, as there are no entrepreneurs with foreign currency denominated debts. Just as in the

(2007) and Ozkan and Unsal (2012) used 12, Kolasa and Lombardo (2014) used 5.2, Ueda (2012) used 2.5, and Davis and Presno (2014) used 2.48. As for the Chinese data, Chen et al. (2012) and Funke and Paetz (2012) calibrated it to 2, Miao and Peng (2011) used 1.18, and Chang et al. (2017) set it at 1.

Table 2. Parameter Calibration

Parameter	Description	Value
Households		
β	subjective discount rate	0.982
Φ_m	weight on utility of money balances	0.06
η	inverse Frisch elasticity of labor supply	2
Ω_b	portfolio adjustment cost	0.6
$\overline{\psi}$	average portfolio share of domestic bonds	0.9
Entrepreneurs		
δ	depreciation rate	0.035
ς	elasticity of the external finance premium	0.61
Ω_k	investment adjustment costs	2
ω	survival rate	0.9933
Firms		
ϕ	cost share of intermediate goods	0.5
α	cost share of capital	0.5
λ_z	mean productivity growth rate	1.023
θ_p	elasticity of substitution between differentiated goods	10
Ω_p	price adjustment cost	60
International sector		
λ_Γ	share of domestic intermediate goods	0.7556
θ_x	export demand elasticity	1.5
Central bank		
ψ_r	degree of interest rate smoothing	0.85
ψ_p	response to inflation	1.2
ψ_y	response to real GDP growth	0.5
Shock process		
ρ_ξ	persistence of exchange rate shock	0.95
ρ_r	persistence of foreign interest rate shock	0.98
ρ_x	persistence of foreign export demand shock	0.95
σ_ξ	standard deviation of exchange rate shock	0.001
σ_r	standard deviation of foreign interest rate shock	0.001
σ_x	standard deviation of foreign export demand shock	0.001

first case, we assumed a fixed exchange rate system, and this is represented as the “Fix” line indicated in the full line in the impulse response in Figures 3, 4 and 5.

Lastly, we analyze the case where the central bank carries out a monetary policy according to the Taylor rule under a floating exchange rate system while also including entrepreneurs as in the first model. This corresponds to the “Flex” line indicated in the marked line in the impulse response in Figures 3, 4 and 5.

5.1 RMB Appreciation Shock

Figure 3 shows the impulse responses of economic variables following an RMB appreciation shock in the three alternative scenarios.

The benchmark model (Base line) shows that in cases where there are shocks that cause an appreciation in the home country currency, the yuan appreciates and exports decrease. Also, due to the shock of appreciation of the domestic currency, the size of the entrepreneurs' foreign borrowings increases and, in turn, investment increases. Though exports decrease, real GDP decreases by a smaller margin due to an increase in investment following the increase in foreign borrowings.[24]

The essence of the second model (the Fix line) is that it has only a trade channel. An RMB appreciation shock sees that the yuan appreciate and exports decrease. As exports fall, the amount of capital inflow decreases, and with the diminishing necessity that the central bank issue bonds or currency (the sterilization policy is needed in a subsequent step) to absorb the foreign currency, inflation falls as well. Though there are no changes in the nominal exchange rate, the real exchange rate changes according to the shock of appreciation in the exchange rate and the fall in domestic price levels. Since the impact of the shock is relatively large, the real value of the domestic currency appreciates (a fall in the real exchange rate). With exports decreasing, real GDP decreases as well.

The last model (the Flex line) shows that with the flexibility of nominal exchange rates, part of the shock causing an appreciation of in the yuan is absorbed by the depreciation of the exchange rate of the yuan (an increase in the yuan/foreign currency exchange rates), and therefore the extent of appreciation in real exchange rates is much smaller than in the two previous cases. As a result, export deficits decrease, the change in exports is negligible and, in turn, the size of foreign capital inflows is not large. Therefore, there will be little change in inflation. As the extent of appreciation in the real exchange rates is small, the size of entrepreneurs' foreign borrowings is smaller than in the first model, and, accordingly, the extent of increase in investments decreases as well. Overall, while the increase in investment falls compared in the first model, export deficits decrease by a larger amount, and this leads to a small increase in real GDP.

Consequently, the scale of foreign currency denominated debt is the key determinant of how exchange rate regimes influence the propagation of a foreign exchange rate shock.

24 These results are consistent with the empirical analysis results of Avdjiev et al. (2017) and of Bruno and Shin (2015), which showed that if the currencies of emerging countries appreciate against the USD, U.S. dollar-denominated capital inflows into emerging countries increase. This takes place together with an easing of emerging countries' financial conditions, and real investments increase as well.

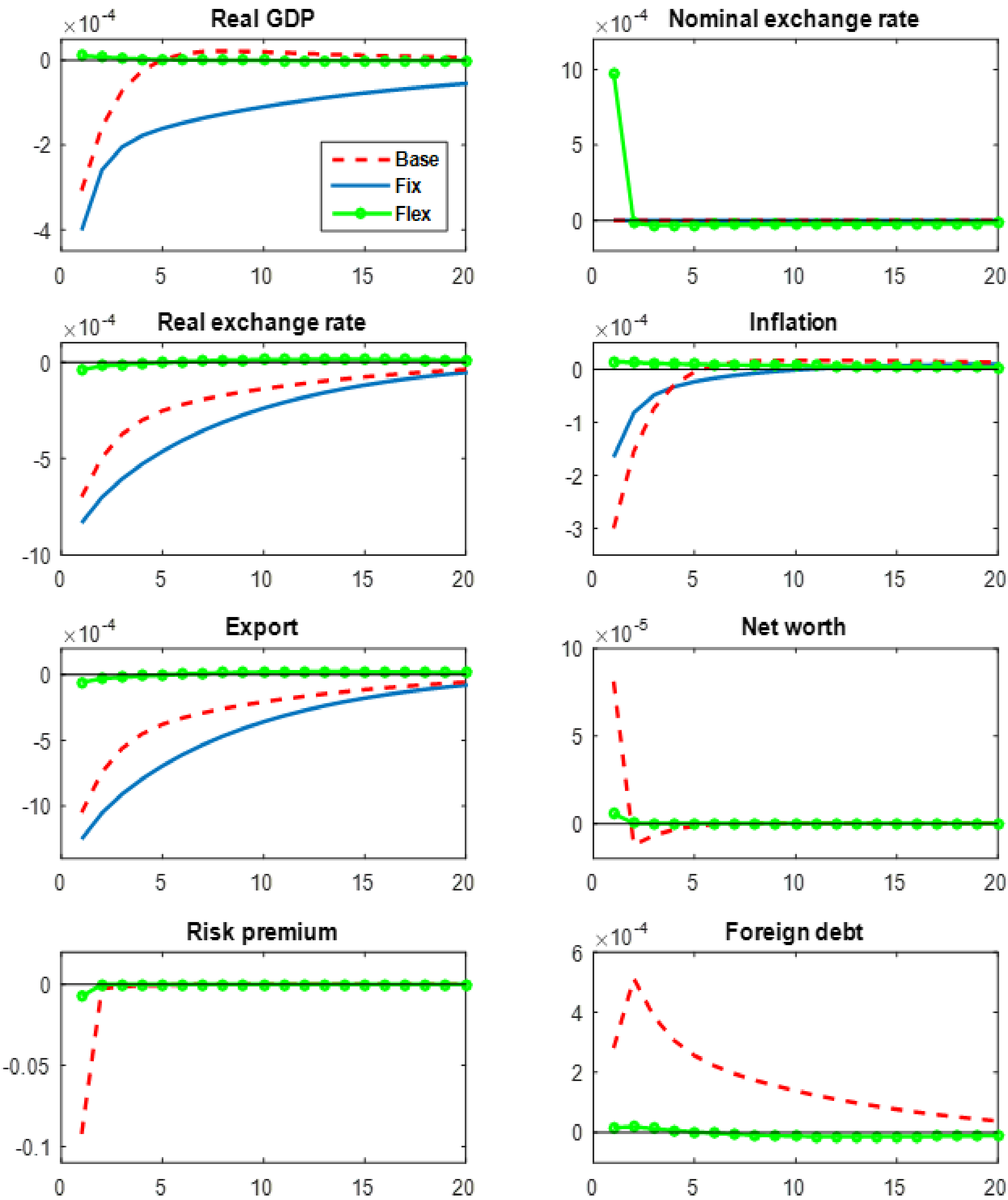

Fig 3. Impulse Responses to RMB Appreciation Shock.

Notes: 1. Base: Benchmark Model (with financial friction, fixed exchange rate regime)
Fix: Alternative Model 1 (with no financial friction, fixed exchange rate regime)
Flex: Alternative Model 2 (with financial friction, flexible exchange rate regime)
2. X-axis: quarterly periods from the shock
Y-axis: percent deviation from steady-state

Summing up the effects on real GDP, analyzed by both the existence of financial friction in the entrepreneurial sector and the two different exchange rate systems, first, the extent of the real GDP decrease narrowed more in the first model that includes the financial accelerator than in the second model. This difference can be seen as a positive effect that the appreciation of the yuan brought to China's domestic economy through financial channels an increase in foreign borrowing and investment. That is, this can be interpreted as the extent to which the financial accelerator mechanism worked through the balance sheet effect.

Compared to the fixed exchange rate system of the first model, in the flexible exchange rate regime of the third model, the effects on real GDP turned positive. The difference between these two models is that as the change in nominal exchange rates absorbs part of the shock to exchange rates, even though the extent of increase of investments decreases due to a decrease in the size of foreign borrowings in the financial channels, export deficits decrease in the trade channels, and, therefore, the overall negative effects on the domestic economy decreased. That is, China is a country with dominant trade channels, and benefits from trade channels that offset losses in financial channels, and this can be attributed to the advantages from the change of exchange rate regimes (from a fixed exchange rate regime to a flexible exchange rate regime).[25]

5.2 Negative Foreign Monetary Policy Shock

Figure 4 shows the impulse responses of economic variables following a negative shock to foreign monetary policy (a decrease in the foreign interest rate) under the three alternative scenarios.

