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Would Currency Appreciation Reduce the Trade Surplus?

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We build a small open economy model with the financial accelerator mechanism to investigate how currency appreciation affects trade imbalances. Contrary to speculation that currency appreciation significantly reduces trade surpluses, our analysis suggests that currency appreciation would lead to a further trade surplus increase and a reduction in output for countries holding a large amount of foreign assets and importing a high proportion of non-consumption goods, such as China.

Key Words: Currency appreciation; Trade surplus; Financial accelerator.
JEL Classification Numbers: F3, F4.

1. INTRODUCTION

It seems to be a natural result that currency appreciation reduces trade surpluses while currency depreciation increases them by altering the relative prices of domestic and foreign products. A simplified model incorporating only the price and quantity of import and export demands would generate this result under the well-known Marshall-Lerner condition, which requires that the absolute sum of long-term demand elasticities of imports and exports exceed unity. Applying this perspective to the global trade imbalance problem, it is unsurprising that many consider the appreciation

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of RMB to be an essential part of the solution,[1] and this belief heavily influences United States foreign policy towards China.[2]

However, whether currency appreciation would necessarily reduce the trade surplus remains debatable. Quite a few macroeconomic forces lead in opposite directions beyond the simple elasticity story of import and export demands. For example, Qiao (2007) borrowed Mckinnon (1990) analysis framework and argued that, for a creditor country, currency appreciation would depress consumption and investment, and then cause a drop in its domestic absorption and ambiguous net impacts on its trade balance, even though exports would also fall. Similarly, Mckinnon (2006) maintained that for creditors such as the East Asian economies, a sharp, discrete appreciation against the dollar would have an ambiguous effect on trade surpluses because of the repercussions on income and spending.

These existing studies rely on models without quantification. In this paper, we build a dynamic stochastic general equilibrium (DSGE) model in a small open economy to directly answer the question of whether currency appreciation could reduce trade surplus and apply it to the Chinese economy. The model is based on Gertler et al. (2007), which introduced the Bernanke et al. (1999) financial accelerator into the open economy context. We also take into account the special characteristics of China, including the colossal importance of the processing trade and, consequently, the disproportionally small share of consumer goods within China's combination of imports, as well as its huge amount of foreign assets.

Our quantitative results suggest that, instead of rebalancing global trade, RMB appreciation would be more likely to create a greater trade surplus for China, yet China would suffer from a considerable drop in output. The former suggests that RMB appreciation would not help the US to solve its current deficit problem, while the latter suggests that it would not be helpful for China either.

By performing such quantitative exercises, we have been able to single out the most important forces that shape the way that currency appreciation affects China's trade surplus and macro-economy: 1) Because a large portion of Chinese imports are intermediate goods (for the processing trade) and capital goods, when RMB appreciation depresses exports it also heavily depresses imports. 2) Because of the large amount of foreign assets that China now holds, RMB appreciation would seriously dampen China's

[1]There is extensive literature on this issue, for example, Bergsten and Williamson (2004), Mussa (2005), Goldstein and Lardy (2006), Cline and Williamson (2008), and Cline and Kim (2010). More details can be found in two edited books by Bergsten and Williamson (2004) and Goldstein and Lardy (2008). There are also other studies, such as Corden (2009) and Knight and Wang (2009), which agree that the exchange rate could be part of the reason but put much less emphasis on it.

[2]Please refer to Bergsten and Wiliamson (2004) and Bergsten (2010) for more details, and there is a short summary in McKinnon (2007).

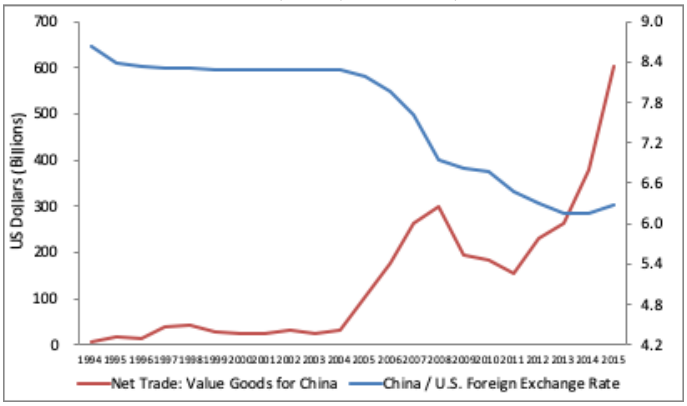
investments by tightening credit constraints after amplification through the financial accelerator effect, which would further intensify the fall in imports. Meanwhile, we have found that some other candidate mechanisms proposed in Qiao (2007) and McKinnon (2007) are not quantitatively important. For example, the fall in output would not generate a large slump in the import of consumer goods; instead, the price effect dominates, and the import of consumer goods would actually increase significantly. Similarly, the negative wealth effect on consumption after currency appreciation would also be minor.

Our results are consistent with the established empirical findings in the literature. Cheung et al. (2009) and Cheung et al. (2012) present various facts and econometric analysis, and find that in the case of currency depreciation, China's imports unexpectedly increase while exports do increase as expected. Here we present in Figure 1 the historical records of the RMB exchange rate and China's trade surplus as direct supporting evidence. Before 2005, the RMB exchange rate and trade surplus remained relatively constant for over a decade, even though China was going through a fundamental economic transition period with rapid growth. Not until 2005, the year that China started RMB appreciation, did the trade surplus begin to mount. And, for years after 2005, the negative correlation between the two series is evident. Anderson (2008) scrutinized the sudden rise in the trade surplus after 2005 and noted that "the main shock was a dramatic fall in import growth," which is exactly the prediction of our model. It is also worth noting that China joined the World Trade Organization (WTO) in 2001, which fundamentally changed China's economic structure and boosted both imports and exports dramatically; however, entry into WTO did not translate into a greater trade surplus, at least not until 2005.

Our results are informative for policymakers shaping and negotiating foreign policies. Our results suggest that RMB appreciation does not help solve the global imbalance problem. It is thus worthwhile for countries to discuss, coordinate, and negotiate a more reasonable plan to achieve a global trade balance and sustainable growth.

