Asset home bias in debtor and creditor countries

Ning Zhang*

January 2019

Abstract

Emerging and developing countries have a less diversified international portfolio than developed countries (Coeurdacier and Rey, 2013). This paper explores the hypothesis that this actually reflects a stronger preference of a creditor country for the local asset than of a debtor country. We first document a significantly positive relation between a country's NFA and its degree of portfolio home bias, and then develop an asymmetric two-country model to show that: (1) when net external positions are unbalanced, countries have an incentive to hedge against the risk associated with international interest payments; (2) depending on their status on external payments, the hedging works the opposite way in the two countries; and (3) taking the local asset as an example, the hedging is positive in the creditor country while negative in the debtor country so the creditor country will demand more local asset than the debtor country.

Keywords: International portfolio choices, Global imbalances, Asset home bias.

JEL Codes: F32, F41

---

*I thank Gianluca Benigno, Richard Dennis, Pierre-Olivier Gourinchas, Tatiana Kirsanova, Campbell Leith, Charles Nolan, Neil Rankin, Ozge Senay, Alan Sutherland and seminar participants at various institutions for helpful comments. Financial support from the ESRC, Grant No. ES/I024174/1, and University of St Andrews is gratefully acknowledged. The full paper appendix are available upon request.
Address: Adam Smith Business School, University of Glasgow, Glasgow, United Kingdom, G12 8QQ. E-mail: ning.zhang.2@glasgow.ac.uk.

1 Introduction

Despite increased financial integration, assets are mostly held domestically.[1] In developing and emerging economies, this asset home bias has been even more salient (Coeurdacier and Rey, 2013): the bias degree in these countries has, on average, been around 15% higher than in developed countries over the last few decades.[2] At the same time, these countries have been also experiencing a 'dramatic improvement' in their net external position as compared to developed countries (Lane and Milesi-Ferretti, 2007). This paper explores the possibility that the asset-bias gap between developing and developed countries actually reflects the difference between creditor and debtor countries. That is, an emerging creditor country needs to hold more domestic assets as required by optimal risk-sharing, which prevents its degree of home bias from declining.

We examine the empirical relevance of this hypothesis by first looking at some cross-country evidence from the late 1980s. Through OLS regressions, we find a very significant positive correlation between one country's degree of home bias and its GDP-scaled NFA. The significance of the relation remains after we control for a series of other factors that may affect the degree of international diversification. In particular, we include the country's trade openness, per-capita GDP and population to control for the effects of integration level, development stage and country size on the bias level. We also exploit a panel data in our investigation. The evidence from both the time-average and panel data regressions generally supports the above hypothesis.

To uncover the casual link between the degree of home bias and net external imbalances, we develop a model of net and gross country portfolios based on a workhorse international macro model (Backus et al., 1994, 1995). According to the recent literature

[1]See, e.g., French and Poterba, 1991, Cooper and Kaplanis, 1994 and Tesar and Werner, 1995, etc, for early contributions.

[2]Coeurdacier and Rey (2013) find that 'emerging markets have less diversified equity portfolios than developed countries and do no exhibit any clear downward trend in home bias'. They also find **a** similar pattern for the bond portfolios. On average, around 70% of the equity are held locally in developed countries while it is 84% for developing and emerging countries (Table 1 of Sercu and Vanpee, 2007, 2008). Using a different measure, i.e. the difference between 1 and the ratio of the share of foreign equity in a country's portfolio over that in the world portfolio to measure the home-bias degree, Coeurdacier and Rey (2013) find an average degree of home bias of 0.9 in emerging and developing countries, which is around 20 percent higher than in developed countries.

on gross country portfolios, in such a framework, the presence of non-tradable income risks accounts for the emergence of home bias (Heathcote and Perri, 2013, Coeurdacier et al., 2010), while according to the literature on net external imbalances, the unequal amount of non-tradable risks across countries contributes to global financial imbalances (Caballero et al., 2008, 2017, Jin 2012). However, these two strands of literature do not formally interact in the sense that the former focuses on identical countries (so that the home bias is symmetric) while the latter typically abstracts from the problem of country portfolios by assuming either only one asset traded internationally or a fully complete asset market (Coeurdacier and Rey, 2013). This paper considers differing non-tradable risks in a two-country portfolio model to allow unbalanced net positions to impact on otherwise symmetrically biased gross positions, from which the pattern of an asymmetric asset home bias arises endogenously.