As the Base model in Figure 4 shows, when there is a negative shock to the foreign interest rate, domestic inflation increases. Since there is no change in the nominal exchange rate due to the fixed exchange rate system, inflation is fully reflected in the real exchange rate causing a decrease in the real exchange rate, and this results in a decrease in exports and in real GDP. Also, the effects of the domestic currency appreciation are added to the foreign borrowing interest rate falling, and thus the changes in foreign borrowings can be amplified.[26] This results in an increase in investment, offsetting any decrease in exports. In the end, since the positive effects from the financial channel are bigger than the negative effects from the export channel, real GDP increases.

When the foreign interest rate falls, it can bring positive effects, such as an increase in domestic output due to an easing of monetary policy. However, in the Fix model, since this

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25 As stated in Friedman (1953) that any adjustment in exchange rates or prices can mitigate economic volatility, many studies have showed that flexible exchange rate regimes have a more mitigating effect on the economy in response to external shocks than fixed exchange rate regimes. For existing studies related to exchange rate regimes, please refer to the reference literature in Section 2.

26 In other words, apart from the direct effect on the borrowing interest rate in terms of price, as the risk premium decreases due to the value of foreign currency denominated debts falling thanks to the domestic currency appreciation, the amount of foreign debts increases in terms of quantity.

model only analyzes the trade channel, the foreign interest rate ended up bringing negative effects to output because the effect of an easing monetary policy is overwhelmed by a decrease in exports following a domestic currency appreciation.

Lastly, in the Flex model, as capital inflows to China and the nominal exchange rate both fall due to the negative shock of the foreign interest rate, the effects on the domestic market become different from a fixed exchange rate system. As the nominal exchange rate falls, the real exchange rate also falls and exports decrease. Meanwhile, domestic currency appreciation increases entrepreneurs' net worth and strengthens their foreign borrowing capability. In addition to a decline in the borrowing interest rate, this results in an increase in foreign debt amounts. In the end, the increase in investment offsets the negative effect of the decline in exports, and the positive effects of the financial channel become big enough to ultimately increase real GDP, like in the Base model.

Looking at the central bank's response and sterilization policy, a negative shock to foreign interest rates leads to an increase in capital inflows into China and an increase in the price level, and the Chinese government purchases foreign assets in order to maintain the fixed exchange rate. In this case, the central bank prefers the purchase to be financed by bond issuances rather than money creation due to the increase in inflation. Figure 3 shows that both in the Base model and the Fix model, while money creation decreases, bond issuance increases. In the Flex model, as the central bank doesn't need an intervention to stabilize the exchange rate and the sterilization policy, the amount of money supply and bond issuance show a different pattern from the previous two models with a fixed exchange rate system.

In summary, when there is a negative shock from the foreign interest rates, in a floating exchange rate system, as the nominal exchange rate appreciates and absorbs the external shock, inflation fluctuations are smaller than in a fixed exchange rate system and real GDP change is similar to that in a fixed exchange rate system.

5.3 Negative Foreign Export Demand Shock

Figure 5 shows the impulse responses of economic variables following a negative shock from foreign export demand under the three alternative scenarios.

In the Base model, exports decrease due to the direct negative shock to export demand, but it is different in terms of the range of fluctuation in GDP due to the financial channel. As exports decrease, capital inflows from export receipts also decrease and the domestic currency depreciates. However, since there are no changes in the nominal exchange rate under a fixed exchange rate system, the real exchange rate depreciates a lot. This causes a decrease in the net worth of companies with foreign currency denominated debts and a rise in the risk

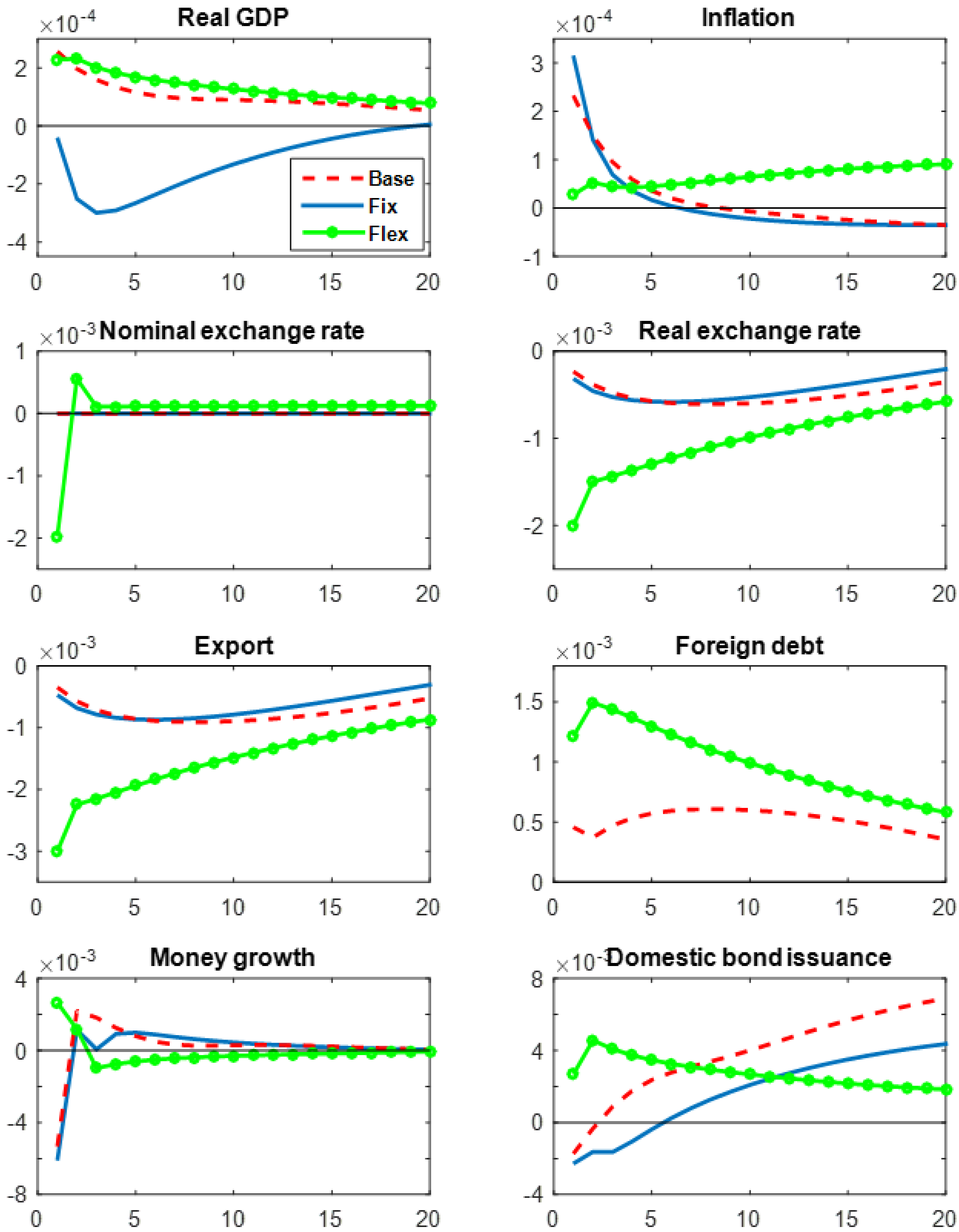

Fig. 4. Impulse Responses to Negative Foreign Interest Rate Shock.

Notes: 1. Base: Benchmark Model (with financial friction, fixed exchange rate regime)
Fix: Alternative Model 1 (with no financial friction, fixed exchange rate regime)
Flex: Alternative Model 2 (with financial friction, flexible exchange rate regime)
2. X-axis: quarterly periods from the shock
Y-axis: percent deviation from steady-state

