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A Model of Chinese Capital Account Liberalisation*

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Abstract

In shaping the evolution of the global financial system in the decade ahead, few events will likely be more significant than capital account liberalisation in China and the internationalisation of the renminbi. This paper provides a theory-based enquiry into the contours of China's international balance sheets after the renminbi becomes convertible under the capital account. We construct a two-country general equilibrium model with trading in equities and bonds and calibrate the model with US and Chinese data. We interpret Chinese capital account liberalisation as a removal of restrictions that prohibit agents from trading Chinese bonds and US equities. We explore how international risk-sharing can be achieved through portfolio diversification in each of these asset market configurations. We also look at how these holdings would change as China gradually rebalances its production with a higher share of labour income, and as the productivity gap between China and the US narrows. We find that both US and Chinese residents would have incentives to increase their holdings in each other's equities, and to issue debt in each other's currency. We interpret the latter observation as the co-existence of the US dollar and the renminbi as major international currencies.

Keywords: China, Country Portfolios, Capital Account Liberalization, Renminbi Internationalization
JEL Classification: F3, F4, G1

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1. Introduction

China has been growing rapidly for the last 30 years and has become the second largest economy in the world. Since China declared renminbi current account convertibility in 1996, the country has transformed itself to a major player in international trade (accounting for 11% of world trade in 2012). Its influence is also clearly visible in global commodity markets. However, China's participation in international financial markets is small relative to the size of its economy and the volume of trade. The key reason is that the renminbi has not been freely convertible under the capital account until now and cross-border financial transactions are constrained by capital controls.

In fact, China has endeavoured to attract foreign direct investment since the 1980s, and has been one of the largest recipients. In recent years, overseas direct investments by Chinese firms have also been encouraged and have risen sharply. But restrictions on cross-border portfolio investments have been prevalent. Nevertheless, the Chinese government realises that opening the capital account is important and has put it on the official agenda. The goal of 'gradually realizing convertibility under the capital account' was reiterated in the 12th Five-Year Program. In 2012, the People's Bank of China (PBC) released a report making the case for a faster pace of capital account liberalisation.[1] The report proposes a roadmap towards liberalisation within a span of 10 years. In fact, over the last few years, a number of policies related to liberalisation of portfolio investment have been rolled out. For instance, the Qualified Foreign Institutional Investor (QFII) scheme, under which foreign residents can invest in Chinese equity and bond markets through collective investment schemes, was launched in 2002 and subsequently expanded. An analogous Qualified Domestic Institutional Investor (QDII) scheme, under which Chinese residents can make portfolio investments overseas through collective investment schemes, was set up in 2006. Although these steps are small, piecemeal and subject to quotas and restrictions, reflecting China's gradualist and controllable approach towards financial liberalisation, the intention to move towards a more liberalised capital account is clear. Going forward, we expect the speed of capital account liberalisation to accelerate.

Capital account liberalisation in China is closely related to the process of the internationalisation of the renminbi. Facilitating the international use of the renminbi was put on the policy agenda by the Chinese authorities in the aftermath of the global financial crisis of 2007-2009. Since mid-2009, the Chinese authorities have moved quickly to remove restrictions against the use of renminbi in current account transactions, and have gradually expanded the scope of the use of renminbi in capital account transactions. Market forces have responded quickly to official policies and the use of renminbi in cross-border trade has risen rapidly, and offshore renminbi markets in Hong Kong and other financial centres have also mushroomed. Although a certain degree of international use of the renminbi does not require full capital account convertibility, sufficient provision of renminbi liquidity in global financial markets will ultimately be dependent on a higher degree of capital account convertibility (He, 2012). In particular, the creation of renminbi liquidity in offshore markets requires

[1] Report by the Financial Survey and Statistics Department of the PBC, 23 February 2012 (in Chinese).

that non-Chinese residents are willing and able to take on renminbi-denominated liabilities (He and McCauley, 2010).

The relatively low capital account convertibility has important implications for China's international balance sheet. Figure 1 illustrates China's international investment positions.[2] China has a large long position in fixed-income securities and a large short position in foreign direct investment (FDI) and equity portfolios. As the gross financial positions have grown over time, the 'long debt, short equity' asymmetry has become more prevalent (Ma and Zhou, 2009). On the asset side, foreign exchange reserves have accumulated rapidly since 2000 and constitute more than two-thirds of assets holding by 2011. The combined outward FDI assets and portfolio equities amount to only 5.8% of GDP in 2011. On the liability side, the inward FDI and the equity portfolios together account for about 75% of the liability position. The large inward FDI is by and large a policy choice by the Chinese authority to facilitate technology transfer.[3] On the other hand, the US external balance sheet is the mirror image of China's: the US borrows by issuing treasury bonds and uses the proceeds to make loans abroad, invest overseas as FDI and equity portfolios. For this reason, Kindleberger (1965) and Despres, Kindleberger and Salant (1966) famously called the US 'the banker of the world'. The evolution of the external balance sheet of the US in recent decades has been described by Gourinchas and Rey (2007) as 'from world banker to world venture capitalist.'

There is an empirical literature that studies how capital account liberalisation in China is likely to affect the financial position in China. These papers typically use cross-country panels in estimations. Ma and Zhou (2009) find that the gross international investment position in OECD countries is positively correlated with country size and openness. Based on OECD experience, they predict that the gross international investment position in China would reach 150% of GDP by 2015, driven by capital account liberalisation and economic growth. He et al. (2012) use data for the OECD, and Asian and Latin American countries to study the determinants of different types of capital flows. Their results suggest that, following capital account liberalisation, both outward FDI and portfolio investment in China would likely increase significantly, and at a faster pace than the inward flows, reflecting an intention to diversify risks. Bayoumi and Ohnsorge (2013) estimate a multi-country portfolio allocation model which takes capital controls into account. Their estimates suggest that capital account liberalisation might be followed by a stock adjustment of Chinese assets abroad of the order of 15-25% GDP and of foreign assets in China of the order of 2-10% GDP.

In this paper, we take a structural approach to study the impact of the capital account liberalisation on China's international balance sheet. The key advantage of this approach is that it provides a theoretical underpinning for the optimal portfolio choices and international investment positions. It also allows us to take into account country specifics when modelling portfolio choices. Moreover, the structural model is immune to the Lucas critique, which allows us to do other counterfactual

[2] The data before 2007 is obtained from the Lane and Milesi-Ferretti (2007) 'External Wealth of Nations' dataset. From 2008 onwards, the data is obtained from CEIC.

[3] See Lardy and Douglass (2011) for a summary of these policies.

experiments, analyzing how economic growth and other ongoing transitions in China affect portfolio holdings. Given the advantages of this approach, we emphasise qualitative predictions regarding the optimal portfolio allocation, focusing on understanding the risk-sharing motives behind these allocations. The quantitative results should not be viewed as precise predictions, due to various limitations and restrictions of the model.[4]

Specifically, we construct a microfounded two-country general equilibrium model with trading in equities and bonds and calibrate the model using US and Chinese data. In our model, households acquire financial assets in order to insure themselves against macroeconomic shocks coming from both countries. We interpret capital account liberalisation as a removal of restrictions that prohibit agents from trading in Chinese bonds and US equities. The optimal steady-state portfolio holdings before and after liberalisation are computed. We explore how international risk-sharing can be achieved through portfolio diversification in each of these asset market configurations. We also look at how these holdings would change as China gradually rebalances its production with a higher share of labour income, and as the productivity gap between China and the US narrows.

Using our baseline model, we derive the following main results. In the steady state before capital account liberalisation, China builds up a positive position in US bonds and a negative position in FDI and portfolio equities consistent with the observed data. This is because households are worried about investment efficiency shocks (which are more volatile than productivity shocks). In the face of such shocks a 'long debt, short equity' portfolio in China yields excess portfolio returns that are negatively correlated with China's relative consumption, enhancing international risk-sharing.

After capital account liberalisation in China, when Chinese and US equities and bonds are both freely tradable, there are as many assets as the number of shocks and households can achieve perfect international risk-sharing. Under this scenario, equities are employed to hedge against fluctuations in wage income that are orthogonal to exchange rate movements, and bonds are used to insure against fluctuations in the real exchange rate. There are three key results. First, the optimal portfolio turns out to be one in which Chinese households invest a substantial amount in US firms, and US households likewise invest more in the Chinese firms. Second, China's desired US bond holding will move from a long position to a short position, increasing the supply of US-dollar bonds. US households will hold these bonds to hedge real exchange rate risk. Third, the US will also hold a negative position in Chinese bonds.[5] The reason is that, in our model the equity holding alone only partly compensates for the fluctuations in relative consumption. Households in each country hold domestic bonds - and short foreign bonds - which yields high returns just when relative consumption is low and the real exchange rate is appreciated. One way through which the US holds a negative position in Chinese bonds is that the US issues renminbi-denominated bonds, which are held by the Chinese. We argue that this

[4] We discuss these limitations in detail in the concluding section of the paper.

[5] Our model only implies that the net position is short. But this need not imply that the US would not invest in renminbi-denominated bonds on a gross basis.

pattern is consistent with both currencies serving as funding currencies in the international monetary system.

In the extended model, we incorporate nominal rigidities and monetary shocks in both countries. We find that nominal rigidities reduce the size of international investment positions after capital account liberalisation. Under our calibrations, these additions enable us to obtain more reasonable predictions of portfolio allocation after capital account liberalisation in China. In particular, we find an increase in Chinese holdings of foreign equities of around 35% of Chinese output from the steady state before liberalisation to the state state after, whereas the increase in foreign holdings of Chinese equities is around 28% of output. In terms of bonds, our result suggests that Chinese holdings of foreign bonds declines from 38% of output before liberalisation to -48% of output in the steady state after Chinese capital account liberalisation, and non-residents issue renminbi-denominated bonds of around 80% of output in the steady state after liberalisation. Finally, we show that as China grows and rebalances its economy, Chinese residents will tend to hold an increasing share of US equities and reduce their holdings of US bonds as a share of US output.

Our work is related to the theoretical literature on international portfolio choice in general equilibrium models. Much of the theoretical literature focuses on resolving the equity home bias puzzle (French and Poterba, 1991). There are two important insights from the recent literature. First, Engel and Matsumoto (2009), Coeurdacier and Gourinchas (2010), Devereux and Sutherland (2008), Coeurdacier et al. (2010) and Coeurdacier and Rey (2012) show that having multiple asset classes (e.g. equities and bonds) can lead to very different portfolio allocations from 'equities-only' models because the existence of other assets alters the risk-sharing motive of holding equities. Second, models with capital accumulation and differentiated goods (such as Heathcote and Perri (2009), Engel and Matsumoto (2009) and Coeurdacier et al. (2010)) can give rise to a plausible degree of equity home bias and a low correlation between excess equity returns and the real exchange rate, consistent with empirical findings (van Wincoop and Warnock, 2010). We borrow these insights from the literature.