A closely related paper is Ahmed (2009) in which the author estimates a static structural elasticity model of multiple import and export goods, including processing trade goods. The results suggest that China's real appreciation against other emerging Asian trading partners, the major source of China's intermediate goods, would impose a positive but insignificant effect on processing exports, while in all other situations, China's real appreciation would always lead to less exports. Overall, this research suggests that China's trade surplus would decline after a real appreciation. We share the opinion that the import of intermediate goods matters, but the missing component of this paper is the investment channel, as the sheer size of China's foreign assets could make a difference. Therefore, it is not

FIG. 1. Net trade of China (goods) vs. RMB / US dollar exchange rate



Note: The left vertical axis denotes net trade and the right vertical axis denotes the China/US foreign exchange rate. (Data source: Federal Reserve Economic Data)

surprising that we have reached opposite conclusions. Devereux and Genberg (2007) built a two-region open economy model to map US—China trade. They found that Chinese currency appreciation might not generate a fall in current accounts, and they emphasized the role of intermediate goods in generating such a result. While we agree with the mechanism, the simulation based on our model suggests that the import of intermediate goods alone would not be quantitatively strong enough to generate such a pattern, and inclusion of the financial accelerator mechanism would also be necessary. On the other hand, Liao et al. (2012) set up a dynamic general equilibrium model with vertical trade to consider the effect of the appreciation of other Asian currencies on China's exports, and they found that the link is not necessarily negative because of vertical trade. Thorbecke and Smith (2008) also considered different effects on processed exports and ordinary goods, and they found that RMB appreciation would not decrease ordinary exports much more than processed exports. Garcia-Herrero and Koivu (2007) argued that RMB appreciation would cause an increase in imports from Germany but a fall from Southeast Asian countries, which also reflects the fact that the processing trade could affect how currency appreciation changes a trade surplus. Zhang and Sato (2012) investigated the problem using a structural Vector AutoRegression (VAR) approach and concluded that the dynamic effect of the exchange rate on the trade balance is "very limited" and China's trade surplus is mainly the result of a sustained comparative advantage.

In summary, compared with the existing research, our findings suggest that both the impacts of intermediate goods imports and the investment

channel are quantitatively important, and thus our analysis provides some new insight into the problem.

Our paper is based on the Bernanke et al. (1999)'s financial accelerator model. The financial accelerator model demonstrates that due to asymmetric information in credit markets, the borrowers' balance sheet conditions play a significant role in the business cycle through the channel of external financing cost. The procyclical nature of net worth set a wedge between the cost of external financing and internal funds. In particular, as emphasized by Krugman (1999), Aghion et al. (2001), and Aoki et al. (2016), emerging domestic residents borrow from the international market in foreign currency, while their incomes are denominated domestic currency. In this scenario, exchange rate devaluation may exacerbate net worth effects and change the real net worth. Accordingly, through the balance sheet channel, a country could decrease its investment spending, pushing down aggregate demand, output, and employment. A wealth of literature, such as Devereux and Lane (2003), Cespedes et al. (2004), Devereux et al. (2006), and Unsal (2013), have also added the financial accelerator effect into small open economy model analyses.[3] These analyses focus mainly on the choice of exchange rate regime or monetary policy. While our analysis similarly emphasizes the role played by the exchange rate policy and share many concerns with Cespedes et al. (2004) in this respect, we have incorporated for the first time several important features intrinsic to China's reality to analyze the influence exerted by currency appreciation on trade surplus adjustment.

The paper proceeds as follows. Section 2 introduces background information, and Section 3 presents the basic model. Section 4 is devoted to the quantitative exercises for China and discussing the implications of the results. In Section 5, we draw our conclusions.

2. BACKGROUND INFORMATION

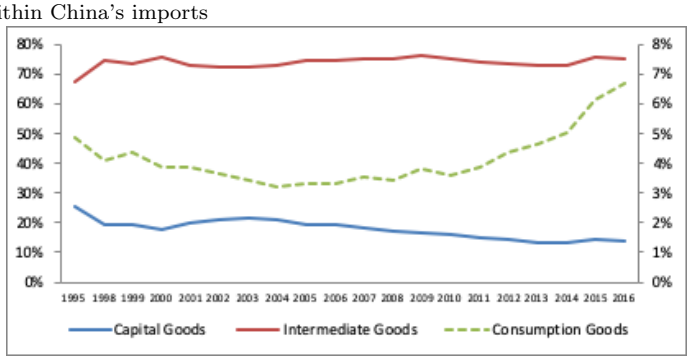
2.1. China's intermediate and capital goods imports

China, along with other Asian countries such as Japan, South Korea, and Malaysia, all actively participate in the global production chain, mainly through their involvement in the processing trade. Koopman et al. (2011) estimated that China's share of domestic content in its manufactured exports was only about 50% before its entry into the WTO and about 60% afterwards. Therefore, it is not surprising that the empirical results of Xing (2012) suggested that the processing trade explained 100% of China's trade surplus from 1993 to 2008.

[3]Faia (2007) developed a two-country open economy of the financial accelerator model.

Figure 2 illustrates the relative proportion of intermediate goods, capital goods, and consumption goods within China's total imports[4]. The proportion of consumption goods has generally remained between 4—5% and rose to no more than 7% in 2016, while the proportions of intermediate goods and capital goods have remained about 75% and 20%, respectively. Figure 3 shows that the largest component of imported intermediate goods-parts and accessories and industrial supplies-accounts for more than 60% of China's total imports. In sum, intermediate goods are the largest component of China's imports, and the most important component of intermediate goods is parts and accessories and industrial supplies that serve for investment and manufacturing new products.

FIG. 2. The proportions of intermediate goods, capital goods, and consumption goods within China's imports



Note: The left vertical axis denotes the proportion of intermediate goods and capital goods, and the right vertical axis denotes the proportion of consumer goods. Data for 1996 and 1997 were not reported by the original source. (Data source: UN Comtrade Database)

Different types of goods play diverse roles in an economy, and the ways they respond to exchange rate fluctuations can vary significantly, as well. RMB appreciation may lower the price of foreign consumption goods and increase both domestic purchasing power and demand. However, because intermediate goods and capital goods are mainly imported for further production, RMB appreciation would lead to a drop in their import and a drop in output, as well.

2.2. The foreign assets of China

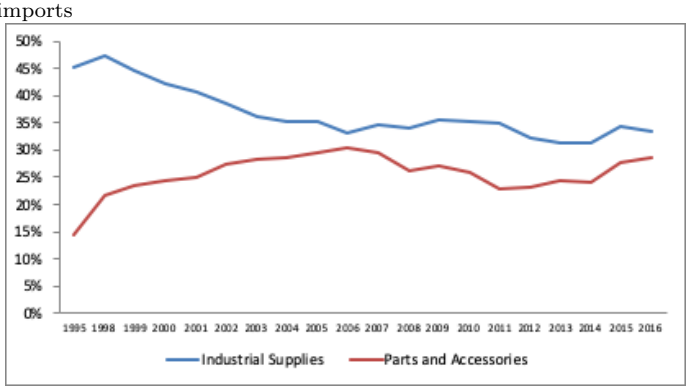
Even though China has not fully liberalized its capital account, it has accumulated a huge amount of foreign assets in the past decades. According

[4]We follow the United Nation's classification by Broad Economic Categories and divide tradable goods into intermediate goods, capital goods, and consumption goods.

to China's State Administration of Foreign Exchange (SAFE)[5], China's total foreign assets reached 6466.6 billion US dollars while its net foreign assets were 1800.5 billion US dollars at the end of 2016.

Among China's foreign assets, the lion's share goes to foreign reserves governed by the SAFE. After the Asian financial crisis, East Asian countries' and especially China's continuing trade surpluses and sustained flows of foreign direct investment (FDI) generated a very high proportion of dollars among their gross assets. Figure 4 presents China's total reserves excluding gold, which were quickly accumulated after entering the WTO in 2001 and peaked at about 4,000 billion dollars in 2014. China suffers from the "conflict virtue" syndrome, as named by Mckinnon (2005), because it cannot lend in its own currency and thus has gradually accumulated a currency mismatch.