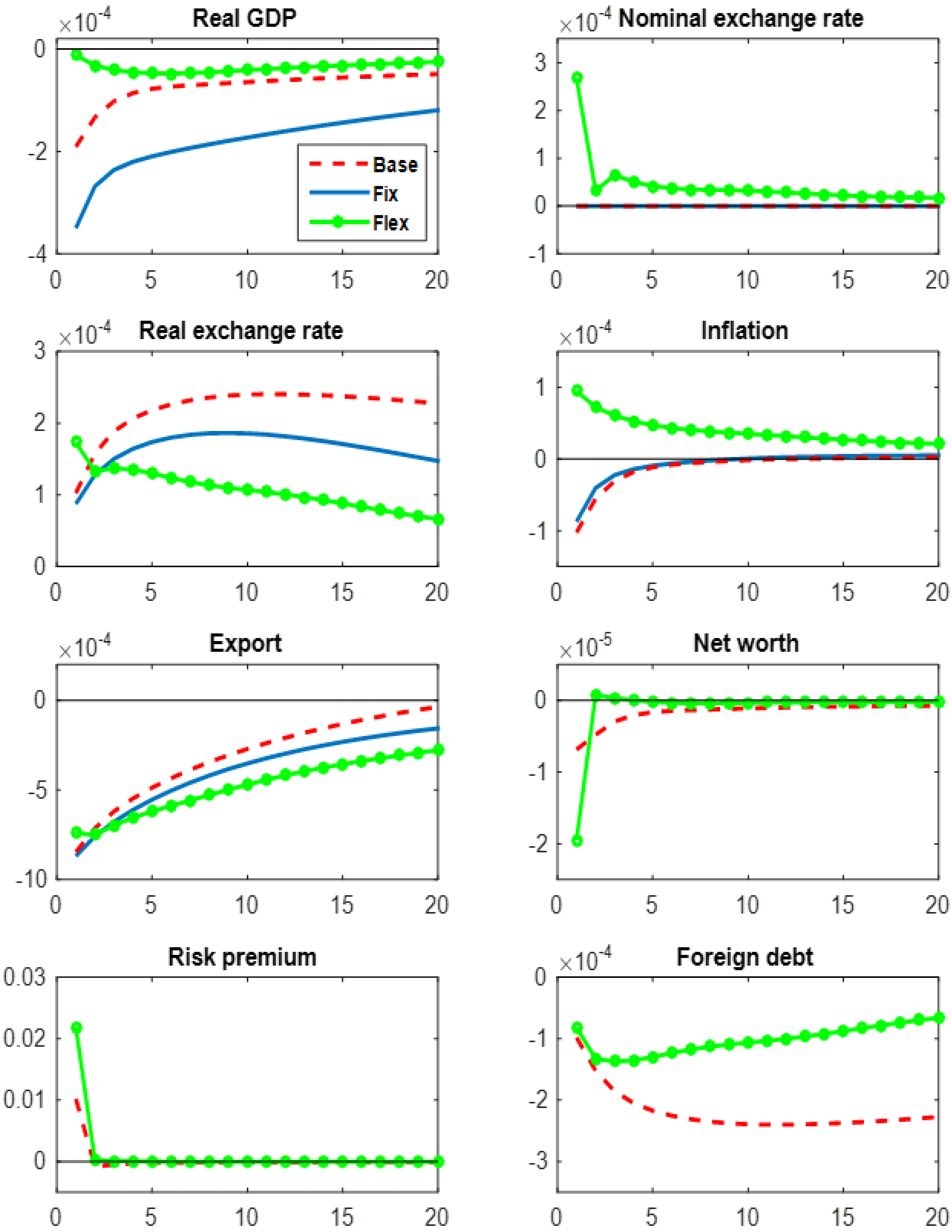

Fig. 5. Impulse Responses to Negative Foreign Export Demand Shock.

Notes: 1. Base: Benchmark Model (with financial friction, fixed exchange rate regime)

Fix: Alternative Model 1 (with no financial friction, fixed exchange rate regime)

Flex: Alternative Model 2 (with financial friction, flexible exchange rate regime)

2. X-axis: quarterly periods from the shock

Y-axis: percent deviation from steady-state premium, resulting in decreasing foreign borrowing debts. This negative effect in the financial channel culminates in a decrease in GDP along with a decrease in exports through the trade channel.

A negative shock from the foreign export demand leads to a decrease in exports, and results in a fall in GDP, as shown in the Fix model.

In the Flex model, as the negative shock to export demand is absorbed by an increase in the nominal exchange rate, the range of real exchange rate depreciation becomes smaller than in the previous two models. In addition to a decrease in exports via the trade channel, the amount of entrepreneurs' foreign borrowing decreases due to real exchange rate depreciation through the financial channel, and, ultimately, real GDP decreases. In the Flex model, since the fall in foreign borrowing is smaller than in the Base model, the negative effects of the financial channel are smaller than in the Base model, and, as a result, the decline in real GDP is smaller than in the Base model, as well. When there is a negative shock to export demand, the real GDP fluctuation is also smaller under a floating exchange rate system than under a fixed exchange rate system.

To sum up the results, first, in the case where there is an RMB appreciation shock, China's trade channel has dominant effects. In the Base model, the positive effects of the financial channel are overwhelmed by the negative effects of the trade channel, and, as a result, real GDP decreased. Meanwhile, in the case of a negative foreign interest rate shock, the effect of the financial channel is dominant. Both in the Base model and the Flex model, a decrease in exports due to real exchange rate appreciation is overwhelmed by an increase in output due to the increase in foreign borrowing and, as a result, real GDP increased.

Second, the financial accelerator mechanism is functioning well. A positive shock to domestic currency appreciation and a negative shock to export demand lead to an increase (decrease) in entrepreneurs' net worth following an appreciation (a depreciation) of the domestic currency, and an increase (a decrease) in the risk premium. This results in a change in GDP. This demonstrates that the risk-taking channel and the balance sheet effect are working well in the Chinese characteristics model.

Third, comparing the Base model and the Flex model, we can see that macro-economic variables are more stable under the floating exchange rate system by allowing change in the nominal exchange rate and therefore absorbing external shocks better than under a fixed exchange rate system.

6. Welfare Analysis

6.1 Financial Policies

As examined in Section 5, the financial channel is working well in the model with Chinese characteristics. However, in the impulse response process caused by external shocks, the side effects, like rapid capital flows and a soaring of entrepreneurs' foreign borrowing leverage ratio, may occur. According to recent studies, in cases where the central bank responds to drastic changes in financial variables by implementing macroprudential policies, such as regulations on capital movement and leverage ratios, along with a conventional monetary policy, the loss of social welfare decreases compared cases that solely rely on monetary policy. In this light, there are continuous arguments that monetary authorities need to consider foreign capital flows systematically in order to conduct an optimal policy to increase social welfare.[27]

Therefore, in this section, we examine whether social welfare improves or not compared to relying solely on conventional interest rate rules if the central bank additionally considers macroprudential policies, such as a capital inflow tax policy, which imposes a tax on entrepreneurs' total foreign borrowing amounts, or a financial regulation policy, which controls companies' foreign borrowing leverage ratios, along with conventional interest rate rules.

Under the same frameworks as in the previous section, we look at four types of financial policies. One is monetary policy as a benchmark policy, and the others are macroprudential policies. In other words, in addition to our benchmark monetary policy, such as a fixed exchange rate policy or an interest rate rule, we consider three kinds of tax policies, such as a capital inflow tax, a financial regulation tax, and the joint implementation of both taxes: (i) fixed exchange rate policy; (ii) fixed exchange rate policy with capital inflow tax; (iii) fixed exchange rate policy with financial regulation tax; (iv) fixed exchange rate policy with joint tax; (v) interest rate rule; (vi) interest rate rule with capital inflow tax; (vii) interest rate rule with financial regulation tax; and, (viii) interest rate rule with joint tax. [28] [29]

Regarding monetary policy, we use a pegged exchange rate policy for the fixed exchange

27 For existing studies related to macroprudential policies, please refer to the reference literature in Section 2.

28 Since the Fix model represents a case without any financial channel, and therefore since comparing the welfare in this model with the welfare in other models (Base and Flex models) is unreasonable, we will not consider the Fix model in the welfare analysis.

29 There are many kinds of capital control taxes, for example, a tax on the difference between the domestic and foreign interest rates, a tax on the amount of foreign borrowing, a tax on the leverage ratio, or a tax on the asset holdings of financial institutions. For existing studies related to tax types, please refer to the reference literature in Section 2.

rate regime and a Taylor-type interest rate rule equation for the flexible exchange rate regime. The capital inflow tax policy is given by

$$T_t^c = \tau_{t-1}^c R_{et-1}^* \Phi_t e_t D_{t-1}^* \quad (46)$$

τ_t^c is the tax rate on total foreign borrowing for Chinese entrepreneurs.[30] T_t^c is the tax revenue from foreign capital inflows and is rebated to the households as a government lump-sum transfer. The evolution of net worth is thus changed to

$$P_t N_t = \omega[\, r_t^k Q_{Kt-1} K_t - (1+\tau_{t-1}^c)\, R_{et-1}^* \Phi_t e_t D_{t-1}^*] \quad (47)$$

The financial regulation tax policy (leverage tax) is given by

$$\tau_t^f = \chi\left(\frac{lev_t}{\overline{lev}} - 1\right), \qquad \text{with } \chi \geq 0 \quad (48)$$

$$T_t^f = \tau_{t-1}^f r_t^k Q_{Kt-1} K_t \quad (49)$$

where $lev_t = \frac{Q_{Kt}K_{t+1}}{P_t N_t}$ is the ratio of capital to net worth, and $\overline{lev}$ is the steady-state leverage ratio which is set at 2.5.[31] This policy is the financial regulatory penalty for taking a higher leverage ratio than the steady state level, and the tax rate τ_t^f on physical capital will be decided by the parameter χ.[32] χ is a non-negative value, so when the leverage ratio is above (below) the steady-state level, the government imposes a tax (subsidy). Therefore, parameter χ presents the sensitivity of financial regulations to the leverage ratio.[33] T_t^f is tax revenues (subsidy expenditures) from foreign capital inflows and is rebated to the households as a government lump-sum transfer. The dynamic of net worth is thus changed to

$$P_t N_t = \omega\left[\left(1-\tau_{t-1}^f\right) r_t^k Q_{Kt-1} K_t - R_{et-1}^* \Phi_t e_t D_{t-1}^*\right] \quad (50)$$

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30 As part of the capital inflow tax policy, the part that indicates the interest rate of foreign borrowings, $R_{et}^* \Phi_{t+1}$ in Equations (13) and (16) will be changed to $(1+\tau_t^c) R_{et}^* \Phi_{t+1}$ after the tax is imposed.

31 Referring to previous studies (Ueda 2012, Kolasa, and Lombardo 2014, Christensen and Did 2008, and Poutineau and Vermandel 2015), we set the steady-state ratio of net worth to capital at 0.4, implying a steady-state leverage ratio of 2.5. Therefore, in the welfare analysis part, the survival rate of entrepreneurs can be backed out using the steady-state leverage ratio.

32 As part of the financial regulation tax policy, the part that indicates a return on capital investments, r_t^k in Equations (13), (16) and (17) will be changed to $(1-\tau_t^f) r_t^k$ after the tax is imposed.

33 According to Liu et al. (2018), the calibrated parameters for the tax rate in China are relatively large (the tax rate on foreign assets is 16.62% and the tax rate on foreign debt is 5.09%). To reflect this real economic situation, we set χ=21.8.