Since most of the literature on portfolio choice is devoted to addressing theoretical puzzles, these papers study symmetric economies. One notable exception is Devereux and Sutherland (2009), in which there is an advanced and an emerging market economy. That paper considers a configuration in which only the bonds of the advanced economy and the equities of the emerging market are traded, and contrasts it with a situation in which equities of both countries together with real bonds are traded. Their model shows that in the former configuration, the advanced economy holds the equities of the emerging market and the emerging market holds the bonds of the advanced economy, a result similar to ours. However, their model also implies foreign equity bias in the latter asset market configuration. Our work differs from theirs in three ways. First, we consider a different setup in which each country issues its own bonds, as the bond denomination has important implications for the international monetary system. Second, we assume consumption home bias in each country. Third, our setup generates equity home bias at all times, consistent with empirical findings.

The rest of the paper is organised as follows. Section 2 sets up the model. Section 3 provides a brief discussion of the solution method used to compute the steady-state portfolio allocation. In section 4, we compute the optimal portfolio holdings before and after liberalisation of the capital account in China. We explain the risk-sharing motives of the households behind these holdings and discuss the implications for the international investment positions in China. In section 5, we simulate the optimal portfolios under two likely future scenarios: (i) a rebalancing of the Chinese economy to less capital-intensive production with a higher share of labour income; and (ii) a narrowing of the productivity gap between the US and China. Section 6 concludes.

2. The Setup

The model is a two-country infinite-horizon model similar to Coeurdacier et al. (2010). Homogenous households in each country consume, supply labour and save by buying financial assets. Decentralised goods producing firms in each country produce country-specific goods using a two-factor production function with capital and labour. They accumulate capital to maximise the expected future discounted dividend stream. Retail firms purchase these goods, sell at a markup and are subject to a Calvo (1983) type price rigidity. A final goods firm in each country produces the finished country-specific good. There are three shocks in each country, namely a productivity shock, an investment efficiency shock and a monetary policy shock. Each country has two assets -- equities and bonds. We consider two asset market configurations. Without capital account restrictions, households in each of the two countries can freely buy and sell the four assets; whereas in the restricted market, only US bonds and Chinese equities are traded. The portfolio choice problem is endogenous. The two countries are asymmetric in terms of their productivity, capital share in production and the volatility of shocks. Time is discrete.

2.1 Households

Households are homogenous in each of the two countries, A and B. We aim to study a situation in which country A is developed and country B is emerging. We will sometimes refer to country A and B as the US and China respectively. Households consume country A and B's goods with home bias, trade financial assets and supply labour. The asset market configuration will be discussed in detail below. The utility of the representative household in country i is given by the following:

$$U_i = E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_{it}^{1-\sigma}}{1-\sigma} - \frac{l_{it}^{1+\omega}}{1+\omega} \right), \qquad \text{for } i \in \{A, B\}, \tag{1}$$

where C_{it} is country i's aggregate consumption in period t and l_{it} the labour supply.

Goods are aggregated by a CES aggregator:

$$C_{it} = \left(a^{\frac{1}{\phi}} (c_{it}^{i})^{\frac{\phi-1}{\phi}} + (1-a)^{\frac{1}{\phi}} (c_{jt}^{i})^{\frac{\phi-1}{\phi}} \right)^{\frac{\phi}{\phi-1}}, \qquad \text{for } j \neq i. \tag{2}$$

where c_{jt}^{i} is the consumption of country j's goods by country i's households in period t. $a > 0.5$ is the degree of goods home bias. We assume that the law of one price holds for each type of good. The corresponding aggregate consumer price index is:

$$P_{it} = \left(a p_{it}^{1-\phi} + (1-a) p_{jt}^{1-\phi} \right)^{\frac{1}{1-\phi}}, \qquad \text{for } j \neq i. \tag{3}$$

where p_{it} is the price of good i in period t.

Country i's consumption demand for country i and j's goods are standard:

$$c_{it}^{i} = a \left(\frac{p_{it}}{P_{it}} \right)^{-\phi} C_{it}, \tag{4}$$

$$c_{jt}^{i} = (1-a) \left(\frac{p_{jt}}{P_{it}} \right)^{-\phi} C_{it}, \qquad \text{for } j \neq i. \tag{5}$$

In the following we describe configuration of the asset market. We consider two regimes. In the first regime, there is international trade in equities and bonds originating from each of the two countries. Country i firms issue equities which are a claim on its stream of future dividends $\{d_{is}\}_{t=s}^{\infty}$. Country i also issues a bond. The bond entitles the owner to one unit of country i's goods in all future periods. Let S_{jt+1}^{i} denote the number of country j's equities held by country i's households at the end of period t, and let b_{jt+1}^{i} denote the number of country j's bonds held by country i's households.[6] Also let the price of country i's equities and bonds in period t be denoted by p_{it}^{S} and p_{it}^{b} respectively. Then, the budget constraint for country i's households is:

[6] As will be clear when we describe the equity dividend in the firms, it should be noted that an equity simply means a claim on the firms' profit. Therefore, equity here can be interpreted as FDI or corporate bonds.

$$P_{it}C_{it} + p_{it}^{S}S_{it+1}^{i} + p_{jt}^{S}S_{jt+1}^{i} + p_{it}^{b}b_{it+1}^{i} + p_{jt}^{b}b_{jt+1}^{i}$$
$$= w_{it}l_{it} + (p_{it}^{S} + d_{it})S_{it}^{i} + (p_{jt}^{S} + d_{jt})S_{jt}^{i} + (p_{it}^{b} + p_{it})b_{it}^{i} + (p_{jt}^{b} + p_{jt})b_{jt}^{i}, \qquad \text{for } j \neq i. \tag{6}$$

where w_{it} is the nominal wage in country i. The budget constraint says country i's households use their non-financial income (wage) and financial income (investments in country A and B's assets) for consumption and to purchase financial assets.

We normalise the supply of equities in each country to unity. This means that:

$$S_{At}^{A} + S_{At}^{B} = 1, \tag{7}$$

$$S_{Bt}^{A} + S_{Bt}^{B} = 1. \tag{8}$$

Bonds for each of the two countries are in zero net supply, so that:

$$b_{At}^{A} + b_{At}^{B} = 0, \tag{9}$$

$$b_{Bt}^{A} + b_{Bt}^{B} = 0. \tag{10}$$

We sometimes refer to this as the regime after capital account liberalisation in China.

We also study a second configuration in which only US bonds and Chinese equities are tradable. These assumptions are reasonable characterizations of the investment options vis-a-vis China until recently. Non-Chinese residents face restrictions on the acquisition of Chinese government bonds, and their holdings have been very small. The same is true for overseas equities and outward FDI by Chinese residents.[7] We do not attempt to model the institutional arrangements which give rise to the growth of the official reserves; but we instead take it as given and study the optimal portfolio allocation between the two countries. If the reserve holding decision is made by a dynamic optimising agent with intertemporal preferences, and if the government is benevolent, this distinction should not make much difference.

[7] The size of China's outward FDI is small but growing rapidly. From 2004 to 2011, China's outward FDI grew from USD$5.5 billion to USD$65 billion a year, and the stock of outward FDI had reached USD$365 billion by the end of 2011 (UnctadStat). Outward portfolio equity must go through the Qualified Domestic Institutional Investor (QDII) scheme, which was introduced in 2006. The total fund raised is less than RMB200 billion, according to Yao and Wang (2012). Taken together the outward FDI and portfolio equity assets constitute less than 6% of Chinese GDP in 2011. The steady state of our model would imply that the share of US equities held by the Chinese is roughly 1%, which is negligible.

Taken together, this asset market configuration implies that $S_{At}^{B} = b_{Bt}^{A} \equiv 0$ for all t. Hence, the budget constraint for the households in country A is:

$$P_{At}C_{At} + p_{Bt}^{S}S_{Bt+1}^{A} + p_{At}^{b}b_{At+1}^{A} = w_{At}l_{At} + (p_{Bt}^{S} + d_{Bt})S_{Bt}^{A} + (p_{At}^{b} + p_{At})b_{At}^{A} + d_{At}. \quad (11)$$

We refer to this regime as one before capital account liberalisation in China.

In the asset market configuration in which all assets are tradable, households in country i maximise utility, Equation (1), subject to the budget constraint (6). The first order conditions are:

$$1 = \beta E_t\left[\left(\frac{C_{it+1}}{C_{it}}\right)^{-\sigma}\left(\frac{P_{it}}{P_{it+1}}\right)R_{At+1}^{S}\right], \quad (12)$$

$$1 = \beta E_t\left[\left(\frac{C_{it+1}}{C_{it}}\right)^{-\sigma}\left(\frac{P_{it}}{P_{it+1}}\right)R_{Bt+1}^{S}\right], \quad (13)$$

$$1 = \beta E_t\left[\left(\frac{C_{it+1}}{C_{it}}\right)^{-\sigma}\left(\frac{P_{it}}{P_{it+1}}\right)R_{At+1}^{b}\right], \quad (14)$$

$$1 = \beta E_t\left[\left(\frac{C_{it+1}}{C_{it}}\right)^{-\sigma}\left(\frac{P_{it}}{P_{it+1}}\right)R_{Bt+1}^{b}\right], \quad (15)$$

$$\frac{w_{it}}{P_{it}} = l_{it}^{\omega}C_{it}^{\sigma}, \quad (16)$$

where

$$R_{it+1}^{S} \equiv \frac{p_{it+1}^{S} + d_{it+1}}{p_{it}^{S}}, \qquad R_{it+1}^{b} \equiv \frac{p_{it+1}^{b} + p_{it+1}}{p_{it}^{b}}, \qquad \text{for } i \in \{A, B\}.$$

The first four equations are the consumption Euler equations for country A and B's equities and bonds respectively. The last equation is the intratemporal tradeoff between consumption and labour.

In the configuration in which only US bonds and Chinese equities are tradable, only the consumption Euler equations for US bonds and Chinese equities remain (that is, Equations (13) and (14)). The labour supply conditions are unchanged.