Specifically, we follow the literature by assuming that the two countries are different such that in the home developed country, financial wealth accounts for a relatively larger proportion of total wealth than in the foreign developing country. We use this asymmetry to capture some deeper aspects that differ between developed and developing countries, meanwhile admitting their role in directing international capital flows. For instance, Caballero et al. (2008, 2017) attribute this to financial development while Jin (2012) relates this to industrial structure. According to the first type of explanation, many factors of financial and social development influence the stock of financial assets that finally formed in the economy by affecting the pledgeability of future income streams. Important reasons include those related to the development of financial markets, the quality of the law system (especially those associated with the protection of property rights), public and corporate governance, etc, which tend to be relatively poor in developing countries and result in a relatively lower asset stock share. This asymmetry may also reflect the possible difference in industrial structure. As argued by Jin (2012), in an economy mainly relying on tea gathering, the country would be more likely to feature a large share of labour income. This international dispersion of industrial structure also underlies the argument of comparative advantage and is widely used in the analysis of international trade.

The differing development of the home and foreign countries, embodied by the assumed asymmetry in wealth division, drives the upstream net capital flows in the model. The home developed country, with a relatively high level of asset supply and facing an excess asset demand from the foreign developing country, ends up being a net debtor while the foreign emerging country is a creditor. What do these persistent global NFA imbalances imply for international diversification? It yields an asymmetric portfolio allocation: while local assets are preferred in both countries, the degree of home bias is higher in the creditor developing country than in the debtor developed country, as observed in the data.

Why is this? As is well known, when distinguishing between labour and financial incomes, the portfolio holdings consist of labour hedging and self-hedging (Baxter and Jermann, 1997). A portfolio home bias emerges due to a positive labour income hedging that offsets the negative self-hedging in a country's holding of domestic assets (Heathcote and Perri, 2013, Coeurdacier et al., 2010, etc.). When countries are identical, these hedging terms are equal in the two countries, i.e. the same degree of home bias in both countries. When country development differs, however, the bias remains but is more (less) salient in the foreign (home) country because: (1) with the attendant global imbalances, optimal country portfolios need to hedge against risks associated with net external imbalances in addition to the aforementioned self-hedging and labour hedging; (2) this additional hedging in the two countries has opposite signs due to their opposite status in international payment; (3) taking a country's holding of domestic assets as an example, it is negative in the debtor country while positive in the creditor country.

The paper is organized as follows. In Section 2, we provide some empirical evidence on the positive relation between a country's net external asset and its degree of home bias. We present our theoretical model in Section 3 and its qualitative implications for country portfolios in Section 4. The model is calibrated and robustness-checked in Section 5. Section 6 concludes the paper.

2 Data pattern

We motivate our theory by looking at the cross-country evidence on the relation between a country's net external position and its degree of asset home bias.

We define and discuss how we measure the two variables first. The net external position is defined as NFA per GDP. In order to measure the bias degree, we follow the literature by relying on the basic international capital asset pricing model ($ICAPM$) to construct an index that measures how far the actual portfolio deviates from the $ICAPM$

benchmark.[3] Under the $ICAPM$, all investors should hold the world market portfolio. That is, the share of domestic assets in each country's portfolio should be equal to that of the world portfolio (correspondingly, the share of foreign assets in the country portfolio is also equal to that of the world portfolio). Or, more conveniently, in each country, the share of the domestic capital stock that is owned by domestic investors should be equal to $1/N$ where N denotes the number of countries in the world.[4] Therefore, one can use the following two approaches to construct the index. Along the first approach, one defines, e.g. Sercu and Vanpee (2007, 2008)

$$\pi_{1h} = \frac{\text{Share of home asset in country i's portfolio}}{\text{Share of home asset in the world market portfolio}} - 1$$

Under the $ICAPM$, the first ratio on the right-hand side equals 1. The index becomes 0, which means no portfolio home bias at all. The higher the index, the further the related allocation is from that implied by the $ICAPM$ (i.e. a higher degree of home bias). Following the same logic, one can define, e.g. Coeurdacier and Rey (2013)

$$\pi_{1f} = 1 - \frac{\text{Share of foreign asset in country i's portfolio}}{\text{Share of foreign asset in the world market portfolio}}$$