Tax revenues T_t^j and the dynamic of net worth obtained from the implementation of a joint tax policy in an environment that allows both tax policies are given by

$$T_t^j = \tau_{t-1}^c R_{et-1}^* \Phi_t e_t D_{t-1}^* + \tau_{t-1}^f r_t^k Q_{Kt-1} K_t \tag{51}$$

$$P_t N_t = \omega\left[\left(1 - \tau_{t-1}^f\right) r_t^k Q_{Kt-1} K_t - (1 + \tau_{t-1}^c)\, R_{et-1}^* \Phi_t e_t D_{t-1}^*\right] \tag{52}$$

6.2 Optimal Ramsey Policies

To characterize the welfare evaluation, we consider optimal Ramsey monetary and macroprudential policies. We derive the Ramsey policies by setting up the Lagrangian problem in which the social planner sets policy instruments optimally to maximize the social welfare subject to the private agents' optimizing decisions. We compute this based on the Matlab procedures developed by Levin et al. (2006).[34]

x_t indicates the $N \times 1$ vector of endogenous variables. Except for the policy instrument, the remaining $N - 1$ endogenous variables in x_t satisfy the $N - 1$ structure conditions as follows:

$$E_t f(x_t, x_{t+1}, \Xi_t) = 0 \tag{53}$$

where the vector Ξ_t is the exogenous variables. We obtain the optimal Ramsey policy from the maximization problem:

$$\max_{\{x_t\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t \, U(x_t, \Xi_t) \tag{54}$$
$$s.t. \; E_t f(x_t, x_{t+1}, \Xi_t) = 0$$

We set up the Lagrangian problem:

$$\mathcal{L}_0 = E_0 \sum_{t=0}^{\infty} \beta^t \left\{U(x_t, \Xi_t) + \lambda_t' f(x_t, x_{t+1}, \Xi_t)\right\} \tag{55}$$

where λ_t indicates the Lagrangian multipliers associated with the first-order conditions of the private sector and the market clearing conditions of the economy in Equation (53). Taking derivatives of $\mathcal{L}_0$ with respect to the N endogenous variables, we derive the N first-order

34 Using Levin et al. (2006)'s codes which read a Dynare model file, we can obtain the first-order conditions of the Ramsey planner.

conditions that are characterized in the following equation:

$$U_1(x_t, \Xi_t) + E_t\lambda_t' f_1(x_t, x_{t+1}, \Xi_t) + \beta^{-1}\lambda_{t-1}' f_2(x_{t-1}, x_t, \Xi_{t-1}) = 0 \tag{56}$$

Taking derivatives of $\mathcal{L}_0$ with respect to λ_t, we get the $N-1$ equilibrium conditions in the private agents in Equation (53). Therefore, the Ramsey equilibrium process can be characterized by the $N-1$ equation in Equation (53), and the N equations in Equation (56). We have the N elements of x and the $N-1$ multipliers of λ. As a result, we have $2N-1$ variables and $2N-1$ equations.

We will explore the optimal Ramsey monetary and macroprudential policies under eight alternative cases: four cases for a fixed exchange regime, and four cases for a flexible exchange rate regime. In the first case, (i) a fixed exchange rate policy without macroprudential policies (i.e., $e_t = \bar{e}$, and $\tau_t^c = \tau_t^f = 0$ for all t), we have N endogeneous variables and N equilibrium conditions. In the peg case with macroprudential policies, (ii) a fixed exchange rate policy with a capital inflow tax (policy instrument τ_t^c, $e_t = \bar{e}$ for all t), or (iii) a fixed exchange rate policy with a financial regulation tax (policy instrument τ_t^f, $e_t = \bar{e}$ for all t), we include τ_t^c or τ_t^f in the endogenous variables and obtain the Ramsey tax policy by letting τ_t^c or τ_t^f be the policy instruments. In these cases, we have $N-1$ equilibrium conditions for N endogenous variables. Including the $N-1$ multipliers, in total we have $2N-1$ variables and $2N-1$ equations. Then we have (iv) a fixed exchange rate policy with a joint tax (policy instrument τ_t^c and τ_t^f, $e_t = \bar{e}$ for all t), we obtain the Ramsey results by letting τ_t^c and τ_t^f be policy instruments. In these cases, we have $N-2$ equilibrium conditions for N endogenous variables. Including the $N-2$ multipliers, in total we have $2N-2$ variables and $2N-2$ equations.

Under the flexible exchange rate regime, there are also four alternative cases, just like under the fixed exchange rate regime. Regarding (v) an interest rate rule without macroprudential policies (policy instrument R_t), e_t is included in the endogenous variables, we let R_t be a policy instrument and get the Ramsey monetary policy. In this case we have $N-1$ equilibrium conditions for N endogenous variables. Including the $N-1$ multipliers, in total we have $2N-1$ variables and $2N-1$ equations. In the flexible exchange rate with macroprudential policies, (vi) an interest rate rule with a capital inflow tax (policy instruments R_t and τ_t^c) or (vii) an interest rate rule with a financial regulation tax (policy instruments R_t and τ_t^f), we include τ_t^c or τ_t^f in the endogenous variables and obtain the Ramsey tax policy by letting τ_t^c or τ_t^f be policy instruments along with R_t. In these cases, we have $N-2$ equilibrium conditions for N endogenous variables. Including the $N-2$ multipliers, in total we have $2N-2$ variables and $2N-2$ equations. Finally, with (viii) an interest rate rule with a joint tax (policy instruments R_t, τ_t^c and τ_t^f), we let R_t, τ_t^c and τ_t^f be policy instruments and get the Ramsey results. In this case, we have $N-3$ equilibrium conditions for N endogenous variables. Including the $N-3$ multipliers, in total we have $2N-3$ variables and $2N-3$ equations.

6.3 Welfare Evaluation

We analyze social welfare comparisons under the two scenarios, the Base and the Flex models, as in Section 5, and measure relatively how much welfare increases (or decreases) in the case of adding respective macroprudential policies compared to using monetary policy only through household welfare.[35] The Ramsey planner's objective function Equation (57) corresponds to the value function of the representative household, except for real money balances (Woodford, 2003).

First of all, we calculate the base conditional welfare (denoted by V_0^b) obtained from the allocation of the fixed exchange rate rule and the interest rate rule, which can be represented as monetary policies respectively under the two scenarios and the alternative welfare (V_0^a) in the case of adding the macroprudential policy (the capital inflow tax, the financial regulation tax, or the joint tax). The conditional welfare is obtained using second-order approximation methods, as argued in Schmitt-Grohé and Uribe (2004).

$$V_0^i = E_0 \sum_{t=0}^{\infty} \beta^t \left[ln\left(C_t^i\right) - \Phi_l \frac{\left(L_t^i\right)^{1+\eta}}{1+\eta} \right], \qquad \text{with } i = a, b \qquad (57)$$

We measure welfare gains under each additional macroprudential policy relative to the benchmark policy as a percentage change in the steady-state consumption that would leave the representative household indifferent as to living in an economy under any given macroprudential policy or in the benchmark economy. The welfare gain of adopting a macroprudential policy on the condition of the calibrated steady state is measured by Δ such that

$$V_0^b = E_0 \sum_{t=0}^{\infty} \beta^t \left[ln\{C_t^a(1-\Delta)\} - \Phi_l \frac{(L_t^a)^{1+\eta}}{1+\eta} \right] \qquad (58)$$

35 The overall welfare in our model could be the weighted sum of households' and entrepreneurs' welfare. However, we can reasonably assume that the fraction of entrepreneurs' consumption is negligible as argued in Bernanke et al. (1999). Therefore, following the previous studies (Elekdag and Tchakarov, 2007 and Kitano and Takaku, 2018a), we also calculate the overall welfare corresponding to households' welfare levels.

where the variables with superscript a denote allocations under the macroprudential policies. With log-utility in consumption, the explicit expression for welfare gains satisfies

$$ln(1-\Delta) = (1-\beta)(V_0^b - V_0^a) \quad (59)$$

6.3.1 Welfare Comparisons

Table 3 shows conditional welfare outcomes under the benchmark policy along with three additional macroprudential policies by each exchange rate system. These results are obtained with the economy being exposed to all shocks, such as exchange rate shocks, foreign interest rate shocks, and export demand shocks.

In Table 3, while the left part shows that the benchmark is a fixed exchange rate policy under a pegged exchange rate regime, the right part shows that the benchmark is the monetary policy under a floating exchange rate regime. This benchmark policy represents the Ramsey optimal monetary policy (a fixed exchange rate or an interest rate rule) without restriction on capital flows or the leverage ratio. The welfare gains (+0.0481%) in the first row show that the Ramsey optimal monetary policy under the floating exchange rate system brings more stability to macroeconomic variables and better welfare compared to the fixed exchange rate rule. This seems to be because there is no need to intervene to ensure the stability of the exchange rate in the floating exchange rate regime, and, therefore, the central bank can respond to output fluctuations by adjusting interest rates since it has more discretion in implementing monetary policy.

In the floating exchange rate regime, we add one more scenario, the simple policy rule, to compare the welfare gains with the optimal Ramsey policy. For the People's Bank of China's monetary policy under the simple policy rule, we use a Taylor-type interest rate rule equation. In comparison to the fixed exchange rate regime, the welfare gain (+0.0481%) with the optimal Ramsey monetary policy is bigger than the welfare gain (+0.0124%) of the simple rule. This result can be understood as the Ramsey policy having maximized welfare along with an optimal real allocation.

We next study the role of macroprudential policies. The second row in Table 3 shows the conditional welfare changes under the three different optimal financial policies by each exchange rate regime. In the fixed exchange rate regime, welfare gains increase more by 0.3902%, 0.0012%, and 0.3903%, respectively, when imposing a capital inflow tax, a financial regulation tax, and a joint tax, than when not applying them. In the floating exchange rate system, welfare gains increase more by 0.3518%, 0.0002%, and 0.3484%, respectively, when using a capital inflow tax, a financial regulation tax, and a joint tax, than when not using them.

Welfare gains (%)	**Fixed exchange rate regime**				**Flexible exchange rate regime**			
	Bench mark	Capital tax	Leverage tax	Joint tax	Benchmark (Simple rule)	Capital tax	Leverage tax	Joint tax
Basic model	–				0.0481 (0.0124)			
	–	0.3902	0.0012	0.3903	–	0.3518	0.0002	0.3484
No financial friction model	–				0.0070 (0.0038)			
	–	0.0169	0.0000	0.0161	–	0.0036	0.0000	0.0056

Table 3. Welfare Gains Under Alternative Financial Policy Rules.