2.2 Final Goods Firm

There is one final goods firm in each country. The final goods firm combines different varieties $z \in [0,1]$ of goods to produce the country's final goods using the Dixit-Stiglitz aggregator:

$$y_{it} \equiv \left(\int_0^1 y_{it}(z)^{\frac{\eta}{\eta-1}} dz \right)^{\frac{\eta-1}{\eta}}, \qquad for\ i \in \{A, B\}. \tag{17}$$

Cost minimisation implies the demand for each variety of goods z is:

$$y_{it}(z) = \left(\frac{p_{it}(z)}{p_{it}} \right)^{-\eta} y_{it} \tag{18}$$

and the price for each country's final goods is $p_{it} \equiv \left(\int_0^1 p_{it}(z)^{1-\eta} dz \right)^{\frac{1}{1-\eta}}$.

2.3 Goods Producing Firms

There are decentralised goods producing firms indexed $z \in [0,1]$ in each country. They produce using a Cobb-Douglas technology with capital and labour inputs as follows:

$$y_{it}(z) = \theta_{it} k_{it}(z)^{\kappa_i} l_{it}(z)^{1-\kappa_i}, \qquad \text{for } i \in \{A, B\}. \tag{19}$$

where $y_{it}(z)$, $k_{it}(z)$ and $l_{it}(z)$ denote output, capital and labour input of firm z in country i. θ_{it} is total factor productivity in country i. We assume that productivity in each country follows an exogenous AR(1) process:

$$\log\left(\frac{\theta_{it}}{\bar{\theta}_i} \right) = \rho_\theta \log\left(\frac{\theta_{it-1}}{\bar{\theta}_i} \right) + \varepsilon_{it}^{\theta}, \qquad \text{for } i \in \{A, B\}. \tag{20}$$

where $\varepsilon_{At}^{\theta}, \varepsilon_{Bt}^{\theta}$ are exogenous innovations with variances $\sigma_{\theta A}^2$ and $\sigma_{\theta B}^2$ respectively. Throughout this paper, $\bar{X}$ denotes the steady-state value of variable X_t.

Since we want to model asymmetric countries, the capital shares in production κ_i, steady-state productivity $\overline{\theta}_i$ and the volatility of productivity shock, $\sigma^2_{\theta i}$ in the two countries may not be identical. We will discuss these in detail in the calibration section.

The law of motion of capital is as follows:

$$k_{it+1}(z) = (1-\delta)k_{it}(z) + \chi_{it} I_{it}(z), \tag{21}$$

where $I_{it}(z)$ is investment by firm z and δ is the depreciation rate. χ_{it} is an investment efficiency shock.[8] The investment efficiency shock, χ_{it}, follows an AR(1) process:

$$\log \chi_{it} = \rho_{\chi} \log \chi_{it-1} + \varepsilon^{\chi}_{it}, \tag{22}$$

where $\varepsilon^{\chi}_{At}, \varepsilon^{\chi}_{Bt}$ are exogenous innovations with variances $\sigma^2_{\chi A}$ and $\sigma^2_{\chi B}$ respectively.

Investment is, similar to consumption, aggregated by a CES aggregator with home bias as follows:

$$I_{it}(z) = \left(a^{\frac{1}{\phi}} (i^i_{it}(z))^{\frac{\phi-1}{\phi}} + (1-a)^{\frac{1}{\phi}} (i^i_{jt}(z))^{\frac{\phi-1}{\phi}} \right)^{\frac{\phi}{\phi-1}}, \qquad \text{for } j \neq i. \tag{23}$$

Clearly, the demands for country A and B's investment inputs are given by:

$$i^i_{it}(z) = a\left(\frac{p_{it}}{P_{it}}\right)^{-\phi} I_{it}(z), \tag{24}$$

$$i^i_{jt}(z) = (1-a)\left(\frac{p_{jt}}{P_{it}}\right)^{-\phi} I_{it}(z), \qquad \text{for } j \neq i. \tag{25}$$

Country i firms maximise the stream of expected discounted future dividends:

[8] This specification follows from Greenwood, Hercowitz and Krusell (1997). Justiniano, Primiceri and Tambalotti (2007) have found empirical evidence to support the view that the shock is helpful in accounting for volatilities in the business cycle.

$$\max_{l_{it}, I_{it}} E_t \sum_{s=0}^{\infty} Q^i_{t,t+s} d_{is}(z) \tag{26}$$

where the dividends for firm z in country i, $d_{it}(z)$ is given by:

$$d_{it}(z) = \tilde{p}_{it} y_{it}(z) - w_{it} l_{it}(z) - P_{it} I_{it}(z), \tag{27}$$

where $\tilde{p}_{it}$ is the common intermediate goods price, $Q^i_{t,t+s} \equiv \beta \left(\frac{C_{it+s}}{C_{it}} \right)^{-\sigma} \left(\frac{P_{it}}{P_{it+s}} \right)$ is the pricing kernel for country i's firms.[9]

The first order conditions are:

$$w_{it} l_{it}(z) = (1-\kappa_i) \tilde{p}_{it} y_{it}(z), \tag{28}$$

$$\frac{P_{it}}{\chi_{it}} = E_t \left[Q^i_{t,t+1} \left(\tilde{p}_{it+1} \kappa_i \frac{y_{it+1}(z)}{k_{it+1}(z)} + (1-\delta) \frac{P_{it+1}}{\chi_{it+1}} \right) \right], \tag{29}$$

for $i \in \{A, B\}$. The first equation is the labour demand condition. With a Cobb-Douglas production function, firms pay a constant fraction $(1-\kappa_i)$ of their revenue to the labour. The second equation is the investment demand, which equates the marginal cost of an additional unit of investment, P_{it}/χ_{it}, to the marginal benefit, which is the discounted sum of marginal revenue product of the additional unit of capital, after accounting for depreciation.

The aggregate quantities are obtained by summing across individual firms:

$$x_t \equiv \int_0^1 x_t(z) dz, \tag{30}$$

where $x_t \in \{k_{it}, i^i_{it}, i^i_{jt}, I_{it}, l_{it}, d_{it}\}$ and $x_t(z)$ are defined analogously.

[9] Without complete financial markets and perfect risk-sharing, the pricing kernel of firms may depend on the share of equities held by country A and B's households. Finding the pricing kernel is therefore non-trivial. Fortunately, to find the steady-state portfolio with local approximation, which is what we are interested in, we just need the first-order approximated system. Moreover, in the first-order approximation, the pricing kernel in both countries is identical, so the assumption does not affect our results.

The aggregate equations are reported as follows. The aggregate production functions is:

$$\Delta_{it} y_{it} = \theta_{it} k_{it}^{\kappa_i} l_{it}^{1-\kappa_i}, \tag{31}$$

where $\Delta_{it} \equiv \int_0^1 \left(\frac{p_{it}(z)}{p_{it}} \right)^{-\eta} dz$ is the price dispersion in country i.

Aggregate capital stock evolves as follows:

$$k_{it+1} = (1-\delta) k_{it} + \chi_{it} I_{it}, \tag{32}$$

The aggregate demand for labour and investment are:

$$w_{it} l_{it} = (1-\kappa_i) \frac{\tilde{p}_{it}}{p_{it}} p_{it} y_{it} \Delta_{it}, \tag{33}$$

$$\frac{P_{it}}{\chi_{it}} = E_t \left[Q_{t,t+1}^i \left(\frac{\tilde{p}_{it+1}}{p_{it+1}} p_{it+1} \kappa_i \frac{y_{it+1} \Delta_{it+1}}{k_{it+1}} + (1-\delta) \frac{P_{it+1}}{\chi_{it+1}} \right) \right]. \tag{34}$$

Also, aggregate dividends are defined as:

$$d_{it} = \frac{\tilde{p}_{it}}{p_{it}} p_{it} y_{it} \Delta_{it} - w_{it} l_{it} - P_{it} I_{it}. \tag{35}$$

The price dispersion in country $i \in \{A, B\}$ evolve as follows:

$$\Delta_{it} = \gamma \Delta_{it-1} + (1-\gamma) \left(\frac{1-\gamma (p_{it}/p_{it-1})^{-(1-\eta)}}{1-\gamma} \right)^{-\frac{\eta}{1-\eta}}. \tag{36}$$

2.4 Retailers

There are retailers indexed z in each country who buy goods from their respective goods producers and sell to the final goods producer. They set selling prices $p_{it}(z)$ subject to the demand for final goods and price rigidities. Specifically, retailers reset their prices with fixed probability $(1-\gamma)$. With

probability γ prices are not reset and are assumed to be unchanged from the last period. This specification follows Calvo (1983).

The retailers thus maximise the following real profit function:

$$E_t \sum_{s=0}^{\infty} Q_{t,t+s}^{i} \gamma^s \left[\frac{p_{it}}{p_{it+s}}(z) y_{it+s}(z) - (1-\mu) \frac{\tilde{p}_{it+s}}{p_{it+s}} y_{it+s}(z) \right] \tag{37}$$

subject to the demand for goods variety z for each period $t+s$:

$$y_{it+s}(z) = \left(\frac{p_{it}(z)}{p_{it+s}} \right)^{-\eta} y_{it+s}, \tag{38}$$

where $\mu \equiv 1/\eta$ is a subsidy to retailers to ensure that the steady state is efficient. This subsidy is assumed to be paid lump-sum by households for simplicity.