FIG. 3. The proportion of parts and accessories and industrial supplies within China's imports



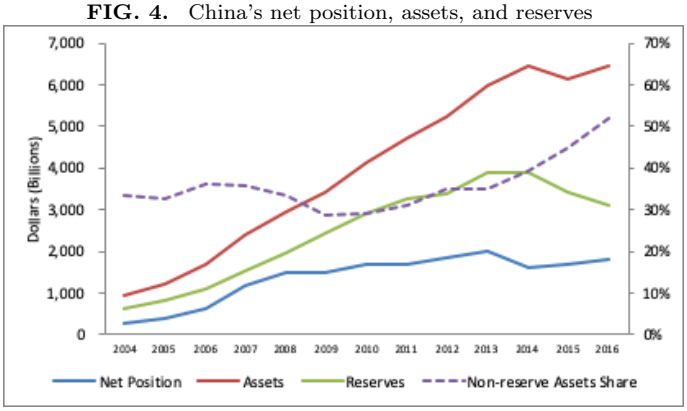
(Data source: UN Comtrade Database)

However, it is worth noting that the non-reserve part of China's foreign assets has risen dramatically in past years as China gradually liberalized its financial account and integrated into the global financial market (He and Luk, 2016). In fact, the share of the non-reserve part has risen to over 50%; that is, it is larger than official reserves. Outward FDI in 2016 was 25 times the size that it was at the end of 2004, and quite a few Chinese firms, most notably Alibaba, have launched initial public offerings (IPOs) in foreign markets. Entrepreneurs in China are no longer constrained to the domestic financial market but also borrow in the international market and in foreign currencies. As a result, the credit constraints on Chinese enterprises are also heavily influenced by exchange rates. If China gradually increased the convertibility of its capital account and completed the process

[5]Data are available on the SAFE's official website: http://www.safe.gov.cn/wps/portal/sy/tjsj_tzctb.

of financial liberalization in a decade, as suggested in official endorsements (He et al., 2012), this influence would be even greater.

FIG. 4. China's net position, assets, and reserves



(Data source: the SAFE)

To better take into consideration this reality of the Chinese market, in our model we assume that 1) while entrepreneurs may hold a certain amount of foreign currency assets, domestic banks remain their main source of finance; and 2) asymmetric information exists between entrepreneurs and financial intermediates. Thus, the appreciation of currency would affect the nominal value of foreign currency assets, bring a negative influence to the balance sheet, and further raise the cost of external financing through the financial accelerator mechanism.

3. THE MODEL

As mentioned, our framework is based on Gertler et al. (2007). The model includes four sectors-household, production, financial intermediaries, and government. Households supply labor, consume goods, and save. Production sector consists of entrepreneurs, capital producers, and retailers. Financial intermediaries borrow money from households and lend to entrepreneurs.

3.1. Household

The representative household's expected lifetime utility function is:

$$E_0 \sum_{t=0}^{\infty} \beta' U(C_t, L_t) \tag{1}$$

where $\beta \in (0,1)$ is the subjective discount factor. E_t denotes the mathematical expectation conditional on information available in the period t. C_t is the aggregate consumption in period t, and L_t is the labor supply. The single-period utility function is:

$$U(C_t, L_t) = \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{\xi}{\nu} L_t^{\nu} \qquad (\sigma, \nu, \xi > 0) \tag{2}$$

where parameters $\{\sigma, \xi, \nu\}$ are the inverse of the intertemporal substitution elasticity, the scale parameter for the disutility of the labor supply, and the inverse elasticity of labor supply respectively.

The aggregate consumption C_t is a composite of domestic consumption $C_{H,t}$ and foreign consumption $C_{F,t}$ using the constant elasticity of substitution (CES) function:

$$C_t = \left[(1-\gamma)^{\frac{1}{\rho}} (C_{H,t})^{\frac{(\rho-1)}{\rho}} + \gamma^{\frac{1}{\rho}} (C_{F,t})^{\frac{(\rho-1)}{\rho}}\right]^{\frac{\rho}{\rho-1}} \tag{3}$$

where γ determines the share of domestic goods and ρ is the elasticity of substitution between domestic goods and foreign goods.

As in Cespedes et al. (2002), we assume that the price of imported goods is normalized to one in foreign currency. In addition, we also assume that imports can be freely traded. Therefore, the domestic currency price of imports is just equal to the nominal exchange rate S_t according to the law of one price. Denoting the price of the domestic good as $P_{H,t}$, the then aggregate price level, or consumer price index (CPI), P_t, can be derived from the consumption function:

$$P_t = \left[(1-\gamma)(P_{H,t})^{1-\rho} + \gamma (S_t)^{1-\rho}\right]^{\frac{1}{(1-\rho)}}, 0 < \gamma < 1, \rho > 0 \tag{4}$$

Let W_t denote nominal wage. The nominal bonds B_t and B_t^* are respectively denominated in domestic and foreign currency, and R_{t-1}^n and ${R_{t-1}^n}^*$ are the corresponding nominal interest rates. The real dividend payment from retail firms is Π_t, and T_t is the lump sum real tax payment. The household's budget constraint is:

$$P_t C_t + B_{t+1} + S_t B_{t+1}^* + T_t = W_t L_t + R_{t-1}^n B_t + S_t \Psi_{t-1} {R_{t-1}^n}^* B_t^* + \pi_t \tag{5}$$

where Ψ_t represents the country's borrowing premium on foreign bond holdings, which depends on the real aggregate net foreign asset position of the domestic economy NF_t and a random shock Φ_t as follows: $\Psi_t = f(NF_t)\Phi_t, f'(\cdot) > 0$. Here, the risk premium is introduced for two reasons:[6]

[6]Following Schmitt-Grohe and Uribe (2001), we set the elasticity of with respect to very close to zero so that the link between a country's borrowing premium and the degree of net foreign indebtedness plays no role in the model dynamics.

(1) to ensure that bonds and consumption are in a well-defined steady state (Schmitt-Grohe and Uribe, 2001; Adolfson et al., 2007) because of a positive blip in the random variable Φ_t which in turn directly raises Ψ_t; (2) to introduce the country's borrowing premium, which is a simple way to model sudden currency appreciation.

The representative household maximizes its expected lifetime utility (1) subject to the budget constraint (5). The first order conditions for this optimization problem are as follows:

$$\frac{C_{H,t}}{C_{F,t}} = \left(\frac{1-\gamma}{\gamma}\right)\left(\frac{S_t}{P_{H,t}}\right)^{-\rho} \tag{6}$$

$$E_t\left\{\beta\frac{P_t C_t^{\sigma}}{P_{t+1}C_{t+1}^{\sigma}}R_t^n\right\} = 1 \tag{7}$$

$$\frac{W_t}{P_t C_t} = \xi L_t^{\nu-1} \tag{8}$$

$$E_t\left\{\frac{1}{P_{t+1}C_{t+1}}\left[R_t^n - \frac{S_{t+1}S_t}{\Psi_t}(R_t^n)^*\right]\right\} = 0 \tag{9}$$

Equation (6) is the optimality condition for the consumption allocation between domestic and foreign goods; Equation (7) is the Euler equation for the decision to consume or save; Equation (8) is the labor supply equation; Equation (9) is the uncovered interest parity condition.