Our Ramsey results have shown that an optimal macroprudential policy improves welfare under both exchange rate regimes. In an economy with only a monetary policy, while domestic monetary policy doesn't have a direct effect on foreign borrowing interest rates, which is a key determinant of foreign debts, in an economy with additional macroprudential policies, it is possible to mitigate volatile capital flows by raising the borrowing interest rate or the cost of a capital using tax. Therefore, a macroprudential policy brings higher welfare under both exchange rate regimes.

The welfare gains under a fixed exchange rate regime are larger than under a floating exchange rate regime with macroprudential policies. This is because financial friction is bigger in the fixed exchange rate regime than in the floating exchange rate regime, and a macroprudential policy brings a bigger welfare gain by solving financial friction. In addition, the cost of price adjustments to peg exchange rates is also bigger in the fixed exchange rate regime, and capital controls contribute to the bigger welfare improvement by solving this distortion, as well. It is also true from the perspective of the Mundellian Trilemma that macroprudential policy brings a welfare gain in the fixed exchange rate regime because capital controls in the fixed exchange rate regime strengthen the autonomy of domestic monetary policy, making it necessary for the PBOC to follow foreign monetary policy.[36]

The optimal capital inflow tax policy significantly outperforms the optimal financial regulation tax policy under both exchange rate regimes. In our model, the sensitivity index of financial regulations to the leverage ratio, χ, is a constant parameter, which decides the financial regulation tax rate. This means that the leverage tax cannot become the state

36 This result is consistent with the findings of Farhi and Werning (2012, 2014). They show that the exchange rate regime is important in an evaluation of capital controls, and show that optimal capital controls are effective in response to a risk premium shock under a fixed exchange rate regime. They also find that, in contrast with the Mundellian view, capital controls are desirable even when the exchange rate is flexible.

contingent tax. If χ varies over time, it will produce an optimal leverage tax for every period, but since it doesn't, the effects of the leverage tax become negligible in terms of welfare gains. On the other hand, since the capital control tax is set optimally in every period, it brings a bigger welfare improvement.

Moreover, in our model, entrepreneurs only hold foreign debts. In this situation, the effects of a financial regulation tax decrease compared to having both foreign and domestic debts, because the demand for foreign borrowing can decrease more by entrepreneurs replacing foreign debts with domestic debts in cases where a leverage tax is imposed on foreign borrowing when they are allowed to have both foreign and domestic debts, which is not the case with our model.

Also, while the capital inflow tax is a tax imposed on the amount of foreign debts that directly affects the rise of the foreign borrowing interest rate, the financial regulation tax affects the resource allocations decision, such as entrepreneurs' capital, net worth and foreign debts, by applying a tax rate on the price of capital. In other words, a financial regulation tax is considered to have a weaker effect because it is slightly more indirect than a tax directly imposed on foreign borrowing.

In the fixed exchange rate regime, welfare gain increases by 0.3903% with a joint tax in place compared to no macroprudential policy, which is higher than when a capital inflow tax (0.3902%) or a financial regulation tax (0.0012%) was imposed. However, in the floating exchange rate regime, welfare gain increases by 0.3484% with a joint tax compared to no tax, lower than when using only a capital control tax (0.3518%). The fact that χ is a parameter means that it brings an ad hoc leverage tax that can result in generating more or fewer welfare gains under a joint tax than under an optimal capital control tax. Therefore, a joint tax will not necessarily have a bigger welfare improvement than only a capital control tax.

Welfare is improved more when using a macroprudential policy than the benchmark model, which can be explained by the fact that macroprudential policy may solve diverse frictions. In our model, various frictions exist, including financial friction, nominal price rigidity, and terms of trade manipulation. Among them, we intend to focus on financial friction and conduct a welfare analysis by classifying them into a financial friction model and a no financial friction model, to verify whether macroprudential policy actually solves financial friction. The second model in Table 3 is the no financial friction model. We evaluate the welfare gain by adjusting the value indicating the level of financial friction in the Basic model, the elasticity of the external finance premium ς 0.61 to 0.3, which means that there's a situation with weakened financial friction. As a result, both in the fixed and floating exchange rate regimes, macroprudential policy diminished welfare gains by a large margin, while the financial regulation tax shows no welfare gains. In other words, in our model, apart from financial friction, other frictions, such as nominal rigidity and terms of trade manipulation, do not play a big role. Also, we can conclude that the welfare improvement with a macroprudential policy in the Basic model is the result of macroprudential policy eliminating financial friction.

6.3.2 Macroprudential Policy Implications

Table 4 compares the simulation results under eight alternative scenarios. In each case, we report the standard deviation and correlations with output and taxes of the main endogenous variables. The stabilization effect of financial policies on an economy can be measured by conditional volatilities of variables, such as output, money supply, bond issuance, consumption, the growth rate of the nominal exchange rate, and entrepreneurs' net worth to aggregate external shocks. Panel A of Table 4 shows that the standard deviations for these variables are higher under a fixed exchange rate regime than under a flexible exchange rate regime. We can infer that this is because a change in the nominal exchange rate absorbs any external shocks in a flexible exchange rate regime. In addition, due to the nominal exchange rate being pegged, this leads to real exchange rate changes and high volatility in the main variables by nominal price adjustments.

Many existing studies also show that under a fixed exchange rate regime, monetary authority's policy discretion decreases due to exchange rate defense. However, under a flexible exchange rate regime, with changes of nominal exchange rates playing a role of shock absorbers, negative impacts on output and investment decreases compared to a fixed exchange rate regime.

Also, we can see volatilities of money supply are much bigger in the fixed exchange rate system than in the floating exchange rate system. This suggests that there is less necessity for the government's intervention by issuing domestic currency to stabilize of exchange rates in the floating exchange rate system. In both exchange rate regimes, macroprudential policies, especially a capital inflow tax, lead to smaller volatilities in the overall macroeconomic variables, which shows that macroprudential policies are effective tools for economic stabilization. This stabilization effect of macroprudential policy is strong under the fixed exchange rate regime.

In terms of the relationship between the main variables and GDP, there is little difference except money supply, bond issuance, and the growth rate of the nominal exchange rate by exchange rate regime.

Under a fixed exchange rate regime, money supply (bond issuance) shows a negative (positive) correlation to GDP, but under a floating exchange rate regime, they show a positive (negative) correlation. The nominal exchange rate shows zero change in the fixed exchange rate regime, while showing a positive correlation in the floating exchange rate regime.

We can check these results with an example of an RMB appreciation shock. In the fixed exchange rate regime, exports decrease due to a decrease in the real exchange rate, despite no change in the nominal exchange rate, resulting in a fall in GDP. In this case, due to the real exchange rate appreciation, foreign borrowing increases largely and, in turn, the central bank absorbs foreign currency by increasing the domestic money supply to maintain the peg. Since inflation is low, there is less incentive for the PBoC to use a sterilization policy, which absorbs domestic currency by issuing bonds, and this leads money supply and bond issuance to show negative and positive correlations to GDP, respectively. However, in the floating exchange rate regime, high inflation pressure leads to the use of the sterilization policy by absorbing domestic currency, causing money supply and bond issuance to show positive and negative correlations to GDP, respectively, as opposed to the fixed exchange rate regime.

Panel C of Table 4 shows the relationship between three key variable changes, and the sign and size of financial taxes for the alternative scenarios. An optimal capital control allows the capital inflow tax to take on a countercyclical stance in the fixed exchange rate regime, and a pro-cyclical stance in the flexible exchange rate regime.

For example, in the case of an RMB appreciation shock under a fixed exchange rate regime, since the nominal exchange rate does not respond to external shocks, the real exchange rate changes by a large margin and, in turn, decreases exports and real GDP. At this point, the decrease in the real exchange rate raises entrepreneurs' foreign borrowing, expanding volatility in the financial sector. Consequently, in this case, a higher tax rate becomes the optimal policy and, therefore, the tax moves in a countercyclical direction to GDP.

In general, when the economy is in a boom, the government stabilizes the economy by imposing a tax, and during an economic downturn, a negative tax (subsidy) is needed. From this, it can be inferred that a tax takes in the pro-cyclical stance. However, we constructed a financial channel that works in the opposite direction to such traditional trade theories: the RMB appreciation shock in our model. In this mechanism, a tax is imposed on foreign borrowing and, therefore, while the economy deteriorates due to an RMB appreciation shock, foreign borrowing increases, making the risk premium rise and, as a result, the tax rate increases to control the financial accelerator mechanism. Like this, an optimal tax works in a countercyclical manner.

On the other hand, in the floating exchange rate regime, where the exchange rate plays a role in absorbing external shocks, the tax takes a procyclical stance to GDP. This shows that macroprudential policy generally acts to mitigate the procyclical characteristics of the financial accelerator mechanism or leverage. In this way, in an economic downturn, macroprudential policy can contribute to welfare gains by acting as a negative tax rate(subsidy) preventing any sudden stop caused by the financial accelerator mechanism.

As such, a macroprudential policy can mitigate economic volatility as a useful complementary instrument of monetary policy, and brings higher welfare regardless of exchange rate regime.