All the retailers who can reset prices will choose the same price, which we call p_{it}^{opt}. The first order condition of these retailers is:

$$\frac{p_{it}^{opt}}{p_{it}} = \frac{E_t \sum_{s=0}^{\infty} Q_{t,t+s}^{i} \gamma^s \left(\frac{p_{it}}{p_{it+s}} \right)^{-\eta} \frac{\tilde{p}_{it+s}}{p_{it+s}} y_{it+s}}{E_t \sum_{s=0}^{\infty} Q_{t,t+s}^{i} \gamma^s \left(\frac{p_{it}}{p_{it+s}} \right)^{1-\eta} y_{it+s}}. \tag{39}$$

And the prices of country i's goods will evolve as follows:

$$p_{it} = \left(\gamma p_{it-1}^{1-\eta} + (1-\gamma) \left(p_{it}^{opt} \right)^{1-\eta} \right)^{\frac{1}{1-\eta}}. \tag{40}$$

2.5 Market Clearing Conditions

Country A's production is used to produce country A and B's aggregate consumption and investment goods. The goods market clearing condition for country A is:

$$c_{At}^{A} + c_{At}^{B} + i_{At}^{A} + i_{Bt}^{A} = y_{At}. \tag{41}$$

Similarly, the goods market clearing condition for country B is:

$$c_{Bt}^{A} + c_{Bt}^{B} + i_{Bt}^{A} + i_{Bt}^{B} = y_{Bt}. \tag{42}$$

2.6 Net Foreign Assets

The household budget constraint in country A can be re-written as the law of motion relating to net foreign assets:

$$NFA_{At+1} = \frac{\tilde{p}_{At}}{p_{At}} p_{At}\Delta_{At} y_{At} - P_{At}C_{At} - P_{At}I_{At} + R_{At}^{b} NFA_{At} + \bar{p}_{A}\bar{y}_{A}\xi_{t}, \tag{43}$$

where ξ_t denotes excess portfolio return. In the configuration in which all four assets are tradable, the net foreign assets and excess portfolio return are defined as:

$$NFA_{At+1} \equiv p_{Bt}^{S} S_{Bt+1}^{A} - p_{At}^{S} S_{At+1}^{B} + p_{At}^{b} b_{At+1}^{A} + p_{B}^{b} b_{Bt+1}^{A}, \tag{44}$$

$$\bar{p}_{A}\bar{y}_{At}\xi_{t} \equiv S_{Bt}^{A} p_{Bt-1}^{S}(R_{Bt}^{S} - R_{At}^{b}) - S_{At}^{B} p_{At-1}^{S}(R_{At}^{S} - R_{At}^{b}) + b_{Bt}^{A} p_{Bt-1}^{b}(R_{Bt}^{b} - R_{At}^{b}), \tag{45}$$

and in the configuration in which there are trades in US bonds and Chinese equities only:

$$NFA_{At+1} \equiv p_{Bt}^{S} S_{Bt+1}^{A} + p_{At}^{b} b_{At+1}^{A}, \tag{46}$$

$$\bar{p}_{A}\bar{y}_{At}\xi_{t} \equiv S_{Bt}^{A} p_{Bt-1}^{S}(R_{Bt}^{S} - R_{At}^{b}). \tag{47}$$

2.7 Monetary Policy

To close the model, we specify the monetary policies. We assume monetary authorities adjust the rate of return on nominal bonds in a way similar to the Taylor rule. In addition, there are financial market disturbances that are outside the control of the monetary authorities. This leads to an interest rate rule as follows:

$$R_{it+1}^{b} = \beta^{-1}\left(\frac{p_{it}}{p_{it-1}}\right)^{\varphi_{i\pi}} m_{it}, \tag{48}$$

where m_{it} is an AR(1) shock:

$$\log m_{it} = \rho_m \log m_{it-1} + \varepsilon_{it}^m, \tag{49}$$

where ε_{At}^m and ε_{Bt}^m are exogenous disturbances with variances σ_{mA}^2 and σ_{mB}^2 respectively. The above rule determines the nominal interest rate as a function of historic PPI inflation rates, following Devereux and Sutherland (2008). These simple Taylor rules are not meant to capture the precise monetary policy framework in the US and China. In particular, the Chinese authorities do not explicitly follow an inflation targeting regime, but they consistently use alternative instruments such as reserve requirement ratios, lending rate floors and deposit rate ceilings as policy tools. However, He and Pauwels (2008) empirically estimate the implicit monetary policy stance and find that the stance can be modelled as a quasi-policy rule with significant inflation feedback. We use Equation (48) as an rough approximation to China's monetary policy.

This completes the description of our model.

3. Model Solution

We are interested in the steady-state optimal portfolio allocation both before and after capital account liberalisation in China and leave the transition dynamics for future research. Devereux and Sutherland (2011) and Tille and van Wincoop (2010) recently developed methodologies to compute portfolio allocation under both complete and incomplete asset markets. We follow the two-step procedure developed by Devereux and Sutherland (2011). In the first step, we approximate the non-portfolio system up to the first order around the deterministic steady state. We temporarily treat the deviation of the excess portfolio return, $\hat{\xi}_t$, as an exogenous *i.i.d* process and solve this first-order model in terms of the state of the economy, the exogenous shocks and the excess portfolio return. The second step makes use of the second-order approximation to the optimal portfolio conditions to compute portfolio allocation.[10] We discuss the two-step procedure in more detail below.

In order to approximate the non-portfolio system, we need to first find the steady state. The deterministic non-portfolio steady-state of the model, under either set of asset market configuration, is the solution to the steady-state versions of equations (3), (14), (16), (31), (32), (33), (34), (36), (39), (40), (41), (42) and (43). It is well-known that in open-macro models, the net foreign asset position follows a unit root process (see Schmitt-Grohe and Uribe, 2003). We choose the net foreign asset position in the steady-state to be zero, following the literature on open economy financial

[10] The meaning of the second-order approximation is the following: Assets have equal returns in the steady state, and they are only distinguishable in terms of their risk characteristics. First-order approximation is unhelpful due to certainty equivalence. The second-order components contain the covariance terms which capture the risk characteristics of the assets.

macroeconomics.[11] We normalise the price of country A's consumption to unity, *i.e.* $\overline{P}_A \equiv 1$. This set of equations solve for the steady state of the following variables:

$$\{\overline{NFA}_A, \overline{y}_i, \overline{C}_i, \overline{k}_i, \overline{l}_i, \overline{w}_i, \overline{p}_i, \overline{P}_i, \overline{\tilde{p}}_i, \overline{p}_i^{opt}, \overline{I}_i, \overline{\Delta}_i, \overline{R}\},$$

where $\overline{R} = \overline{R}_A^S = \overline{R}_B^S = \overline{R}_A^b = \overline{R}_B^b$ and $i \in \{A, B\}$.

We approximate the set of equations described above up to the first order around the deterministic steady state.[12] This set of equations, together with the shock process and the initial condition of the predetermined variables, determines the first-order transition path of the non-portfolio part of the model, taking the behaviour of the excess portfolio return, $\hat{\xi}_t$, as exogenous. Specifically, denote s_t, c_t, ε_t as the vector of state variables, non-state variables and the exogenous shock process respectively, that is:

$$s_t = [\hat{NFA}_{At} \;\; \hat{k}_{At} \;\; \hat{k}_{Bt} \;\; \hat{\theta}_{At-1} \;\; \hat{\theta}_{Bt-1} \;\; \hat{\chi}_{At-1} \;\; \hat{\chi}_{Bt-1} \;\; \hat{m}_{At-1} \;\; \hat{m}_{Bt-1}]',$$

$$c_t = [\hat{y}_{At} \;\; \hat{y}_{Bt} \;\; \hat{C}_{At} \;\; \hat{C}_{Bt} \;\; \hat{I}_{At} \;\; \hat{I}_{Bt} \;\; \hat{q}_t \;\; \hat{\tilde{p}}_{At} \;\; \hat{\tilde{p}}_{Bt} \;\; \pi_{At} \;\; \pi_{Bt}]',$$

$$\varepsilon_t = [\varepsilon_{At}^{\theta} \;\; \varepsilon_{Bt}^{\theta} \;\; \varepsilon_{At}^{\chi} \;\; \varepsilon_{Bt}^{\chi} \;\; \varepsilon_{At}^{m} \;\; \varepsilon_{Bt}^{m}]'.$$

where $\hat{X}_t \equiv (X_t - \overline{X})/\overline{X}$ is the percentage deviation of the variable X_t from its steady state $\overline{X}$ and $\hat{NFA}_{At} \equiv \dfrac{dNFA_{At}}{\overline{p}_A \overline{y}_A}$. Then the transition path of the non-portfolio part of the model is:

$$s_{t+1} = F_1 s_t + F_2 \varepsilon_t + F_3 \hat{\xi}_t, \tag{50}$$

$$c_t = G_1 s_t + G_2 \varepsilon_t + G_3 \hat{\xi}_t. \tag{51}$$

where $F_1, F_2, F_3, G_1, G_2, G_3$ are the unknown conformable matrix which can be solved using standard methods.

[11] As a robustness check, we have also tried to use a negative net foreign asset for the US (but this implies a trade surplus in the US). The steady-state values and the quantitative results of the portfolios and international investment positions are not sensitive to the net foreign asset positions. All of our qualitative results remain valid.

[12] A technical appendix of the deviations is available upon request.

The second step of the procedure involves a second-order approximation to country A and B's optimal portfolio condition to capture the covariance relations. For instance, country A's portfolio choice condition is:

$$0 = E_t\left[\beta\left(\frac{C_{At+1}}{C_{At}}\right)^{-\sigma}\left(\frac{P_{At}}{P_{At+1}}\right)R_{xt+1}\right] \tag{52}$$

and similarly for country B. R_{xt} denotes the excess return. Before capital account liberalisation, since cross-border asset holdings are restricted, the excess return is:

$$R_{xt} \equiv R_{Bt}^S - R_{At}^b.$$

After capital account liberalisation, the vector of excess return becomes:

$$R_{xt} \equiv \left[R_{Bt}^S - R_{At}^b,\ R_{Bt}^b - R_{At}^b,\ R_{At}^S - R_{At}^b\right]'.$$

The second-order approximation of the country A and B's portfolio choice conditions results in the following orthogonality condition:

$$0 = E_t[\left(\sigma\left(\hat{C}_{At+1} - \hat{C}_{Bt+1}\right) + (\tilde{a}_A + \tilde{a}_B - 1)\hat{q}_{t+1}\right)\hat{R}_{xt+1}], \tag{53}$$

where $\hat{q}_t$ is the terms of trade, defined as $\hat{q}_t \equiv \hat{p}_{At} - \hat{p}_{Bt}$, so that a fall in $\hat{q}_t$ is a worsening in the terms of trade in country A, or the US. $\hat{R}_{xt}$ is defined as $\hat{R}_{Bt}^S - \hat{R}_{At}^b$ before capital account liberalisation, and $[\hat{R}_{Bt}^S - \hat{R}_{At}^b,\ \hat{R}_{Bt}^b - \hat{R}_{At}^b,\ \hat{R}_{At}^S - \hat{R}_{At}^b]'$ after liberalisation. Finally, the parameters $\tilde{a}_A$ and $\tilde{a}_B$ are functions of home bias a and steady-state prices and $0 < \tilde{a}_A, \tilde{a}_B < 1$.[13] Equation (53) is a risk-sharing condition. On the right hand side is the covariance between the relative marginal rate of substitution and the excess portfolio return, both in their first-order approximated form. From the first step of the procedure, we know the first-order approximated behaviour of each of these two terms conditional on the steady-state portfolio allocation through $\hat{\xi}_{t+1}$. Hence, this equation can be used to

[13] Specifically,

$$\tilde{a}_A \equiv \frac{a\bar{p}_A^{1-\phi}}{a\bar{p}_A^{1-\phi} + (1-a)\bar{p}_B^{1-\phi}}, \qquad \tilde{a}_B \equiv \frac{a\bar{p}_B^{1-\phi}}{a\bar{p}_B^{1-\phi} + (1-a)\bar{p}_A^{1-\phi}}.$$

back out the unique steady-state portfolio such that the correlation is zero, using a method developed in Devereux and Sutherland (2011).