3.2. Production sector

The production sector includes entrepreneurs, capital producers, and retailers. Entrepreneurs produce wholesale goods and borrow from bank to finance the capital used in the production process. Due to financial frictions in the credit market, entrepreneurs' demand for capital depends on their respective financial positions—a key aspect of the financial accelerator. Capital producers produce new investment goods and sell them to entrepreneurs. Retailers purchase wholesale goods from entrepreneurs and sell them to capital producers and households. Retailers set nominal prices as Calvo (1983), and provide the source of nominal price stickiness.

3.2.1. Entrepreneurs

Risk neutral entrepreneurs are the managers of the firms producing wholesale goods. They need to make the optimal production choice and finance the capital used in the production process as Bernanke et al. (1999).

At the end of the period t, entrepreneurs purchase capital K_{t+1} at the real price Q_t for the production of period $t+1$. The cost of the period $t+1$ capital, $Q_t K_{t+1}$, is financed by entrepreneurs' net worth N_t and

nominal bonds B_{t+1} issued in domestic currency by financial intermediaries as follows:

$$N_t + \frac{B_{t+1}}{P_t} = Q_t^k K_{t+1} \tag{10}$$

Due to informational asymmetries between entrepreneurs and financial intermediaries, the lenders (financial intermediaries) must pay an audit cost in order to observe borrowers' (entrepreneurs) output. Entrepreneurs choose whether to repay their debt or default after observing their project outcome. In case of a default, the financial intermediaries audit the loan and get all the project outcome. Bernanke et al. (1999) showed that the existence of an agency problem that makes external financing more expensive than internal funds and the external finance premium $\eta(\cdot)$ rises up to the entrepreneurs' leverage ratio.[7] Accordingly, the demand for capital should satisfy the following optimality condition:

$$E_t F_{t+1} = E_t \left[\eta_{t+1} R_t^n \left(\frac{P_t}{P_{t+1}} \right) \right] \tag{11}$$

where $R_t^n \left(\frac{P_t}{P_{t+1}} \right)$ is an expected real interest rate and the external finance premium is given by:

$$\eta_{t+1} = \eta \left(\frac{Q_t^k K_{t+1}}{N_t} \right), \text{ with } \eta(1) = 1 \text{ and } \eta'(\cdot) > 0. \tag{12}$$

Rewriting Equation (10) to be $\frac{Q_t^k K_{t+1}}{N_t} = 1 + [(B_{t+1}/P_t)/N_t]$. This suggests that the external finance premium $\eta'(\cdot)$ depends on the size of borrowers' leverage ratio $(B_{t+1}/P_t)/N_t$. As $\frac{Q_t^k K_{t+1}}{N_t}$ rises, borrowers rely more on uncollateralized borrowing (a higher leverage) to fund their projects. The higher leverage ratio is, the riskier loan are, and the higher the cost of borrowing would be.

The log-linearized equation for the external funds rate can be derived from Equations (11) and (12) as:

$$\hat{F}_{t+1} = \hat{R}_t^n - \hat{\pi}_{t+1} + u(\hat{Q}_t^K + \hat{K}_{t+1} - \hat{N}_t) \tag{13}$$

Variables with hats are log deviations from steady-state values. The parameter u represents the elasticity of the external finance premium with

[7] For details, see Céspedes et al. (2000) and Gertler et al. (2007), who provide additional details, as well as novel extensions, along with Bernanke et al. (1999) for the full exposition.

respect to a change in the leverage position of entrepreneurs. If $u = 0$, i.e.,$\eta(x) = 1$, the enterprise's loan interest rate equals risk free rate and the financial accelerator mechanism is not operational.

Entrepreneurs purchase capital K_{t+1} for use in the $t+1$ period at the real price Q_t^k. The enterprises' production function is $Y_t = AK_{t-1}^{\alpha}L_t^{1-\alpha}(0 < \alpha < 1)$, where A is a positive constant. Entrepreneurs sell the wholesale goods to retailers. Let X_t be the gross markup of retail goods over wholesale goods. Accordingly, we can derive the first order condition for labor demand:

$$\frac{W_t}{P_{H,t}} = \frac{1-\alpha}{X_t}\frac{Y_t}{L_t} \tag{14}$$

The entrepreneurs' demand for capital depends not only on the expected marginal return of capital but also the expected marginal external financing cost at $t+1$. Consequently, the optimal entrepreneurs' capital demand guarantees:

$$E_t F_{t+1} = \frac{E_t\left\{\frac{1}{X_{t+1}}\frac{\alpha Y_{t+1}}{K_{t+1}} + (1-\delta)Q_{t+1}^k\right\}}{Q_t^k}$$

The expected marginal return of capital is governed by the marginal productivity of capital at $t+1$ and the value of capital used in $t+1$, where δ is the capital depreciation rate.

At the beginning of period t, entrepreneurs collect capital returns and also repay debt. Each period some entrepreneurs would die and only the share ϕ of them can survive to the next period. We assume that entrepreneurs consume the rest $(1-\phi)$ on imports as in Cespedes et al. (2004). As Caballero et al. (2008) noted, emerging market countries sought to store value abroad after the 1990s crisis in order for the reliable financial assets. We assume that entrepreneurs hold a certain proportion of assets denominated in dollars, which reflects the "conflict virtue" (McKinnon, 2007)—the important role that foreign assets play in Chinese and other East-Asian portfolios. The proportion of assets denominated in foreign currency (dollars) is ω and the assets in domestic currency is $1-\omega$.[8] Then, entrepreneurial net worth evolves according to the equation:

[8]The assumption that the proportion of assets denominated as foreign currency is exogenous in the model is based on the following considerations: (1) the appreciation shock generated from exogenous impacts is sudden and immediate. However, because of the underdeveloped financial market, the lag in the development of the derivative market then leads to an adjustment in enterprises' portfolios through selling assets thought to be slow and costly; (2) this assumption may also facilitate the simple discussion of an appreciation's influence on the economy in different kinds of currency mismatches. If we chose to make the portfolios of the enterprises endogenous, we would only be able to

Plugging in Equations (10) and (11), we could rewrite the above equation:

$$N_t = \phi\left\{(1-\omega)+\omega S_t/P_{H,t}\right\}\left\{R_t^k Q_{t-1}^k K_t - R_{t-1}^n \frac{P_{t-1}}{P_t}\eta\left(\frac{Q_{t-1}^k K_t}{N_{t-1}}\right)(Q_{t-1}^k K_t - N_{t-1})\right\} \tag{15}$$

In the wake of a currency appreciation, S_t decreases, and N_t also decreases according to Equation (15) when the model is properly calibrated, which ultimately leads to a rise in both the leverage ratio and the risk premium. This not only reduces investment but also raises the loan interest in the next period, further lowering firms' net worth. This Equation (15) plays a key role in our model[9]. It connects entrepreneurs' investments with the change in the exchange rate by the financial accelerator, amplifying the impact of the exchange rate change on entrepreneurial behavior.