In the case of a joint tax, the capital inflow tax shows a similar correlation to GDP in both direction and size, compared to when used alone, but the financial regulation tax shows a counter-direction correlation to GDP, compared to when used alone. Since χ is a parameter, the financial regulation tax becomes an ad hoc leverage tax, a non-state contingent tax, and,

	Fixed exchange rate regime				**Flexible exchange rate regime**			
	Bench mark	Capital tax	Leverage tax	Joint tax	Bench mark	Capital tax	Leverage tax	Joint tax
Panel A : Volatility (%)								
Y	1.7162	0.1061	1.7258	0.1052	0.1247	0.1399	0.1246	0.1168
m	0.3380	0.0264	0.3392	0.0263	0.2440	0.0296	0.2440	0.0313
b	0.0083	0.0008	0.0084	0.0008	0.0090	0.0011	0.0090	0.0012
C	0.2082	0.0159	0.2089	0.0158	0.1064	0.0420	0.1064	0.0425
S	-	-	-	-	0.7446	0.1599	0.7446	0.1437
N	0.2006	0.0015	0.2019	0.0015	0.1407	0.0005	0.1407	0.0008
Panel B : Correlation with GDP								
Y	0.67	0.69	0.67	0.70	0.86	0.79	0.86	0.79
m	-0.22	-0.29	-0.22	-0.29	0.35	0.63	0.35	0.63
b	0.42	0.35	0.42	0.35	-0.20	-0.65	-0.20	-0.67
C	0.92	0.23	0.92	0.23	0.95	0.83	0.95	0.82
S	0.00	0.00	-0.02	0.00	0.31	0.45	0.31	0.45
N	0.52	0.42	0.52	0.40	0.59	0.25	0.59	0.31
Panel C : Correlation with τ^c or (τ^f)								
GDP		-0.35	(-0.27)	-0.36 (0.20)		0.42	(-0.34)	0.47 (-0.22)
D^*		-0.98	(-0.20)	-0.98 (0.79)		-0.97	(-0.18)	-0.96 (0.78)
Φ		-0.89	(0.97)	-0.89 (0.95)		-0.15	(0.79)	-0.09 (0.64)

Table 4. Model Moments.
Note: The correlations are sample means of statistics computed for each of 500 simulations. Each simulation consists of 500 periods.

therefore, when combined with an optimal capital control tax, the welfare can become higher or lower than when solely including the optimal capital tax. In our case, the result reveals that when using a joint tax, the capital inflow tax is so strong it can substitute for the effect of the financial regulation tax.

Tax and foreign debt have a negative correlation both in the fixed and floating exchange rate regimes, and this confirms that foreign borrowing decreases by imposing taxes, such as a capital inflow tax and a financial regulation tax. When imposing a capital flow tax, a very strong negative correlation appears at -0.98 in the fixed exchange rate regime and at -0.97 in the floating exchange rate regime, indicating that a capital flow tax is a very effective rule in both exchange rate regimes. Meanwhile, in the case of a joint tax, since the financial regulation tax turns to a positive correlation, we can infer that a capital flow tax plays a substitution role for the financial regulation tax.

In both exchange rate regimes, as the capital flow tax increases, the risk premium decreases, but the correlation in the fixed rate regime (-0.89) is bigger than in the floating exchange rate regime (-0.15), which means that raising taxes under a fixed rate regime leads to a sharp drop in the risk premium.

Meanwhile, the financial regulation tax shows a positive correlation with the risk premium. This is because despite the amount of foreign borrowing decreasing due to the tax rate increase, a tax on capital stock brings a decrease in entrepreneurs' net asset by a larger margin, which is one of decisive determinants of the risk premium.

6.3.3 Leverage Ratio Management

Our model confirms that macroprudential policy contributes to welfare gains both in the fixed and floating exchange rate regimes. This is because our model contains a financial accelerator mechanism that is triggered by foreign borrowing as a financial friction, and macroprudential policy plays a role in mitigating this mechanism and improves welfare.

After all, what is important is the ratio of foreign borrowing, and it is expected that macroprudential policy will increase welfare gains more in an economy with high foreign borrowing (an economy with a high steady state leverage ratio) due to a strong financial accelerator mechanism. To verify this, we conduct welfare evaluations in an economy with an entrepreneur low leverage ratio (2.4) and a high leverage ratio (2.6), along with the basic model of the steady state leverage ratio of 2.5.

Table 5 shows the welfare gains following macroprudential policy by alternative leverage ratios. In the economy with a high foreign borrowing ratio at the steady state (2.6), welfare gains with a macroprudential policy are bigger than in the basic model, regardless of exchange rate regime. On the other hand, in the economy with a low foreign borrowing ratio (2.4), the effects of a macroprudential policy are smaller than in the basic model. These results also show that, as in the basic model, macroprudential policy contributes more to welfare gains in a fixed exchange rate regime.

In addition, the difference in welfare gains between the two exchange rate regimes becomes larger as the leverage ratio goes up, which means that a higher leverage ratio requires a bigger nominal price adjustment to peg the exchange rate in a fixed exchange rate regime and this, in turn, shows that there existed bigger distortions in the fixed exchange rate regime. These results prove that the higher the steady state leverage ratio, the bigger the effect of macroprudential policy. It highlights the importance of managing the size of foreign borrowing at the steady state.

In conclusion, as the steady state foreign debt leverage ratio becomes high, the mitigation effect on the financial accelerator is bigger when using macroprudential policy, and the cost of nominal price adjustments also decreases, resulting in a further welfare improvement. This shows how important it is to manage the size of foreign borrowing at the steady state.

According to the traditional theory, capital controls were necessary for economic stabilization because they provided a degree of monetary independence under a fixed exchange rate regime, but capital controls were unnecessary and economic stabilization could be achieved through the monetary policy under a flexible exchange rate regime. However, recent studies have shown that surges in capital inflows can lead to economic instability, even in economies with a flexible exchange rate and an independent monetary policy. In a model with Chinese characteristics, our study shows that macroprudential policies, such as capital inflow taxes and financial regulations, can be beneficial to welfare improvement even when monetary policy is determined optimally under a flexible exchange rate system, as well as under a fixed exchange rate system.

Leverage ratio	**Fixed exchange rate regime**				**Flexible exchange rate regime**			
	Bench mark	Capital tax	Leverage tax	Joint tax	Bench mark	Capital tax	Leverage tax	Joint tax
2.4	−				0.0084			
	−	0.3010	0.0001	0.3006	−	0.2972	0.0000	0.2969
2.5	−				0.0481			
	−	0.3902	0.0012	0.3903	−	0.3518	0.0002	0.3484
2.6	−				0.0738			
	−	0.4371	0.0035	0.4401	−	0.3755	0.0005	0.3789

Table 5. Welfare Gains with Varying Steady State Leverage Ratio.

7. Conclusion

The main findings of our study may be summarized as follows. First, the financial channel has already become highly important in China's current situation. We were able to confirm that a change in the value of the domestic currency causes a change in foreign borrowing and, in turn, the risk-taking channel or the balance sheet effect, which influence investment and output, operates well by constructing a model with both a trade channel and a financial channel. A change in the exchange rate can bring opposite effects on the economy through the trade channel and the financial channel, and as the financial channel in China is growing in importance over time, this suggests that the financial channel will be able to offset the effects of the trade channel.

Second, major macroeconomic variables are more stable under a floating exchange rate system than under a fixed exchange rate system. These results are consistent with many existing studies that show that the nominal exchange rate has a function in absorbing external shocks. As a result, welfare is higher under a floating exchange rate system than under a fixed exchange rate system, which suggests that there are policy implications concerning the choice of exchange rate regime in China.

Lastly, this study confirms that macroprudential policies are important in the process of gradually opening China's capital markets. In our model, foreign debt is an important driving force for an increase in investment and output, but, at the same time, it can generate a drastic impact on the domestic economy thorough the financial accelerator mechanism. The fact that welfare can be increased by imposing a tax on capital flows and restrictions on the leverage ratio suggests that the management of foreign debts can be used as an important tool to stabilize the domestic economy and financial system, as well as traditional monetary policy, during the process of opening China's financial markets in the future.[37]

The importance and influence of the financial channel through exchange rate change is increasingly becoming bigger. Therefore, to more accurately analyze the impact of external shocks on the domestic economy, we should consider the trade channel and the financial channel together. Using a model that contains both channels, we can confirm that macroeconomic variables are more stable under a floating exchange rate system than under a fixed exchange rate system, which also has important policy implications concerning the direction of exchange rate regime reforms in China.

Rapid capital inflows into emerging markets after the global financial crisis and recent

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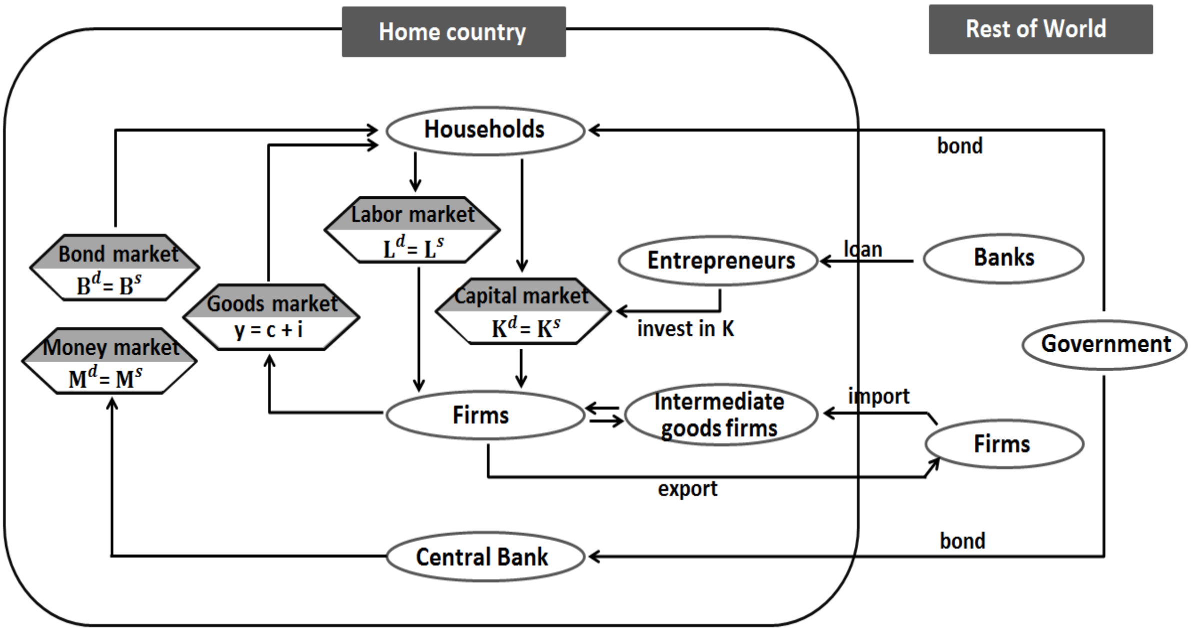
37 Gopinath (2017) also points out that policies that encourage a switch away from foreign currency denominated debts should continue to be part of the capital flow management tool kit.

rapid capital outflows from emerging markets during the process of monetary policy normalization by advanced countries both demonstrate that external shocks can bring adverse effects to the economic fundamentals of emerging countries through the financial channel. In the future, as China expands the range of exchange rate volatility and strengthens the function of the market in determining its exchange rates in the course of opening its financial markets, the volatility of capital flows through the financial channel is likely to be amplified. Therefore, it is necessary to figure out how to mitigate the drastic impact on domestic financial markets through the financial accelerator mechanism by properly utilizing macroprudential policy. For this foreign debt management, our results suggest important policy implications.