These two indices should make consistent predictions. But this is not always true,[5] which undermines either of them as a good measure of the bias degree. In fact, taking into account heterogeneous market capitalisation, π_{1h} tends to overstate the home bias while π_{1f} understates it for a country of lower capitalisation.[6] Along the second approach, one can define

$$\pi_{2h} = \text{Share of domestic asset held domestically} - \frac{1}{N}$$

$$\pi_{2f} = \frac{N-1}{N} - \text{Share of domestic asset held by international investors}$$

which are free of this inconsistency problem. Therefore, throughout this paper, we use the share of the domestic capital stock held domestically as the index of the home-bias degree.[7]

[3] See survey papers by, for instance, Sercu and Vanpee, 2007 and Coeurdacier and Rey, 2013.

[4] See Panel A of Figure 1 as an example.

[5] See Panel B of Figure 1 as an example.

[6] The opposite happens for a country of higher capitalisation, see Figure 1 as an example.

[7] $1/N$ disappears because it is the same for all countries.

For the explained reason, i.e. π_{1h} and π_{1f} overstate or understate the home bias depending on whether a country has a lower or higher market capitalisation, our result in this paper becomes more robust if π_{1h} is adopted. Our result does not necessarily hold if π_{1f} is adopted.

In our samples, we include the countries for which we can find consistent data of the above two measures.[8] The final sample is composed of 17 developed countries and 17 emerging countries (Appendix A). The sample period spans over the two decades before the last global crises, $1987-2007$, which is slightly longer than that of similar studies by Heathcote and Perri (2013) and Mukherjee (2015).

Like Heathcote and Perri (2013), we interpret the asset in our theoretical model to be any asset that represents a claim to country output. Thus, to construct the index of home bias, defined by '(Value of capital stock - Total external liabilities)/Value of capital stock', we need the data on gross foreign liabilities and the total value of the asset stock. We obtain the data on gross external assets/liabilities (and NFA positions) from the exhaustive data set collated by Lane and Milesi-Ferretti (2007). For the total value of the asset stock, before 1990, we use the formula of 'Value of capital stock = GDP$\times$Capital output ratio' where the 'Capital output ratio' is directly taken from Dhareshwar and Nehru (1995). For those after 1990, we follow Heathcote and Perri (2013) in computing it using the perpetual inventory method. To apply this method, we require output and investment data which are obtained from the World Bank development indicators. The other macroeconomic series, such as those of total population and international trade, are also obtained from the World Bank.

Figure 2 plots the time averages of the degree of home bias across countries against that of net external positions. The data, first of all, confirm that the asset home bias is a prevalent fact in international investment. Then, we observe that a country with a higher net external surplus tends to have a deeper home bias. We add a line in the figure to represent the best linear fit for the data, which makes this positive relation clearer.

We use OLS regressions to test the significance of the above relation, see Table 1. In column (1), we report the result of the regression when the regressor contains only the net external positions. It appears that NFA/GDP and the home-bias degree are very significantly correlated, with a positive coefficient of 0.203. Like Heathcote and Perri (2013), in columns (2) to (4), we control for trade openness, output and country size that may have effects on gross portfolio choices. In addition, we add a dummy of developing country to allow these effects to differ between the developing and developed countries. It turns out that the above correlation is still significant. The associated

[8] Due to the special role of some countries as a financial centre, a few samples are dropped out.