3.2.2. Capital producers

Based on standard DSGE models (Christiano et al., 2007; Christensen and Dib, 2008), we incorporated capital producers into our model. Capital producers purchase K_t capital goods from entrepreneurs and new investment goods I_t from the domestic and foreign goods market at the end of period t, and then use them to produce new capital goods K_{t+1} according to the production function $\Phi(I_t/K_t)K_t$. The function $\Phi(I_t/K_t)K_t$ has a constant return to scale,[10] where $\Phi(0) = 0$, $\Phi'(\cdot) > 0$, $\Phi''(\cdot) < 0$. The evolution of capital goods is as follows:

$$K_{t+1} = \Phi\left(\frac{I_t}{K_t}\right)K_t + (1-\delta)K_t \tag{16}$$

Investment goods I_t is the combination of domestic investment goods $I_{H,t}$ and foreign investment goods $I_{F,t}$ in CES form. $P_{H,t}$ and S_t denote the price of domestic investment goods and foreign investment goods, respec-

discuss the influence of appreciation on the economy for the extent of currency mismatch that is just within the vicinity the equilibrium rather than for that on different levels.

[9] If we assume the entrepreneur borrows in terms of foreign currency, the results would be completely opposite. In that case, if RMB appreciates, the net asset of entrepreneur denominated in foreign currency rises, which pushes down the leverage ratio and the risk premium. In China, the entrepreneurs usually raise fund from domestic financial market denominated in RMB, and therefore we choose to set up the model that the entrepreneur borrows in domestic currency.

[10] Generally specified as $\Phi(I_t/K_t)K_t = \left[\frac{I_t}{K_t} - \frac{\phi}{2}\left(\frac{I_t}{K_t} - \delta\right)^2\right]K_t$.

tively. I_t is specified as:

$$I_t = \left[(1-\gamma_i)^{\rho_i}(I_{H,t})^{\frac{\rho_i-1}{\rho_i}} + \gamma_i^{\rho_i}(I_{F,t})^{\frac{\rho_i-1}{\rho_i}}\right], 0 < \gamma_i < 1, \rho_i > 0 \tag{17}$$

As a result, the unit price of investment goods is:

$$P_{I,t} = [(1-\gamma_i)(P_{H,t})^{1-\rho_i} + \gamma_i(S_t)^{1-\rho_i}] \tag{18}$$

where ρ_i is the elasticity of the substitution between domestic and foreign investment goods and denotes the proportion of foreign investment goods.

Subject to Equation (16), capital producers solve their profit maximization problem $\max_{I_t} E_0 \sum_{t=0}^{\infty} \Lambda_t \{Q_t^k K_{t+1} - Q_t^k K_t - \frac{P_{I,t}}{P_t} I_t\}$ with discount factor $\Lambda = \beta^t \left(\frac{C_t}{C_0}\right)$. Then, the real price of investment goods evolves according to:

$$Q_t^k = \left[\Phi'\left(\frac{I_t}{K_t}\right)\right]^{-1} \frac{P_{I,t}}{P_t} \tag{19}$$

3.2.3. Retailers

The role of retailer sector is to introduce price stickiness into our model. The retailer index z is distributed on the interval $[0, 1]$. Retailers purchase wholesale goods Y_t from entrepreneurs at the competitive market price $P_{H,t}^w$, then differentiate them costlessly and sell the differentiated retail goods $Y_t(z)$ at price $P_{H,t}(z)$. Composite goods $Y_{H,t}$, purchased by residents, consist of differentiated retail goods as described by the following function:

$$Y_{H,t} = \left(\int_0^1 Y_t(z)^{\frac{\varepsilon-1}{\varepsilon}} dz\right)^{\frac{\varepsilon}{\varepsilon-1}}, \quad (\varepsilon > 1) \tag{20}$$

The corresponding price index is:

$$P_{H,t} = \left(\int_0^1 P_{H,t}(z)^{1-\varepsilon} dz\right)^{\frac{1}{1-\varepsilon}}$$

The demand curve of retailer z is:

$$Y_t(z) = \left(\frac{P_{H,t}(z)}{P_{H,t}}\right)^{-\varepsilon} Y_{H,t}$$

Following Calvo (1983), we assume that only some retailers with the probability $1-\theta$ can re-optimize the price each period when $P_{H,t}^w$ and the

demand curve are given. Then, these retailers set the optimal price $P^*_{H,t}(z)$ — the corresponding optimal demand is $Y^*_t(z)$ — to maximize the expected profit:

$$E_t \sum_{k=0}^{+\infty} \theta^k \Delta_{t,t+k} \left(\frac{P^*_{H,t}(z)}{P_{H,t+k}} - \frac{P^w_{H,t+k}}{P_{H,t+k}} \right) Y^*_t(z)$$

where $\Delta_{t,t+k} = \beta^k (C_{t+k}/C_t)^{-1}$ and $P_{H,t} = X_t P^w_{H,t}$. X_t is the price markup and entrepreneurs' profit will finally be allocated to residents. Combined with the demand curve $Y^*_t(z)$, the optimization condition is:

$$E_t \sum_{k=0}^{+\infty} \theta^k \Delta_{t,t+k} \left\{ \left(\frac{P^*_{H,t}(z)}{P_{H,t+k}} \right)^{-\varepsilon} Y^*_{t+k}(z) \left[\frac{P^*_{H,t}(z)}{P_{H,t+k}} - \left(\frac{\varepsilon}{\varepsilon - 1} \right) \frac{P^w_{H,t+k}}{P_{H,t+k}} \right] \right\} = 0 \tag{21}$$

The change in the aggregate price satisfies the following function:

$$P_{H,t} = (\theta P_{H,t-1}^{1-\varepsilon} + (1-\theta) {P^*_{H,t}}^{1-\varepsilon})^{\frac{1}{1-\varepsilon}} \tag{22}$$

Log-linearized Equations (20) and (21) derive the standard New Keynesian Phillips curve:

$$\pi_{H,t} = P_{H,t}/P_{H,t-1} - 1 \tag{23}$$

$$\hat{\pi}_{H,t} = \beta E_t \hat{\pi}_{H,t+1} - \lambda \hat{X}_t, \quad \lambda = (1-\theta)(1-\beta\theta)/\theta \tag{24}$$