We plan to consider many future extensions of our model. For an evaluation of macroprudential instruments, we could introduce alternative assumptions into the model, such as commitment and discretion (as in Devereux et al., 2018 and in Devereux and Yu, 2018). It would be also interesting to explore alternative Chinese characteristics, such as a two-sector model (as in Chang et al., 2017 and in Liu et al., 2018).

China's influence on Korea is growing in importance, as both strong trade connections and growing financial linkages are being developed. Changes in the yuan value, therefore, are likely to directly affect the Korean economy more than before, and so further studies in such regard will be required in the future.

Appendix A: Model Structure (Small Open Economy Model)



Appendix B: Summary of Equilibrium Conditions

This appendix provides a detailed description of the stationary equilibrium conditions used in this paper. We focus on a stationary equilibrium with balanced growth. On a balanced growth path, output, consumption, investment, capital, net worth, intermediate inputs, real money balance, real domestic debt, real foreign asset holdings, real foreign borrowings, the trade balance, the current account balance, and real wages all grow at a constant rate. Aggregate productivity Z_t grows at the constant rate λ_z. Hence, we make the stationary transformations to obtain balanced growth:

$$\tilde{Y}_t = \frac{Y_t}{Z_t},\ \ \tilde{C}_t = \frac{C_t}{Z_t},\ \ \tilde{I}_t = \frac{I_t}{Z_t},\ \ \tilde{K}_t = \frac{K_t}{Z_{t-1}},\ \ \tilde{N}_t = \frac{N_t}{Z_t},\ \ \tilde{\Gamma}_{ht} = \frac{\Gamma_{ht}}{Z_t},\ \ \tilde{\Gamma}_{ft} = \frac{\Gamma_{ft}}{Z_t},$$

$$\tilde{m}_t = \frac{M_t}{P_t Z_t},\ \ \tilde{b}_t = \frac{B_t}{P_t Z_t},\ \ \tilde{b}_t^* = \frac{B_t^*}{P_t^* Z_t},\ \ \tilde{b}_{pt}^* = \frac{B_{pt}^*}{P_t^* Z_t},\ \ \tilde{b}_{gt}^* = \frac{B_{gt}^*}{P_t^* Z_t},\ \ \tilde{d}_t^* = \frac{D_t^*}{P_t^* Z_t},$$

$$\tilde{X}_t = \frac{X_t}{Z_t},\ \ \tilde{X}_t^* = \frac{X_t^*}{Z_t},\ \ \widetilde{ta}_t = \frac{ta_t}{Z_t},\ \ \widetilde{ca}_t = \frac{ca_t}{Z_t},\ \ \tilde{w}_t = \frac{w_t}{Z_t},\ \ \tilde{q}_t^k = \frac{\tilde{\Lambda}_t^k}{\tilde{\Lambda}_t},\ \ \tilde{\Lambda}_t = \Lambda_t Z_t$$

We summarize the non-linear equilibrium conditions below.

(Households)

$$\tilde{\Lambda}_t = \frac{1}{\tilde{C}_t} \tag{A1}$$

$$\frac{\Phi_m}{\widetilde{m}_t\widetilde{\Lambda}_t} = 1 - E_t\frac{\beta\widetilde{\Lambda}_{t+1}}{\widetilde{\Lambda}_t\lambda_z}\frac{1}{\pi_{t+1}} \tag{A2}$$

$$\widetilde{w}_t = \frac{\Phi_l L_t^{\eta}}{\widetilde{\Lambda}_t} \tag{A3}$$

$$E_t\frac{\beta\widetilde{\Lambda}_{t+1}}{\widetilde{\Lambda}_t\lambda_z} r_t^k \frac{1}{\pi_{t+1}} = 1 \tag{A4}$$

$$E_t\frac{\beta\widetilde{\Lambda}_{t+1}}{\widetilde{\Lambda}_t\lambda_z}\frac{R_t}{\pi_{t+1}} = 1 + \frac{\Omega_b}{2}\left(\psi_t - \overline{\psi}\right)^2 + \Omega_b(\psi_t - \overline{\psi})(1-\psi_t) \tag{A5}$$

$$\Omega_b\left(\psi_t - \overline{\psi}\right) = E_t\frac{\beta\widetilde{\Lambda}_{t+1}}{\widetilde{\Lambda}_t\lambda_z}\frac{1}{\pi_{t+1}}\left[R_t - R_t^*\frac{e_{t+1}}{e_t}\right] \tag{A6}$$

$$\psi_t = \frac{\tilde{b}_t}{\tilde{b}_t + q_t\tilde{b}_{pt}^*} \tag{A7}$$

$$\widetilde{K}_{t+1} = \tilde{I}_t + (1-\delta)\frac{\widetilde{K}_t}{\lambda_z} - \frac{\Omega_k}{2}\left(\frac{\tilde{I}_t}{\widetilde{K}_t}\lambda_z - (\lambda_z - 1 + \delta)\right)^2\frac{\widetilde{K}_t}{\lambda_z} \tag{A8}$$

$$q_{Kt} = \left[1 - \Omega_k\left(\frac{\tilde{I}_t}{\widetilde{K}_t}\lambda_z - (\lambda_z - 1 + \delta)\right)\right]^{-1}, \quad q_{Kt} \equiv \frac{Q_{Kt}}{P_t}, \text{ the real price of capital} \tag{A9}$$

(Entrepreneurs)

$$\widetilde{N}_t + q_t\tilde{d}_t^* = q_{Kt}\widetilde{K}_{t+1} \tag{A10}$$

$$E_t\frac{r_{t+1}^k}{S_{et+1}} = R_{et}^*\Phi_{t+1} \tag{A11}$$

$$\Phi_{t+1} = \left(\frac{q_{Kt}\widetilde{K}_{t+1}}{\widetilde{N}_t}\right)^{\varsigma} \tag{A12}$$

$$\widetilde{N}_t = \omega\left(\frac{r_t^k q_{Kt-1}\widetilde{K}_t}{\pi_t\lambda_z} - \frac{R_{et-1}^*\Phi_t q_t\tilde{d}_{t-1}^*}{\pi_t^*\lambda_z}\right) \tag{A13}$$

$$r_{t+1}^k = \frac{r_{t+1}}{q_{Kt}}\pi_{t+1} + \frac{q_{Kt+1}}{q_{Kt}}\pi_{t+1} \times$$
$$\left[(1-\delta) + \Omega_k\left(\frac{\tilde{I}_{t+1}}{\widetilde{K}_{t+1}}\lambda_z - (\lambda_z - 1 + \delta)\right)\frac{\tilde{I}_{t+1}}{\widetilde{K}_{t+1}}\lambda_z - \frac{\Omega_k}{2}\left(\frac{\tilde{I}_{t+1}}{\widetilde{K}_{t+1}}\lambda_z - (\lambda_z - 1 + \delta)\right)^2\right] \tag{A14}$$

(Final Goods Firms)

$$\tilde{Y}_t = \tilde{\Gamma}_t^{\phi} L_t^{(1-\alpha)(1-\phi)}\left(\frac{\widetilde{K}_t}{\lambda_z}\right)^{\alpha(1-\phi)} \tag{A15}$$

$$mc_t = \tilde{\phi}\tilde{\alpha} q_{mt}^{\phi}\widetilde{w}_t^{(1-\alpha)(1-\phi)} r_t^{\alpha(1-\phi)} \tag{A16}$$

$$\widetilde{w}_t = (1-\alpha)(1-\phi)\ \frac{mc_t\tilde{Y}_t}{L_t} \tag{A17}$$

$$r_t = \alpha(1-\phi)\ \frac{mc_t\tilde{Y}_t}{\widetilde{K}_t}\lambda_z \tag{A18}$$

$$\frac{\theta_p - 1}{\theta_p} = mc_t - \frac{\Omega_p}{\theta_p}\frac{\tilde{C}_t}{\tilde{Y}_t}\left[\left(\frac{\pi_t}{\pi} - 1\right)\frac{\pi_t}{\pi} - \beta E_t\left(\frac{\pi_{t+1}}{\pi} - 1\right)\frac{\pi_{t+1}}{\pi}\right] \tag{A19}$$

(Intermediate Goods Firms)

$$\tilde{\Gamma}_t = \tilde{\Gamma}_{ht}^{\lambda_\Gamma}\tilde{\Gamma}_{ft}^{1-\lambda_\Gamma} \tag{A20}$$

$$q_t = \frac{(1-\lambda_\Gamma)}{\lambda_\Gamma}\frac{\tilde{\Gamma}_{ht}}{\tilde{\Gamma}_{ft}} \tag{A21}$$

$$q_{mt} = \tilde{\lambda}_\Gamma q_t^{1-\lambda_\Gamma} \tag{A22}$$

$$\frac{q_t}{q_{t-1}} = S_{et}\frac{\pi_t^*}{\pi_t}\frac{\xi_t}{\xi_{t-1}} \tag{A23}$$