4. Model Property

In this section, we study the properties of this model in two steps. In the first step, we turn off the price rigidity. We call this model the 'baseline' model. In this case, the model is real, which means that monetary shocks are irrelevant. Consequently, the financial market is complete after capital account liberalisation in China. This helps us explain the intuition behind the portfolio allocation. In the second step, we study the model with nominal rigidities and show that this 'extended' model can give a more reasonable numerical approximation of the portfolio allocation.

4.1 Baseline Model without Nominal Rigidities

In the absence of nominal rigidities, retailers in each country can re-optimise with probability one, *i.e.* $\gamma = 0$. The model collapses to one similar to Coeurdacier et al. (2010) but with different country size and asymmetric shocks. The following discusses the calibrations, computes portfolio holdings and explains the risk-sharing motives behind these allocations.

4.1.1 Calibration

Given the complexity of the model, we solve the model numerically. We choose parameter values to fit the model based on quarterly frequency. We choose the discount factor $\beta = 0.96^{1/4}$ so that the steady-state interest rate is around 4.2% per annum. We set the degree of home consumption and investment bias at $a = 0.75$, which reflects G7 countries' mean import to GDP ratio of about 25%. We set the coefficient of relative risk aversion to $\sigma = 2.5$. The inverse of the Frisch elasticity of labour supply is set to $\omega = 1$, consistent with the estimate by Kimball and Shapiro (2008). The depreciation, δ, is assumed to be 0.025. There is a wide range of estimates for the Armington elasticity of substitution between home and foreign goods. Feenstra et al. (2012) estimate that the macro elasticity is not significantly different from unity but the micro elasticity is much larger. In the portfolio choice literature, common values are slightly above unity. Backus, Kehoe and Kydland (1994) and Engel and Matsumoto (2009) use a value of 1.5, Heathcote and Perri (2002) use 1.2. We use $\phi = 1.1$ for our calibration. All the above calibrated values are well within the range of values used in the macroeconomic literature.

We allow the capital share in production and the level of productivity to be different for the US and China. We use $\kappa_A = 0.35$ for the capital share in the US production function. For the counterpart in China, Brandt, Hsieh and Zhu (2008) estimate that the labour share in production for agricultural and non-agricultural sectors are both in the vicinity of 0.5. Hence, we set $\kappa_B = 0.5$. For the level of

productivity, we normalise the $\bar{\theta}_A = 1$ in the US. According to Zhu (2012), productivity in China is around 13% of that in the US. We set $\bar{\theta}_B$ to be 0.13.

We calibrate the parameters relating to shocks. Coeurdacier et al. (2010) estimate VARs for total factor productivity across G7 countries. Due to a lack of relevant data for China, we follow their estimates of $\rho_\theta^a = 0.75$, $\sigma_{\theta A}^a = 0.012$ and $Corr(\varepsilon_{At}^\theta, \varepsilon_{Bt}^\theta) = 0.45$.[14] Garcia-Cicco et al. (2010) find a higher volatility of productivity shocks in emerging markets. This assumption is taken on board in the portfolio choice problem in Devereux and Sutherland (2009). Shi, Wu and Xu (2012) construct a business cycle model of China and estimate that the $\sigma_{\theta B}^a = 0.017$, which we follow. For the investment efficiency shocks, we are not aware of any empirical estimates for China. So we use the following values estimated by Coeurdacier et al. (2010) for G7 countries: $\rho_\chi^a = 0.79, \sigma_{\chi A}^a = \sigma_{\chi_B}^a = 0.0173, Corr(\varepsilon_{At}^\chi, \varepsilon_{Bt}^\chi) = 0.19$, but also experiment with other values. The correlation between productivity and investment efficiency shocks is set to zero.

4.1.2 Steady State Portfolio before Capital Account Liberalisation

In this section, we consider the optimal portfolio allocation in the system in which only US bonds and Chinese equities are tradable. Given the insight of the optimal portfolio choice Equation (53), we consider the relative marginal rate of substitution and the excess portfolio return when the system is hit by each of the four shocks, assuming that there is no portfolio diversification. This assumption of zero portfolio holding is important because in this case ($\hat{\xi}_t = 0$), the solution to the first-order approximation is known.

Suppose US productivity (ε_{At}^θ) rises. Both consumption and output in the US rise and the real exchange rate depreciates. In China, consumption also rises, but not by as much as in the US. As a result, relative consumption in the US increases. Due to the real exchange rate effect, Chinese equities now pay a higher dividend relative to US bonds. This means that the relative return on Chinese equities is positively correlated with relative consumption in the US, and therefore buying US bonds and selling Chinese equities can hedge productivity shocks stemming from the US. On the

[14] Parameters with superscript 'a' indicate annual frequency. Shock persistences and variances are converted to quarterly frequency using the following transformations:

$$\rho = \rho_a^{1/4},$$

$$\sigma_\varepsilon^2 = \frac{8(1-\rho^2)}{2+3\rho+2\rho^2+\rho^3}\frac{\sigma_{\varepsilon,a}^2}{1-\rho_a^2}.$$

See Guerrieri and Lorenzoni (2011) for details of the transformation.

other hand, when Chinese productivity ($\varepsilon_{Bt}^{\theta}$) rises, relative consumption in the US falls. Holding US bonds is beneficial for two reasons. First, as the Chinese exchange rate depreciates, US prices are higher. Second, Chinese firms increase their investment and hence reduce their dividend payout. Again, US households have an incentive to hold their own bonds for risk-sharing purposes.

When the US receives a positive investment efficiency shock (ε_{At}^{χ}), relative consumption in the US declines because it is optimal to switch consumption for investment. Since US firms use more of their own goods for investment, the real exchange rate appreciates. As a result, Chinese firms reduce their investment and increase their dividend payout. In this case, holding Chinese equities enhances risk-sharing for US households. On the other hand, suppose China receives a favourable investment efficiency shock (ε_{Bt}^{χ}). In order to make room for the rise in investment, Chinese firms reduce their dividends and households reduce their consumption relative to US households. Again, for the US households, Chinese equities provide a better hedge against consumption volatility.

Hence, productivity shocks and investment efficiency shocks induce households to hold a different mix of assets. Since the financial market is incomplete, risk-sharing is imperfect. The optimal portfolio depends on the relative volatility of the two types of shocks. In particular, the more volatile are productivity shocks, the greater the home bias in asset holdings in equilibrium.

As explained in the calibration section, we assume that the volatility of investment efficiency shocks is larger than that of the productivity shocks in a way that is consistent with empirical data.[15] As a result, the steady-state asset portfolio is one in which US households short their own bonds and purchase Chinese equities. We find that $\bar{S}_B^B = 89\%$ and $\bar{b}_A^A = -0.03$. In terms of asset portfolio holdings, US holding of Chinese equities is 39% of Chinese nominal income, whereas Chinese holdings of US bonds as a ratio of US nominal income is about 32%. The numerical values are within reasonable range compared to actual data. In particular, the international investment positions derived here also appears to be consistent with the observed data reported in Figure 1.

4.1.3 Steady State Portfolio after Capital Account Liberalisation

After capital account liberalisation in China, equities and bonds in both of the countries are tradable. Coeurdacier et al. (2010) and Coeurdacier and Rey (2012) analyse similar set-ups. Our model is a generalisation of theirs as we allow for asymmetric country size and different capital shares in production. Nevertheless, we can still borrow insights from these models.

[15] Since there is not much empirical guidance regarding the volatility of investment efficiency shocks in China, we have experimented with other values in robustness checks. As $\sigma_{B\chi}$ is increased from 1.5% to 2.5%, US holdings of Chinese equities as a fraction of Chinese nominal GDP rises from 35% to 49%. The main qualitative results are not affected.

There are two sources of risks in this type of model: real exchange rate risk and non-tradable income risk. Real exchange rate risk relates to a situation in which the real exchange rate depreciates so that foreign goods become more costly. Non-tradable income risk relates to the fact that households earn wage income in their respective countries, which is non-diversifiable. After the liberalisation of the capital account, since there are as many assets as the number of shocks, and asset returns are not linearly dependent, the financial market is complete. An optimal combination of assets can achieve perfect risk-sharing.[16]

What combination of assets achieves perfect risk-sharing? First, notice that the relative payoff of US bonds is just the terms of trade, $\hat{q}_t$, which is perfectly correlated with the real exchange rate. This means that any real exchange rate risks can be hedged against with bonds. This leaves equities the job of hedging non-tradable income risk. Next, it is easy to see that the relative dividend payment depends on output and investment, which is correlated with wage income conditional on the real exchange rate. (See the labour demand Equation (33).) Suppose for example that a combination of exogenous shocks raises the relative investment in the US but leaves the terms of trade unchanged. Then due to investment home bias, relative output rises in the US, raising labour income of US households. On the other hand, US firms reduce their dividend payout relative to Chinese firms in order to increase their investment.[17] This means that wage income and relative dividends are negatively correlated, which makes holding US equities helpful to risk-sharing. For other realisations of shocks that move the terms of trade as well, the correlation between non-financial income and relative dividends conditional on the terms of trade is still negative, so holding local equities is desirable. This is because, as discussed, 'residual' real exchange rate risk has been hedged by bond holdings.

Next, we discuss the holding of bonds. Suppose we ignore non-tradable income risk, then there is a home bias in bonds. A positive productivity shock in the US raises relative consumption and depreciates the real exchange rate; a positive shock to investment efficiency reduces relative US consumption and appreciates the real exchange rate. In both cases, relative consumption is negatively correlated with the real exchange rate.