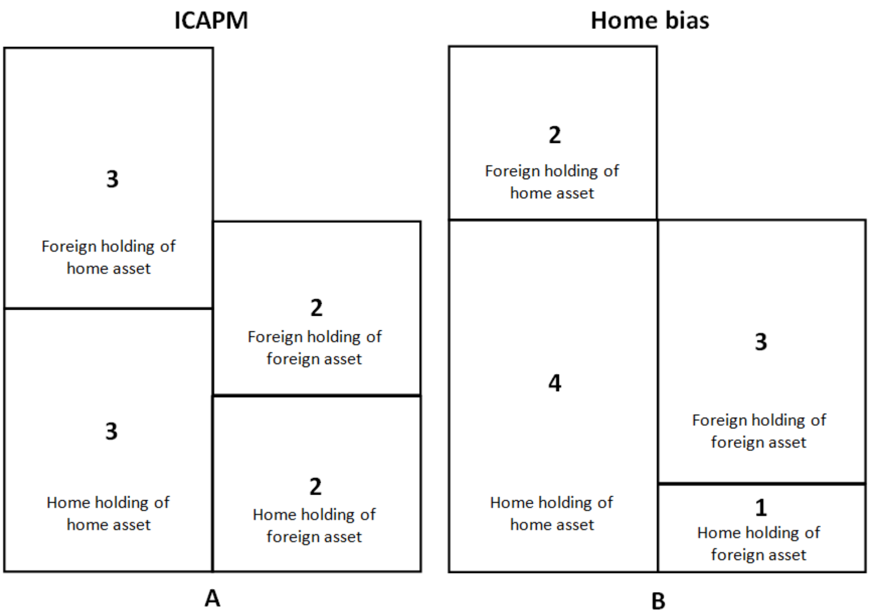

Figure 1: International portfolio allocations: Full diversification and home bias. Note: Assume two countries with a market capitalisation of 6 (home) and 4 (foreign), respectively. The optimal portfolio (ICAPM) will be such that (Panel A): in net terms, the home holdings of home and foreign assets are 3 and 2 and the foreign holdings of foreign and home assets are 2 and 3. The share of the domestic asset in the country portfolio is equal to that of the world portfolio, 3/5 in the home country and 2/5 in the foreign country. The share of the domestic asset held locally is 1/2 for both countries. Consider a case of home bias (Panel B) where each country holds one unit more of the local asset for the same market capitalisations: in net terms, the home holdings of home and foreign assets are 4 and 1 and the foreign holdings of foreign and home assets are 3 and 2. In the home country, $\pi_{1h} = 1/3$ is lower than that in the foreign country $\pi^*_{1h} = 1/2$, indicating a higher bias degree in the foreign country. By contrast, in the home country $\pi_{1f} = 1/2$ is higher than that in the foreign country $\pi^*_{1f} = 1/3$, suggesting, however, the opposite conclusion.

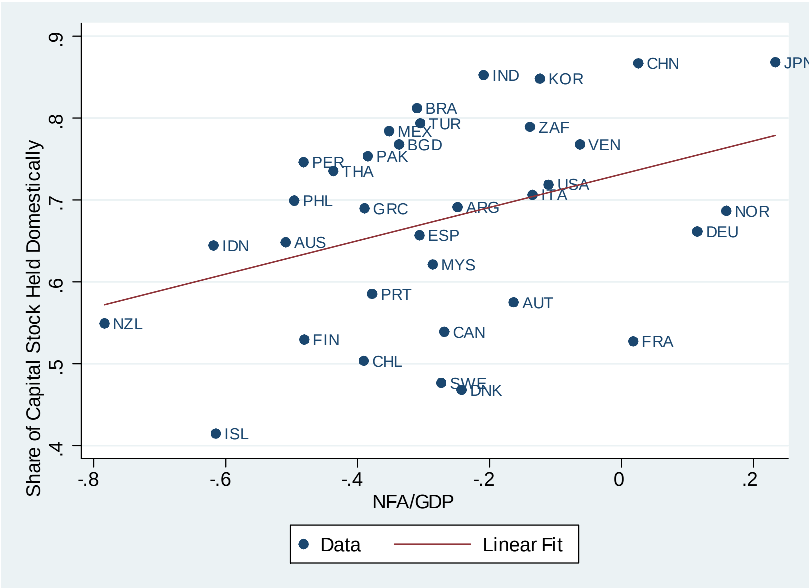

Figure 2: Net external position versus Portfolio home bias

	(1)	(2)	(3)	(4)	(5)	(6)
NFA per capita	0.268***	0.243***	0.303***	0.324***	0.315***	0.295***
	(0.0512)	(0.0493)	(0.0480)	(0.0439)	(0.0448)	(0.0489)
Trade openness		-0.466***	-0.414***	-0.435***	-0.460***	-0.441***
		(0.0540)	(0.0403)	(0.0437)	(0.0437)	(0.0403)
Log GDP per capita			-0.134***	-0.149***	-0.103***	-0.0875***
			(0.0131)	(0.0124)	(0.0176)	(0.0192)
Log population				-0.0213	-0.0201	
				(0.0160)	(0.0160)	
Developing country					0.0674***	0.0686***
					(0.0189)	(0.0188)
Constant	0.749***	0.862***	1.393***	1.625***	1.404***	1.181***
	(0.0141)	(0.0160)	(0.0588)	(0.154)	(0.160)	(0.0894)
Observations	714	714	714	714	714	714
Adjusted R^2	0.111	0.216	0.364	0.365	0.370	0.369

Table 1: Asset home bias and external imbalance: Time average. Robust standard errors in parentheses. ***, **, * represent significance at the 0.01, 0.05, 0.1 level respectively.