3.2.4. Government

The government relies on lump-sum taxes T_t and issues money M_t to finance the government expenditure G_t, keeping the budget balanced in each period. We assume that government spending is used to buy goods for domestic consumption:

$$\frac{M_t - M_{t-1} + T_t}{P_t} = G_t$$

To specifically investigate the impact of currency appreciation on the economy, we follow Cespedes et al. (2004) and assume that monetary policy targets the price of domestic outputs and does not response to the exchange rate and other economic variables:

$$P_{H,t} = P_{H,t-1} = P_H$$

3.2.5. Export and trade balance

EX_t denotes export and is specified as $EX_t = \left(\frac{P_{H,t}}{S_t P^*_{F,t}}\right)^{\vartheta} Y^*_{F,t}$. EX_t is determined by the price ratio of domestic goods to foreign goods (Gertler, 2007) and foreigner's demand $Y^*_{F,t}$ for domestic goods. $\vartheta < 0$ is the price elasticity of exports. The resource constraint for the whole economy is:

$$Y_{H,t} = C_{H,t} + I_{H,t} + G_t + EX_t \tag{25}$$

According to the economic links, domestic residents and entrepreneurs import foreign consumption goods and investment goods, and at the same time, domestic goods are exported to other countries. Then the trade balance in the model can be described as:

$$TB_t = P_{H,t}EX_t - P_{F,t}C_{F,t} - P_{F,t}I_{F,t} \tag{26}$$

Currency appreciation will change the relative price of domestic goods to foreign goods and the decision-making of residents and entrepreneurs regarding consumption and investment. Therefore, it will change imports, exports, and the trade balance.

4. CALIBRATION AND SIMULATION

4.1. Calibration

The model is a relatively standard small open economy model with financial friction, and we summarize the calibration in Table 1. For standard parameters, we mainly follow Bernanke et al. (1999), Cook (2004), Céspedes et al. (2004), Devereux et al. (2006), and Gertler et al. (2007), all of which include economic parameters for emerging market economies in their studies. In addition, we use Chinese data to estimate the specific parameter that describes the structure of the Chinese economy.

We choose the quarterly subjective discount rate β to be 0.99 (the risk-free quarterly interest rate being $r^n = 1/\beta$). The quarterly depreciation rate δ is 0.025, making the annual depreciation rate to be 0.1; the elasticity of the labor supply ν is generally between 1 and 2, and in our case we choose 1.2; the price stickiness θ is set at 0.75, i.e, the price of all goods is adjusted once a year; the risk aversion coefficient for households σ is 2. The values of these parameters are consistent with standard macroeconomic models. The elasticity of the asset-price-to-investment-asset ratio φ ranges from 0 to 0.5, and we set this value at 0.25 following Bernanke et al. (1999). We also follow Bernanke et al. (1999) by choosing the entrepreneur survival

rate to be 0.0275 and the elasticity parameter for investment demands on marginal output ϖ to be 0.81.

We set the substitute elasticity of consumption goods to be 1, the substitute elasticity of domestic and foreign investment goods to be 0.25, and the price elasticity of exports to be 1,[11] referring to Gertler et al.'s (2007) estimation of the East Asian emerging markets countries' pricing elasticity.

We further calibrated parameters that are specific to China. In the period 2003–2011, the average exports-to-GDP ratios and gross-capital-formation-to-GDP were approximately 0.3 and 0.4, respectively, and the proportion of consumption goods imported among total imports was about 4%. Therefore, we choose the steady-state ratio of exports to domestic output to be 0.3, the capital share to be 0.5 and the share of domestic goods in the investment composite γ_i to be 0.5. In the following numerical stimulation, we first used the baseline calibration parameters and then conducted a robustness analysis on variables that affect the qualitative results of the model.

TABLE 1.

Baseline Calibration of the Model

Symbol	Calibration	Description
β	0.99	Households discount
σ	2	Inverse of elasticity of substitution in consumption
δ	0.025	Capital depreciation rate
ν	1.33	Elasticity of the labor supply
θ	0.75	Probability of not adjusting price
ϖ	0.8	$(1-\delta)/\{(1-\delta)+\alpha Y_H/XK\}$
λ	2	Steady-state firm leverage (ratio of capital to net worth)
Ψ	0.05	Steady-state elasticity of risk premium to leverage, $f'(x)/f(x)$
φ	0.25	Steady-state elasticity of I/K to Q^k, $(\Phi''(I_t/K_t)/\Phi'(I_t/K_t))$
ρ	1	Consumption intra-temporal elasticity of substitution
ρ_i	0.25	Investment intra-temporal elasticity of substitution
α	0.5	Share of capital in the production function
γ	0.02	Share of foreign goods consumed
γ_i	0.6	Share of foreign goods within total investment
ϑ	1	Elasticity of export demand

To take into account the influence of the proportion of foreign assets within entrepreneurs' net worth, takes the value of 10% and 20%. In the models of Céspedes et al. (2004), Devereux et al. (2006), and Gertler et al.

[11] In the simulation, we set the price elasticity of exports to be more than 1 and ran robust tests.

(2007), the coefficient u normally takes the value range of $0 \sim 0.2$. We used different values of u to check its impacts and, when $u = 0$, the accelerator shuts down.

4.2. Numerical simulation

4.2.1. An illustration of potential mechanisms

FIG. 5. The mechanism of exchange rate conduct on the economy

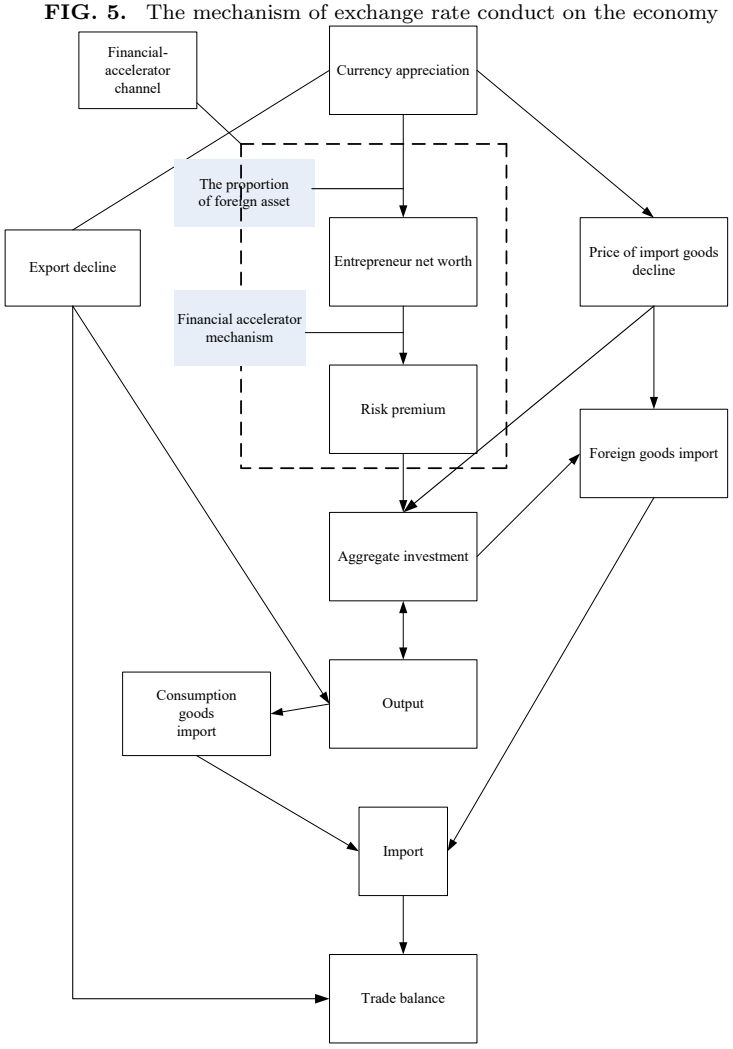


Figure 5 summarizes the three main mechanisms for how an exchange rate appreciation affects the trade balance. On the left side, the exchange

rate appreciation reduces exports and has negative impacts on output and investment. On the right side, the exchange rate appreciation decreases the price of imported goods, resulting in a rise in the purchase power of entrepreneurs and households, leading to an increase in imports.