But wage income and equity income are also dependent of the terms of trade, and when households choose their equity portfolio to insure against non-tradable income risks as described previously, the terms of trade component of this income may have already provided some degree of risk-sharing. Taking into account this contingent income, Coeurdacier et al. (2010) show that theoretically the optimal steady-state portfolio may entail positive or negative holding of local bonds, depending on the preference parameters and the elasticity of substitution between home and foreign goods, ϕ. When the elasticity is high (above unity), terms of trade movements are small in response to shocks, and

[16] This implies that the portfolios after capital account liberalisation do not depend on the volatility, correlation and persistence of shocks.

[17] This can be verified by substituting the goods market clearing conditions into the relative dividend equation.

wage and equity income taken together have only partly offset the need to hedge against real exchange rate risk, and in this case, there is a home bias in bond holdings.

In our calibration, guided by the data before capital account liberalisation, we use a value of ϕ above unity, and steady-state holdings of bonds exhibit home bias. We find that $\bar{b}_A^A = 0.149$ and $\bar{b}_B^B = 0.063$. Moreover, each country takes a positive position in the equities of the other country. We find that $\bar{S}_A^A = 80\%$ and $\bar{S}_B^B = 56\%$. The optimal steady-state portfolios are reported in Table 1. The implied international investment positions are reported in Table 2.

One important advantage of our model over Devereux and Sutherland (2009) is that the optimal steady-state portfolio holding computed in our model exhibits equity home bias, that is:

$$\bar{S}_A^A > \frac{\bar{p}_A \bar{y}_A}{\bar{p}_A \bar{y}_A + \bar{p}_B \bar{y}_B}, \qquad \bar{S}_B^B > \frac{\bar{p}_B \bar{y}_B}{\bar{p}_A \bar{y}_A + \bar{p}_B \bar{y}_B}.$$

Equity home bias is a robust empirical finding by French and Poterba (1991). Our model can generate this feature because shocks generate a redistribution of firm revenue between labour income and dividends, which in turn relies on the introduction of differentiated goods across countries and endogenous capital accumulation. Without differentiated goods, the steady-state portfolios in Devereux and Sutherland (2009) with complete markets are ones with a large foreign equity bias. In their model, as well as Baxter and Jermann (1997), home labour income and home equity returns are positively correlated.

We compare the portfolio holdings before and after capital account liberalisation in China. First, consistent with other research in the literature and empirical evidence (such as Sorensen et al., 2007), financial liberalisation allows better risk-sharing and leads to a reduction in equity home bias. For China, this means that both outward FDI and portfolio investment, and inward FDI and portfolio investment will increase.

Second, the international investment positions in China will rise substantially after the liberalisation. Our numerical results show that the average of external financial assets and liabilities as a ratio to GDP will rise from 39% before the liberalisation to over 300% after the liberalisation.

Third, a perhaps striking result, is that after liberalisation of the Chinese capital account, Chinese holdings of US bonds will decline, from a long position to a large short position. The reason is the following. Before capital account liberalisation, when China receives a positive investment efficiency shock, without any portfolio diversification Chinese consumption has to be reduced to finance investment. Holding Chinese equities yield low dividends for the same reason. Hence, Chinese households are better off saving with the alternative, US bonds. After capital account liberalisation, Chinese households can hold US equities instead, which is a better hedge against non-financial

income risk than US bonds. The large short position in US bonds is then required to reduce exposure to exchange rate risk.

Last, US households, in return, will hold a negative position in Chinese bonds. One way through which non-Chinese residents can hold a short position in renminbi-denominated bonds is by offshore bond issuance. These bonds are sometimes referred to as 'dim sum bonds'. The first dim sum bond was issued in 2007, and since 2010 issuance has grown sharply. The analysis above suggests that, once the capital account in China is liberalised, circulation of renminbi-denominated bonds in international markets will increase substantially. This would be a major boost to renminbi internationalisation.

One may find the international investment position after capital account liberalisation too large. In fact, large quantities of bond holdings are commonly found in endogenous portfolio choice models such as Devereux and Sutherland (2009). The next section incorporates price rigidities into the model, and we show that the extended model yields optimal portfolios of a more reasonable size.

4.2 The Extended Model with Price Rigidities

In the extended model with nominal rigidities, retailers reset prices with a probability $(1-\gamma)$ smaller than one. This implies that monetary shocks have real effects to the macroeconomy and therefore affect optimal portfolio allocation. In the following, we calibrate additional model parameters and re-calculate the optimal portfolio before and after capital account liberalisation in China.

To ensure consistency in our calibrations, we do not change the values for the parameters previously described. There are a number of additional parameters relating to the Phillips curve and Taylor rule. For the fraction of price-resetting firms $(1-\gamma)$, we consider both micro-level data and the macroeconomic literature. Bil and Klenow (2004) analyse disaggregated price data for goods and services in the US and find that on average goods prices adjust every 5.5 months, or 2.18 times a year. However, the macro literature more frequently assumes prices adjust only once a year. We use the average of these numbers, which leads to $\gamma = 0.6$. We assume the same value for China. For the Taylor rule parameter in the US, we use $\varphi_{A\pi} = 1.5$. As for China, He and Pauwels (2008) show that the PBC's implicit policy stance can be represented by a quasi-policy rule akin to the Taylor rule. We follow their estimates to use $\varphi_{B\pi} = 1.382$.

The monetary shocks are calibrated as follows. We use a persistence of $\rho_m^a = 0.4$ for both countries. Also, we assume $\sigma_{mA}^a = 0.0065$ in the US. These values are in line with Juillard et al. (2006) in which monetary policy shocks in the US are estimated within a DSGE framework. Further, we assume China has the same distribution of shocks in monetary policy and that $Corr(\varepsilon_{At}^m, \varepsilon_{Bt}^m) = 0.2$.

The optimal portfolio allocations and international investment positions are computed and reported in Table 3 and 4 respectively. The optimal portfolio has identical signs to the baseline model. This means that before capital account liberlisation, the optimal portfolio implies a 'long debt, short equity' feature in China's international balance sheet as in the baseline model. After liberalisation, it remains true that Chinese residents hold a positive quantity of US equities and a short position in US bonds, and that US residents hold a positive amount of Chinese equities and a short position in Chinese bonds. Furthermore, other features of the portfolio holdings described in the baseline model remain true in this extended model.

In addition, the extended model shows that as price rigidity γ rises, the size of the optimal asset portfolio after liberalisation falls. The reason is the following. Suppose a combination of shocks hits the Chinese economy which raises the intermediate goods prices ($\widetilde{p}_{it}$) in China while keeping the real output unchanged up to a first-order approximation. Given the Cobb-Douglas production function, nominal wages rise by the same proportion. In the presence of price rigidities, some retailers cannot reset their prices and the price of final goods rises by less than the amount required in the flexible price economy. This means that the real wage rises by more. Moreover, as a result of price rigidities, the price of investment goods rises by less, investment increases and dividends fall relative to the flexible price economy. This means that the real wage and relative dividends become more negatively correlated. From the discussion in the previous section, a more negative correlation implies more home bias in equity holdings.

In terms of bond holdings, recall that bonds are used to insure against exchange rate risk. Households reduce their holdings of home currency denominated bonds in the presence of price rigidities for two reasons. First, the rigidity reduces the fluctuation in the real exchange rate and the need to hedge against it. Second, as discussed in the previous section, bonds are used to hedge against 'residual' exchange rate risk after taking into account the exchange rate hedging effect provided by equities. As households' equity portfolio become more home biased, the equity portfolio provides much of the insurance against exchange rate risk, so there is less need to buy home bonds.

5. Comparative Statics

In this section, we apply the extended model to consider two economic transitions that are likely to happen in China in the future and study the implications for the optimal asset portfolio and asset holdings between China and the US. We study two scenarios. In the first, we consider an internal rebalancing in China which reduces the capital share in production and increases the share of labour income. The second scenario considers a sustained rise in productivity in China relative to the US.

5.1 China Moves to a More Labour-Intensive Production

China is likely to rebalance its production with a higher share of labour income in future for two reasons. First, China at the moment has a large capital-intensive manufacturing sector, leading to a capital share of about 0.5 (Brandt et al. 2008), which is much higher than the G7 average of about 0.35. Following the experience of developed economies, a continuing transition is likely to move more workers towards the labour-intensive service sector. This will lower the capital share in production. Second, Song et al. (2011) and Brandt et al. (2010) argue that the state sector has a significantly higher capital-to-labour ratio than the non-state sector. As rebalancing takes place and capital market distortions are being removed, the capital-to-output ratio is likely to fall. In terms of the model, the transition is captured by a rise in the labour share in Chinese production, or a fall in κ_B.

Simulation results are shown in Figure 2 and Figure 3. The red solid lines in Figure 2 report the steady-state portfolio in the economy for different values of κ_B before capital account liberalisation. The key result is that when China shifts its production towards a labour-intensive service-based one, Chinese households hold more of their own equities and fewer US bonds. This reduces foreign asset holdings, which reduces asymmetry in China's international balance sheet. The reason is simple. As the steady-state capital-to-output ratio is lower, investment efficiency shocks become less important in China, *ceteris paribus*, relative to productivity shocks. When households care more about productivity shocks, they raise their holdings of Chinese equities and reduce their holdings of US bonds, reducing their investment positions. The red solid line in Figure 3 shows the corresponding international investment positions. The simulation results suggest that, *ceteris paribus*, when the capital share κ_B falls from 50% to, say, 35%, consistent with the value in major advanced economies, US holdings of Chinese equities as a ratio of Chinese output will fall by half, from 38% to 19%.

If the rebalancing occurs after capital account liberalisation in China, we obtain a similar qualitative result: that the international investment positions will decline. The blue 'dash-dotted' lines in Figure 2 and Figure 3 show the optimal portfolio and international investment positions for different values of κ_B after capital account liberalisation. A rise in the labour share in production means that more production revenue goes to the wages. Consequently, the non-diversifiable income risk for Chinese households become more severe. Chinese households switch their portfolio towards equities (both Chinese and US) in order to hedge against non-financial income risk. Larger holdings of equities have compensated for some real exchange rate risk, so there is a shift of the portfolio away from bonds. Quantitatively, when the capital share κ_B falls from 50% to 35%, US holdings of Chinese equities declines from 66% of Chinese output to 36%.

5.2 Productivity Growth in China

We also analyse the situation in which the level of productivity in China catches up with that of the US. Using growth accounting techniques, Zhu (2012) estimates that current productivity in China is very

low (13%) relative to the US. He argues that through gradual and persistent institutional reforms and policy changes that reduce distortions and better align economic incentives, productivity in China is likely to experience sustained growth in the near future, relative to the US. We therefore do a comparative statics analysis by increasing the steady-state level of productivity in China $\overline{\theta}_B$.