(International Sector)

$$\widetilde{tb}_t = \tilde{X}_t - \ q_t\tilde{\Gamma}_{ft} \tag{A24}$$

$$\tilde{X}_t = q_t^{\theta_x}\tilde{X}_t^* \tag{A25}$$

$$\widetilde{ca}_t = \widetilde{tb}_t + \frac{q_t}{\pi_t^*\lambda_z}\left[(R_{t-1}^* - 1)\tilde{b}_{t-1}^* - (R_{et-1}^*\Phi_t - 1)\tilde{d}_{t-1}^*\right] \tag{A26}$$

$$\widetilde{ca}_t = q_t\left[\left(\tilde{b}_t^* - \frac{\tilde{b}_{t-1}^*}{\pi_t^*\lambda_z}\right) - \left(\tilde{d}_t^* - \frac{\tilde{d}_{t-1}^*}{\pi_t^*\lambda_z}\right)\right] \tag{A27}$$

(Central Bank)

$$q_t\left(\tilde{b}_{gt}^* - \frac{R_{t-1}^*\tilde{b}_{gt-1}^*}{\pi_t^*\lambda_z}\right) \leq \tilde{b}_t - \frac{R_{t-1}\tilde{b}_{t-1}}{\pi_t\lambda_z} + \widetilde{m}_t - \frac{\widetilde{m}_{t-1}}{\pi_t\lambda_z} \tag{A28}$$

(Market Clearing)

$$\tilde{Y}_t = \tilde{C}_t + \tilde{I}_t + \tilde{\Gamma}_{ht} + \tilde{X}_t + \frac{\Omega_p}{2}\left(\frac{\pi_t}{\pi} - 1\right)^2\tilde{C}_t + \frac{\Omega_b}{2}\left(\psi_t - \overline{\psi}\right)^2\left(\tilde{b}_t + q_t\tilde{b}_{pt}^*\right) \tag{A29}$$

$$\tilde{b}_t^* = \tilde{b}_{pt}^* + \tilde{b}_{gt}^* \tag{A30}$$

$$G\widetilde{D}P_t = \tilde{C}_t + \tilde{I}_t + \tilde{X}_t - q_t\tilde{\Gamma}_{ft} \tag{A31}$$

$$\frac{\widetilde{m}_t}{\widetilde{m}_{t-1}} = \frac{\mu_t}{\pi_t \lambda_z} \tag{A32}$$

(Monetary Policy)

$$S_{et} = \overline{S}_e \tag{A33}$$

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\psi_r} \left[\left(\frac{\pi_t}{\pi}\right)^{\psi_p} \left(\frac{G\widetilde{D}P_t}{G\widetilde{D}P}\right)^{\psi_y}\right]^{(1-\psi_r)} \tag{A34}$$

(Shock Process)

$$ln\xi_t = \left(1-\rho_\xi\right) ln\xi + \rho_\xi ln\xi_{t-1} + \sigma_\xi \varepsilon_{\xi_t} \tag{A35}$$

$$lnR_t^* = (1-\rho_r) lnR^* + \rho_r lnR_{t-1}^* + \sigma_r \varepsilon_{r_t} \tag{A36}$$

$$ln\widetilde{X}_t^* = (1-\rho_x) ln\widetilde{X}^* + \rho_x ln\widetilde{X}_{t-1}^* + \sigma_x \varepsilon_{x_t} \tag{A37}$$

Appendix C: The Steady-State Equilibrium Conditions

This appendix provides the steady-state equilibrium that is solved recursively with the following steps.

(1) Use the steady-state pricing decision (A19) to have the real marginal cost $mc = \frac{\theta_p - 1}{\theta_p} = 0.9$ (steady-state net markup is 11%).

(2) The import-GDP ratio is 20% and the export-GDP ratio is 23% in our sample. GDP is related to gross output through

$$GDP = Y - \Gamma_h - q\Gamma_f = (1-\phi mc)Y$$

Imports are related to gross output through $IM = q\Gamma_f = (1-\lambda_\Gamma) q_m \Gamma = (1-\lambda_\Gamma)\, \phi mcY$. Hence, we obtain

$$0.2 = \frac{IM}{GDP} = \frac{(1-\lambda_\Gamma)\, \phi mc}{1-\phi mc}$$

which gives a steady-state value of λ_Γ, 0.7556, given the values of $\phi = 0.5$ and $mc = 0.9$.

(3) The export-GDP ratio is 23%. If we obtain a solution for Y, then we can get a solution for X given by

$$X = 0.23GDP = 0.23(1-\phi mc)Y$$

(4) Target steady-state employment of L is 40%, which means representative households spend 40% of their total time endowment on working. From the equation (A4) and (A14), the steady-

state real return of capital $r^k = \pi\lambda_z/\beta$ and the real rental rate on capital $r = q_K(r^k - \pi(1-\delta))/\pi$. Noting that $q_K = 1$ at the steady-state, we can obtain r. Using the optimal capital demand condition $r = \alpha(1-\phi)mcY\lambda_z/K$, we can get K. The steady-state real exchange rate is $q = 1$, which gives restrictions on X^* through the export demand function $X = q^\theta X^*$ for given X. We can then obtain Y using the production function:

$$Y = \Gamma^\phi L^{(1-\alpha)(1-\phi)} \left(\frac{K}{\lambda_z}\right)^{\alpha(1-\phi)} = \left(\frac{\phi mcY}{\tilde{\lambda}_\Gamma q^{1-\lambda_\Gamma}}\right)^\phi L^{(1-\alpha)(1-\phi)} \left(\frac{\alpha(1-\phi)mcY}{r}\right)^{\alpha(1-\phi)}$$

where $q_m\Gamma = \phi\, mcY$ and $q_m = \tilde{\lambda}_\Gamma q^{1-\lambda_\Gamma}$ from the cost-minimization condition.

(5) Since there are investment adjustment costs at the steady-state, equation (A8) implies that

$$I = (\lambda_z - 1 + \delta)K/\lambda_z$$

(6) Using two equations (A10) and (A13) to eliminate net worth N, and through the equation (A11), we can obtain

$$\Phi = \frac{\lambda_z\pi}{\omega R_e^*}$$

(7) From equation (A12), we can get net worth.

$$N = \frac{q_K K}{\Phi^{\frac{1}{\varsigma}}}$$

(8) From equation (A10), we can get the foreign debt amount.

$$d^* = \frac{q_K K - N}{q}$$

(9) Given Y, we have $GDP = (1-\phi mc)Y$, $IM = 0.2GDP$, and $X = 0.23GDP$. At the steady state $q = 1$, we can get $X^* = X/q^\theta = X$.

(10) Net exports are $tb = X - IM = 0.03GDP$. Hence, consumption is $C = GDP - tb - I$.

(11) Given Y, L and K, real wages and the real capital rental rate are

$$w = (1-\alpha)(1-\phi)mcY/L$$

$$r = \alpha(1-\phi)mcY\lambda_z/K$$

The labor supply equation pins down the value of the disutility weight parameter for labor $\Phi_l = \frac{w}{CL^\eta}$.

(12) From the equation $\Gamma_h = \lambda_\Gamma\phi mcY$, and $\Gamma_f = (1-\lambda_\Gamma)\phi mcY/q$, the composite intermediate input is $\Gamma = \Gamma_h^{\lambda_\Gamma}\Gamma_f^{(1-\lambda_\Gamma)}$.

(13) The UIP condition at the steady-state implies that $R = R^* S_e$ and $\pi = \pi^* S_e$.

(14) The money growth rate is $\mu = \pi\lambda_z$.

(15) Given R and C, we can have the real money balance $m = \Phi_m CR/(R-1)$.

(16) Using two equations of the current account balance (A26) and (A27), we can obtain

$$tb = q\left[b^*\left(1-\frac{R^*}{\pi^*\lambda_z}\right) - d^*\left(1-\frac{R_e^*\Phi}{\pi^*\lambda_z}\right)\right] \quad \text{(a1)}$$

(17) Given $q = 1$ and $tb = 0.03GDP$, we can solve for b. The portfolio share equation (A7) implies that

$$qb_p^*\left(1-\frac{R^*}{\pi^*\lambda_z}\right) = \frac{1-\psi}{\psi} b\left(1-\frac{R^*}{\pi^*\lambda_z}\right)$$

The central bank budget constraint (A28) implies that

$$qb_g^*\left(1-\frac{R^*}{\pi^*\lambda_z}\right) = b\left(1-\frac{R}{\pi\lambda_z}\right) + m\left(1-\frac{1}{\mu}\right)$$

From these two equations, we can obtain

$$qb^*\left(1-\frac{R^*}{\pi^*\lambda_z}\right) = \frac{1-\psi}{\psi} b\left(1-\frac{R^*}{\pi^*\lambda_z}\right) + b\left(1-\frac{R}{\pi\lambda_z}\right) + m\left(1-\frac{1}{\mu}\right) \quad \text{(a2)}$$

Noting that $\frac{R}{\pi\lambda_z} = \frac{R^*}{\pi^*\lambda_z}$ and equation (a1), we get

$$tb = b\frac{1}{\psi}\left(1-\frac{R}{\pi\lambda_z}\right) - qd^*\left(1-\frac{R_e^*\Phi}{\pi\lambda_z}\right) + m\left(1-\frac{1}{\mu}\right)$$

Because m has been solved, above, this relationship gives the solution for b

$$b = \frac{\psi\left[tb + qd^*\left(1-\frac{R_e^*\Phi}{\pi\lambda_z}\right) - m\left(1-\frac{1}{\mu}\right)\right]}{\left(1-\frac{R}{\pi\lambda_z}\right)}$$

(18) From the portfolio share target of $\psi = 0.9$ and b, we can solve for b_p^*

$$b_p^* = \frac{1-\psi}{q\psi} b$$

(19) Given tb, we can obtain b^* from the equation (a2), and then we have b_g^*.

$$b_g^* = b^* - b_p^*$$

(20) From the current account balance equation (A26) and (a1), we have ca.

$$ca = tb + \frac{qb^*}{\pi^*\lambda_z}(R^*-1) - \frac{qd^*}{\pi^*\lambda_z}(R_e^*\Phi - 1) = q(b^*-d^*)\left(1-\frac{1}{\pi^*\lambda_z}\right)$$

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