In the middle of Figure 5 lies the third mechanism, that is, the financial accelerator mechanism. In the wake of domestic currency appreciation, the decrease of the exchange rate reduces entrepreneurs' net worth. Owing to financial friction and entrepreneurs' holding of foreign assets, the decrease in entrepreneurs' net worth raises the external finance premium. The degree of this effect depends on the elasticity of the risk premium with respect to firm leverage. A rise in the external finance premium leads to an increase in the cost of external financing and a decrease in the demand for capital and investment. The drop in demand for investment decreases imports of foreign investment goods, resulting in a negative effect on aggregate imports. The magnitude of this effect depends on the proportion of investment goods within aggregate imports.

The final effect of currency appreciation on the trade balance depends on the combination of these three mechanisms. The quantitative exercises are meant to provide a demonstration of their relative strengths.

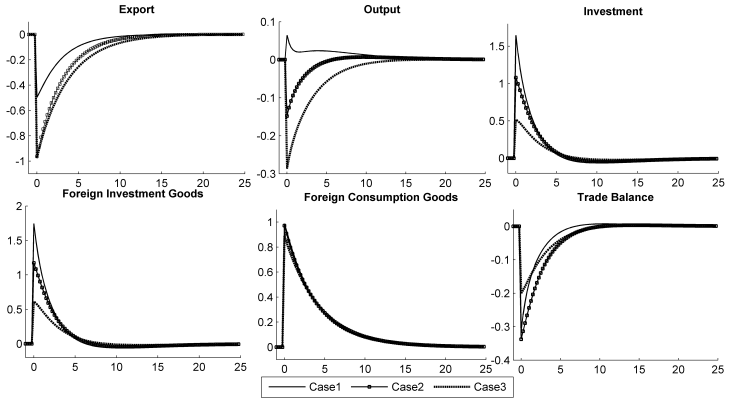
4.2.2. Simulation results

We present the simulation results in Figures 6–10. Each time we changed specific parameters and checked how the economy responds to a temporary 1% appreciation varied as a result. Each variable's response denotes the percentage deviation from its steady-state level.

In our model, entrepreneurs received loans under a risk-included interest rate that is equal to the sum of the risk-free interest rate and the risk premiums, which is given by Equation (11). When the coefficient u of the risk premium elasticity is 0, the change in the net worth of entrepreneurs does not affect external financing costs and the entrepreneurs' interest rate equals the risk-free interest rate. In this case, the financial accelerator is shut down.

Figure 6 shows the responses of exports, output, investment, imports of capital goods and consumer goods, and the trade surplus to a temporary 1% appreciation without the financial accelerator mechanism. In the benchmark case, exports decrease because of higher domestic prices, but imports increase which helps to generate more investment and leads to higher output. Overall, the trade balance deteriorates because of strong import growth. Case 2 corresponds to the situation where the share of for-

FIG. 6. The economy without the financial accelerator mechanism: case 1 (baseline), case 2 ($\gamma_i = 0.2$), and case 3 ($\vartheta = 2$).



eign goods within total investment is much smaller. As a result, the fall in foreign goods does not encourage imports as much as it does in the baseline case. The output actually falls because the decrease in exports dominates the effect of higher investment, and the drop in exports also shrinks due to weaker domestic demand. Even though the trade balance is still negative, its size contracts because of the smaller rise in imports and smaller drop in exports. Case 3 assumes a large elasticity of export demand; that is, ϑ equals to 2 rather than 1. In this case, currency appreciation leads to a huge drop in exports and correspondingly in output, but this also depresses increases in investment and imports. Overall, the trade balance deteriorates but with the smallest magnitude among the three cases.

In sum, in the absence of the financial accelerator mechanism, currency appreciation may help or hurt output, but it does reduce the trade surplus. When the proportion of investment goods within imports is large, currency appreciation helps output by boosting investment more than dampening export; otherwise, it would depress total output. In addition, when currency appreciation does discourage output, the consequent wealth effect is minor and does not reduce imports enough to rebalance trade. Thus, the overall effect of currency appreciation on trade balance is always negative.

When the risk premium elasticity coefficient does not take the value of 0, the cost of external financing depends on both the risk-free interest rate and the risk premium. The larger the u is, the more significantly a temporary 1% change of the entrepreneurs' net worth would affect the risk premium of external financing.

FIG. 7. The economy with the financial accelerator mechanism but holding no foreign assets: case 1 (baseline, $u = 0$), case 2 ($u = 0.05$), case 3 ($u = 0.1$).

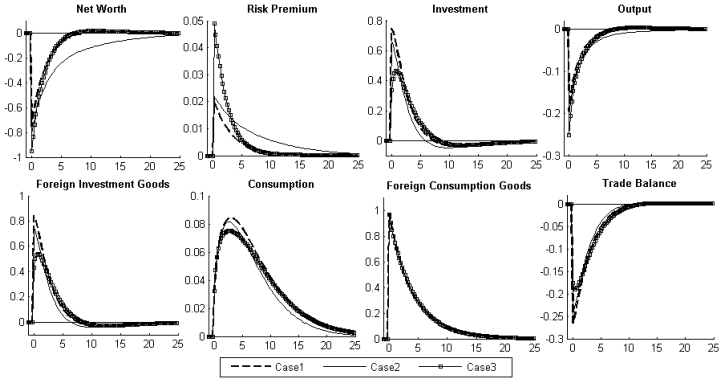


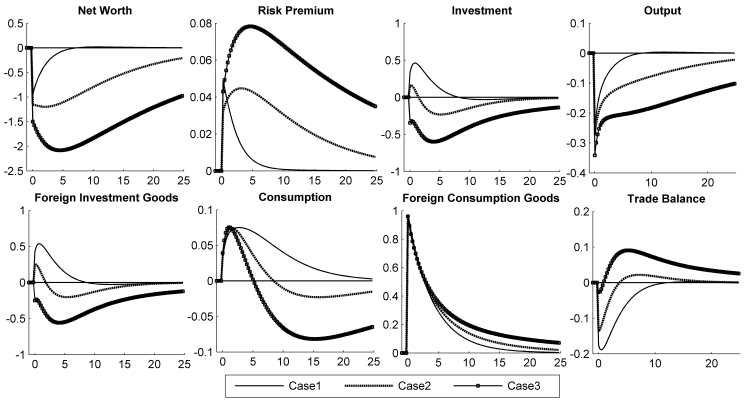
Figure 7 presents the influence of currency appreciation on the economy in the presence of the financial accelerator mechanism when no foreign assets are held. Because zero foreign assets are held, it is not surprising that the financial accelerator effect is small. Similar to previous results, the effect of a price drop in investment goods caused by the appreciation is predominant, but the overall change in output is rather small. Moreover, due to the limited impact of appreciation on entrepreneurs' net worth, the risk premium due to the accelerator is small.