Figure 4 and Figure 5 summarize the simulation results of this exercise. The red solid lines in Figure 4 report the steady-state portfolio for different values of Chinese productivity before capital account liberalisation. The effect of a relative rise to Chinese productivity is similar to a fall in the share of capital in output: Chinese households hold a larger fraction of domestic equities. The reason is that a rise in Chinese productivity increases the relative importance of productivity shocks, which can be insured by holding a larger fraction of wealth in domestic equities. The numerical results for the corresponding international investment positions are displayed in Figure 5. Suppose China replicates its extraordinary growth performance for another two decades, so that by the end of this period the productivity gap narrows to about 0.4. In this case, US holdings of Chinese equities decline modestly from 38% to 33% of Chinese output. On the other hand, Chinese holdings of US bonds as a ratio of Chinese output fall by the same amount.

The blue dash-dotted lines in Figure 4 and Figure 5 report the steady-state portfolio and international investment positions respectively for different values of Chinese productivity after capital account liberalisation. Chinese households hold a larger share of US equities as steady-state productivity rises. The quantitative effects are small, however, because the elasticity of substitution between home and foreign goods is close to unity.

The bottom line of these comparative statics analysis is that as China rebalances its economy with a higher share of labour income and experiences further economic growth, the asymmetry in China's international balance sheet is likely to be moderated. In particular, China will increase its FDI and portfolio equity investment in the US. Moreover, in the long run, as long as the Chinese economy maintains a fast rate of growth and greater integration with the global economy, we may see growing popularity of renminbi-denominated bonds in international bond markets.

6. Conclusions

In this paper, we constructed and calibrated a microfounded model with multiple assets to study the optimal portfolio choice before and after capital account liberalisation in China. The model is able to generate a ‘long debt, short equity’ portfolio in China before liberalisation, something which is consistent with observed data. We then used the model to predict the portfolio choice after capital account liberalisation and obtained results that broadly agree with the ones in the empirical literature (such as He et al., 2012). Our results suggest the following after capital account liberalisation in China:

1. Portfolio equity and FDI flows, both into and out of China, will increase significantly.

2. China as a whole will reverse its US bond holdings, from a long position currently to a short position.

3. The US as a whole will take a short position in Chinese bonds.

4. Continued economic growth in China and a reduction in the capital share in production can help to rebalance China's international balance sheet.

This set of results has important implications for the internationalisation of the renminbi. Based on this model, non-Chinese residents will have an incentive to issue renminbi-denominated bonds for risk-sharing purposes. Ultimately, we can envisage an international monetary system in which the private and public sectors use other major currencies such as the renminbi as both investment and funding currencies along with the US dollar.

There are a number of caveats to our analysis and results. First, given the simple nature of the model, it does not capture every important feature of the international monetary system (such as the existence of other countries and curriencies), and our numerical results should not be viewed as accurate predictions regarding future portfolio allocation and international investment position. Rather, in this paper we emphasise qualitative changes after Chinese capital account liberalisation as well as the risk-sharing motives behind these changes. For more realistic quantitative results, one would need a three-country model and financial frictions in Chinese financial markets would have to be explicitly modelled.

Second, in this paper we focused on the deterministic steady state in the general equilibrium model. This means that equities and bonds in this steady state have equal returns. (Otherwise, the assets with higher return will be in excess demand, which cannot be an equilibrium.) Hence, this model does not generate any equity premium and does not take account of the 'exorbitant privilege' of the US which reflects the fact that US external asset returns tend to be higher than for other countries.[18] Without excess asset returns in the steady state, our model cannot generate both a net foreign liability position and a trade deficit for the US.

Third, the analysis assumes either fully open or fully closed capital accounts. This means that it does not deal with transition dynamics, or capital flow management measures, that can be adopted in the face of disruptive flows during the process of capital account liberalisation. In addition, barriers to capital flows such as transaction costs, information costs and other non-policy barriers are not modelled in the analysis. We leave these issues for future research.

[18] See Gourinchas et al. (2010) for a model that studies the exorbitant privilege.

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Table 1. Steady-State Portfolio in the Baseline Model Without Nominal Rigidities

Before Chinese capital account liberalisation:				
Steady-state Portfolio	$\bar{S}_A^A$	$\bar{S}_B^B$	$\bar{b}_A^A$	$\bar{b}_B^B$
Values	1 *	0.89	-0.03	0 *
After Chinese capital account liberalisation:				
Steady-state Portfolio	$\bar{S}_A^A$	$\bar{S}_B^B$	$\bar{b}_A^A$	$\bar{b}_B^B$
Values	0.80	0.56	0.149	0.063

* Model restriction.

Table 2. Steady-State International Investment Positions in the Baseline Model Without Nominal Rigidities

	Before Liberalisation	After Liberalisation
US holding of Chinese equity to Chinese nominal income	39%	161%
Chinese holding of US bond to Chinese nominal income	39%	-192%
US holding of Chinese bond to Chinese nominal income	0*	-291%
Chinese holding of US equity to Chinese nominal income	0*	63%

* Model restriction.

Table 3. Steady-State Portfolio in the Extended Model with Nominal Rigidities

Before Chinese capital account liberalisation:				
Steady-state Portfolio	$\bar{S}_A^A$	$\bar{S}_B^B$	$\bar{b}_A^A$	$\bar{b}_B^B$
Values	1 *	0.90	-0.029	0 *
After Chinese capital account liberalisation:				
Steady-state Portfolio	$\bar{S}_A^A$	$\bar{S}_B^B$	$\bar{b}_A^A$	$\bar{b}_B^B$
Values	0.89	0.82	0.037	0.017

* Model restriction.

Table 4. Steady-State International Investment Positions in the Extended Model with Nominal Rigidities

	Before Liberalisation	After Liberalisation
US holding of Chinese equity to Chinese nominal income	38%	66%
Chinese holding of US bond to Chinese nominal income	38%	-48%
US holding of Chinese bond to Chinese nominal income	0*	-80%
Chinese holding of US equity to Chinese nominal income	0*	35%

* Model restriction.

Figure 1. China's International Investment Positions

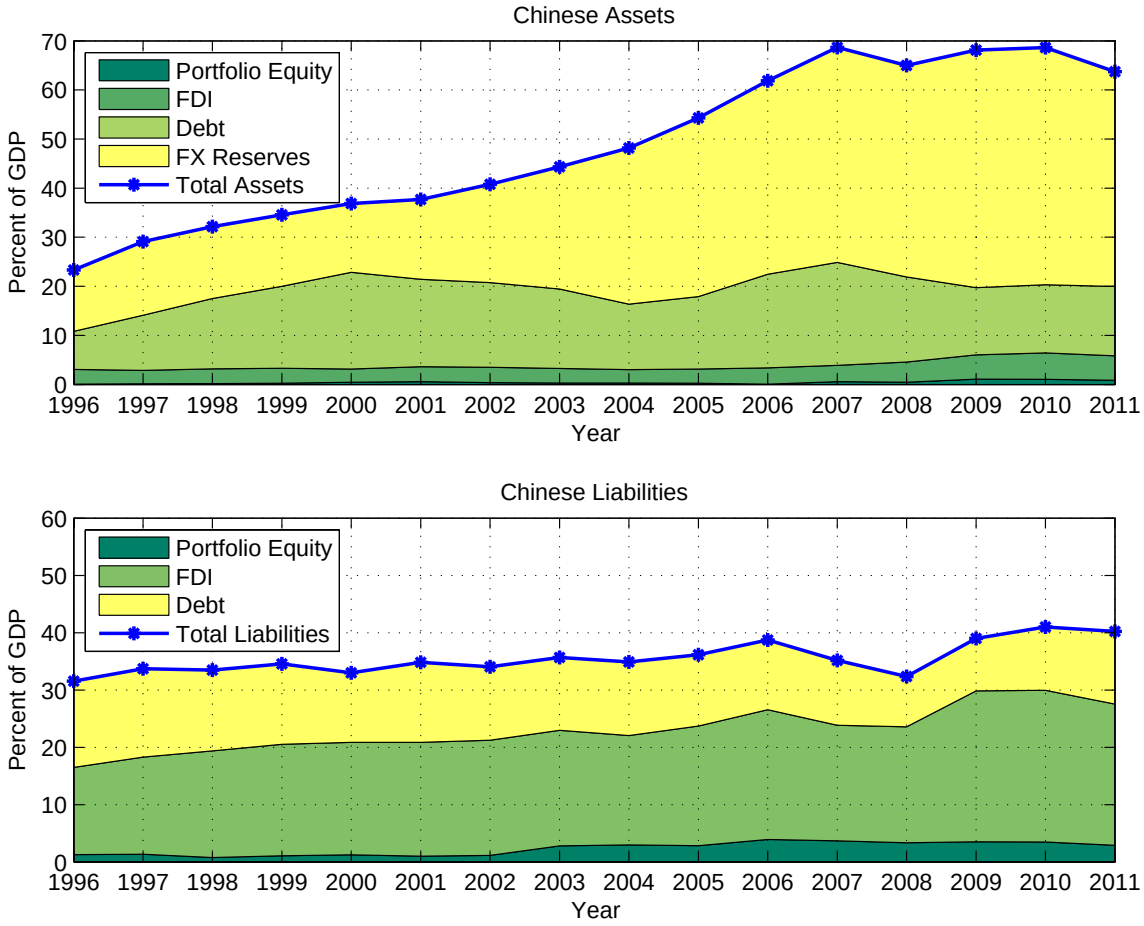

Figure 2. Asset Portfolios when China Moves to a More Labour-Intensive Production

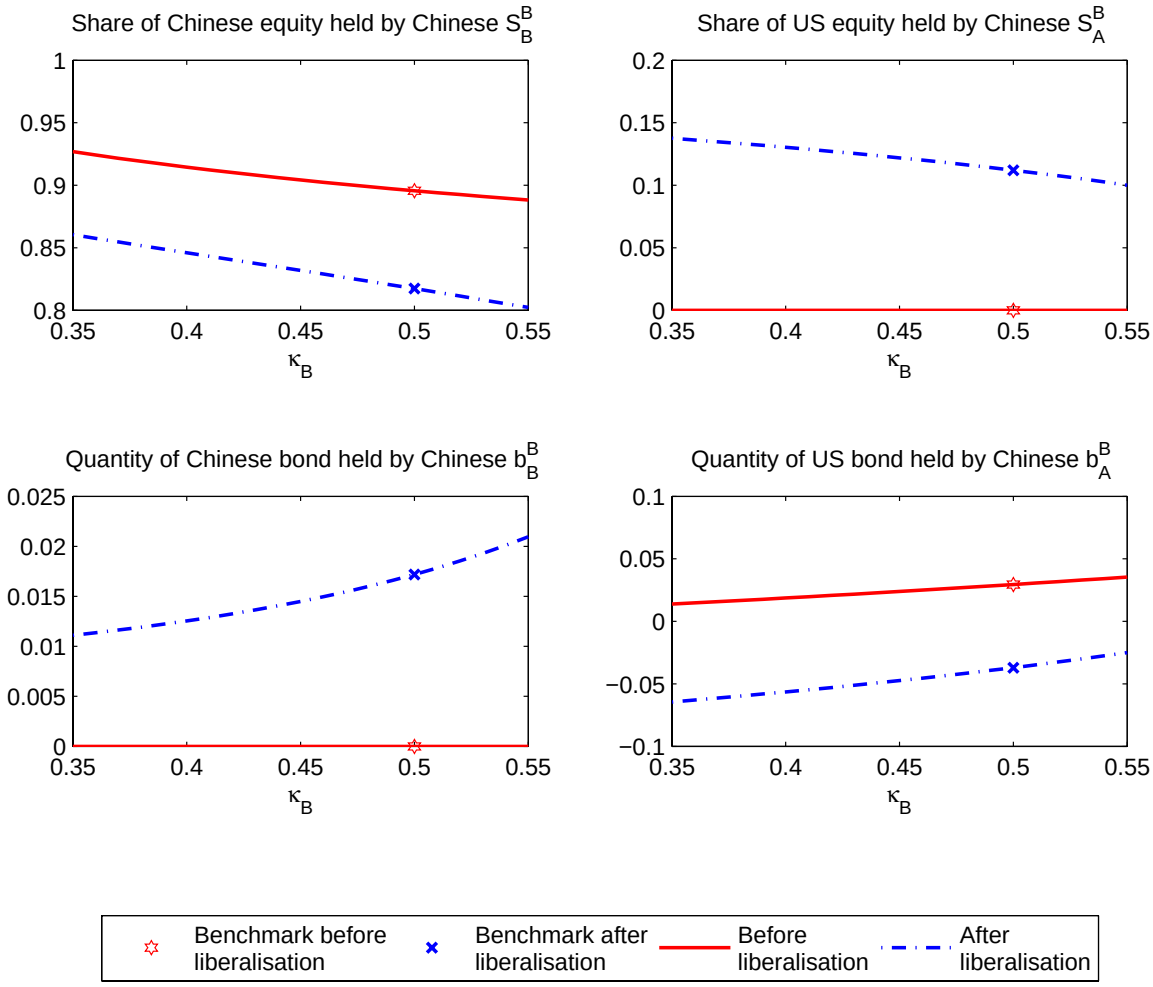

Figure 3. International Investment Positions when China Moves to a More Labour-Intensive Production

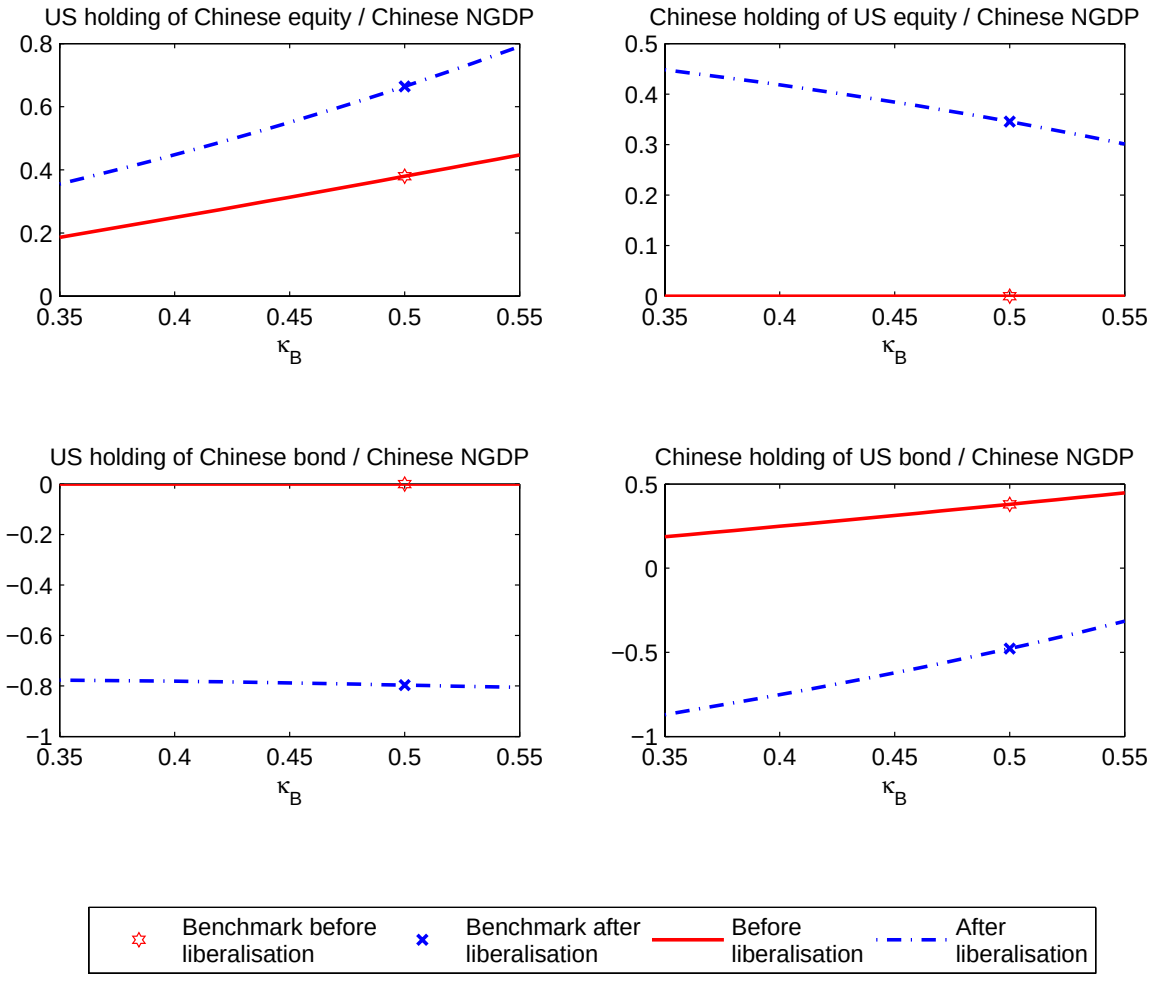

Figure 4. Asset Portfolios as Productivity in China Catches Up

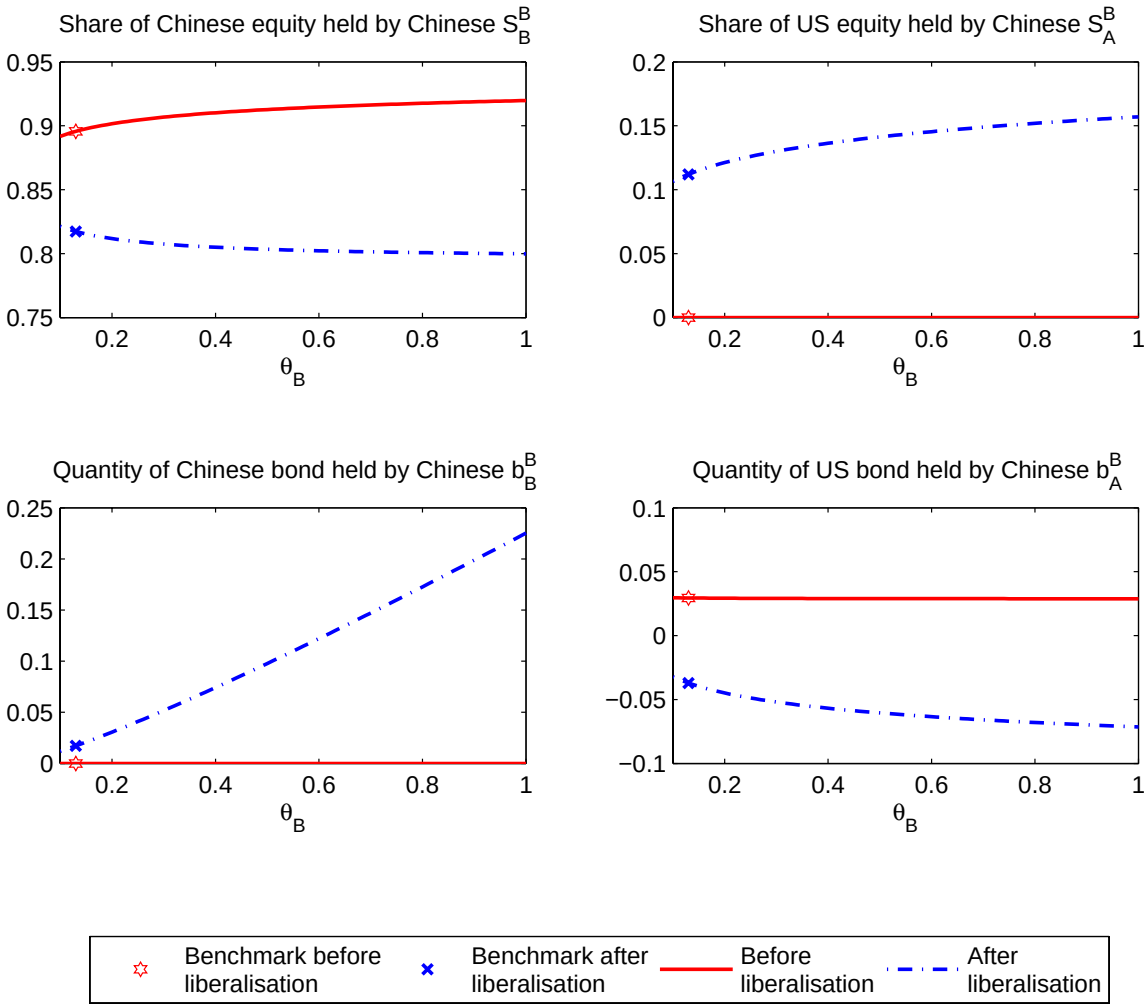

Figure 5. International Investment Positions as Productivity in China Catches Up