However, China and other East Asian countries have achieved sustained current account surpluses and have already accumulated a huge amount of foreign assets, both in private and government sectors, creating a currency mismatch. Thus, the zero foreign asset holding assumption shown in Figure 7 is not feasible for China.

Therefore, we include foreign assets in our further analysis and present the results in Figure 8. When the asset?currency mismatch is present, because of the foreign assets held by entrepreneurs, currency appreciation would directly affect entrepreneurs' balance sheets and even more their net worth. The higher the proportion of foreign assets is, the more entrepreneurs' net worth would be reduced. As the drop in net worth increases external financing costs through the financial accelerator, it also decreases the entrepreneurs' investments, output, and imports.

In our simulation, we consider three different values for the share of foreign assets ω, that is, $\omega = 0$ (none), $\omega = 0.1$ (low), and $\omega = 0.2$ (high). When they take the value of 0.2, meaning that the proportion of foreign assets within entrepreneur net worth is 20%, the net worth drop under

FIG. 8. The economy with the financial accelerator mechanism and hold foreign assets: case 1 ($u = 0.05$, $\omega = 0$), case 2 ($u = 0.05, \omega = 0.1$), case 3 ($u = 0.05, \omega = 0.2$).



currency appreciation is relatively large, and then the risk premium rises. In the wake of currency appreciation, the negative effect of a large increase in the risk premium far exceeds the positive effect brought by the drop in the price of the investment goods, making total investment decrease sharply and lowering output to a position below the steady-state level. Although the appreciation increases the purchasing power of domestic residents and increases imports of the consumer goods, total imports would still drop due to the wealth effect, and the trade surplus would then increase. This should not be surprising considering the dominant position of investment goods among imports.

FIG. 9. The economy with the financial accelerator mechanism and holding foreign asset: case 1 ($\omega = 0.2, u = 0$), case 2 ($\omega = 0.2, u = 0.05$), case 3 ($\omega = 0.2, u = 0.1$).

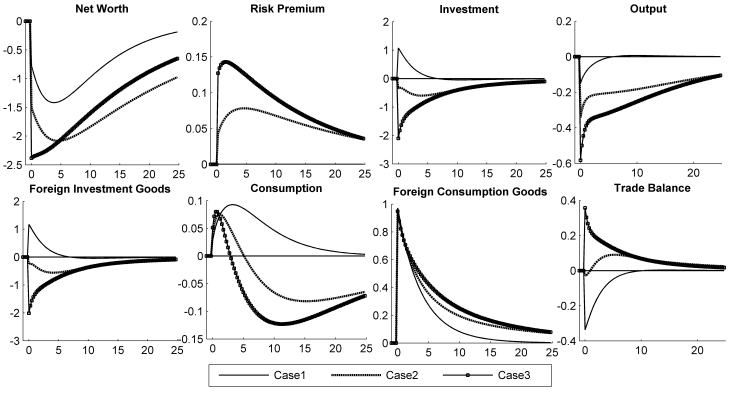


Figure 9 shows the effects that the currency appreciation has on the economy under different levels of the financial accelerator effect ($u = 0/0.05/0.1$), but with the proportion of foreign assets being fixed ($\omega = 0.2$). The changes in the trade surplus are closely related to the strength of the financial accelerator effect. In different situations, the net worth drop caused by the rise in the risk premium would differ, which leads to dissimilar investment decisions generating utterly different paths for changes in output, imports of investment goods, and the trade surplus. The stronger the effect is the greater the import reduction caused by the appreciation would be, and when the accelerator effect reaches a certain point (for example, $u = 0.05$ as in case 2), currency appreciation could enlarge the trade surplus.

FIG. 10. The economy with the financial accelerator mechanism and holding foreign asset ($u = 0.05, \omega = 0.2$): case 1 ($\gamma = 0.04$), case 2 ($\gamma = 0.1$), case 3 ($\gamma = 0.2$).

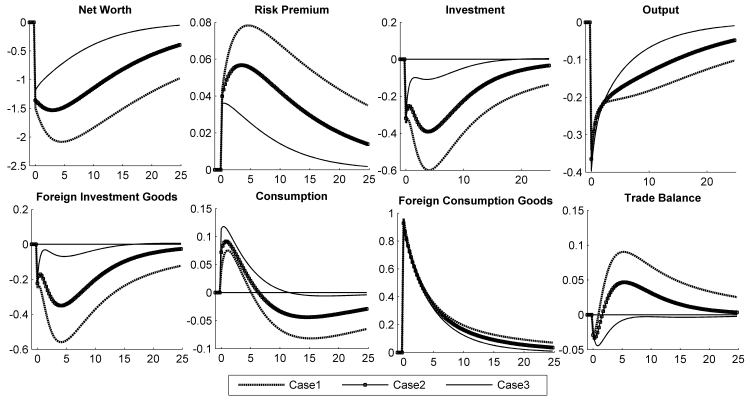


Figure 10 shows the influence of the appreciation on the trade surplus under different γ, the proportion of consumer goods within imports. Currency appreciation elevates the purchasing power of domestic residents, increasing their consumption of foreign products. But meanwhile the appreciation would have negative effects on the import of investment goods through the financial accelerator effect. Therefore, the ultimate effect of the appreciation on imports would be a combination of these opposite forces, and it would be closely related to the proportions of consumer goods and investment goods within imports. The higher the proportion of consumer goods was, the stronger the currency appreciation's positive effect on imports would be. In Figure 8, when the proportion of consumer goods reaches a certain point (for example, $\gamma = 0.2$), even though the country holds foreign assets and the financial accelerator effect exists, currency appreciation could still significantly reduce the trade surplus.

5. CONCLUSIONS

Will currency appreciation reduce the trade surplus? Although economists do not fully agree on the answer, an affirmative response has already been used to validate foreign policy. A simple elasticity model would justify such a positive reply, but as argued in Mckinnon (2005) and Qiao (2007), the elasticity models pervasively used to analyze the effect of exchange rate changes on trade balances are based on the past insular economies rather than today's open economies.

In this paper, by extending the work of Gertler et al. (2007), we build a small open economy DSGE model to answer this important question for China based on a quantitative exercise. The model incorporates several features that are shared by China and other East Asian economies, including domestic entrepreneurs holding foreign assets and consumer goods making up only a minor part of the countries' imports (while intermediate and capital goods form the majority). Our results show that, whether currency appreciation reduces the trade surplus really depends on the strength of these special features, and using a reasonable calibration for China, RMB appreciation would actually lead to a further increase in the trade surplus but a recession in output. Therefore, in the case of China, currency appreciation can neither bring a rebalance in trade nor lead to economic growth.

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