	(1)	(2)	(3)	(4)	(5)
NFA per capita	0.398**	0.409**	0.418***	0.419***	0.385***
	(0.179)	(0.154)	(0.149)	(0.152)	(0.135)
Trade openness		-1.632***	-1.112**	-1.090*	-0.214
		(0.373)	(0.522)	(0.571)	(0.348)
Log GDP per capita			-0.524	-0.510	0.276
			(0.425)	(0.423)	(0.198)
Log population				-0.0890	2.726***
				(0.560)	(0.603)
Constant	0.785***	1.209***	3.140*	3.752	-20.54***
	(0.0489)	(0.107)	(1.590)	(4.298)	(4.857)
Observations	714	714	714	714	714
Countries	34	34	34	34	34
Adjusted R^2	0.119	0.407	0.424	0.424	0.630
Country FE	YES	YES	YES	YES	YES
Year dummies					YES

Table 2: Asset home bias and external imbalance: Panel data. Robust standard errors in parentheses. ***, **, * represent significance at the 0.01, 0.05, 0.1 level, respectively.

coefficients are always positive, with their values varying across specifications, but do not change radically as compared to column (1). We also comment on the coefficients of these additional variables. Similar to the findings of Heathcote and Perri (2013), the trade openness of a country tends to be negatively associated with the home bias. This is because the more open is the country, the higher is the level of risk-sharing provided by terms-of-trade responses, which makes a more biased portfolio less required (Cole and Obstfeld, 1991). Heathcote and Perri (2013) do not find a significant effect of per-capita output on portfolio diversification, while we obtain an accurate estimate here. This is due to our inclusion of a group of emerging markets in the sample. The associated coefficient is below zero, in line with the observation that low-income countries tend to have a less-diversified portfolio. Similar interpretations apply to the positive coefficient of developing countries. However, the magnitude of these effects is relatively small as compared to that of NFA/GDP. To interpret this, even though the net external imbalances have roots in a country's underdevelopments, once the imbalances are controlled, the effects contributed by the remaining country differences are limited. We view this as evidence supporting the idea that the net portfolio global imbalances matter more in explaining a gross portfolio home bias. Like Heathcote and Perri (2013), we do not find any significant effect of country size on the degree of asset home bias. We get rid of this factor. The result of our preferred model in column (6) shows that a 1% increase of NFA/GDP is associated with around a 0.3 percentage increase of the bias degree in the data.

Besides, we make use of the panel data for analysis, attempting to check if the evolution of net external imbalances is closely related to the variations of the degree of portfolio diversification as our hypothesis would suggest. We use the same set of controls as above, see Table 2. The coefficients of NFA/GDP are always positive (with a value of around 0.4) and very accurately estimated, indicating that an improvement of net external positions significantly strengthens the preference for domestic assets.

To sum up, we find that debtor (creditor) countries tend to hold less (more) home assets in their portfolios. We develop a model of country portfolios to explain why this is the case.

3 A model of net and gross country portfolios

Consider an open economy of two countries, Home and Foreign. Each country is populated by the infinitely lived OLG households à la Weil (1989). That is, a population of measure 1 is born at time $t = 0$ and then grows at a net rate of n (the gross rate defined as $\tilde{n} \equiv 1 + n$). Any per-capita variable x can then be obtained by aggregating individual variables x_t^v via

$$x_t = \frac{x_t^0 + nx_t^1 + n\tilde{n}x_t^2 ... + n\tilde{n}^{t-1}x_t^t}{\tilde{n}^t}$$

where v and t of x_t^v denote vintage and time respectively.

The rest of the model follows Backus et al. (1994, 1995) and, more recently, Heathcote and Perri (2013) with international portfolios.[9] As compared to Heathcote and Perri (2013), the innovative aspects of our model are to introduce differing country developments, specified below, and the above OLG structure.[10] We present the whole model now.

3.1 Households' problem

Households of vintage v have a total utility function at time t

$$U_t^v = E_t \sum_{i=0}^{\infty} \beta^i \left[\log \left(c_{t+i}^v \right) + \gamma \log \left(1 - h_{t+i}^v \right) \right]$$

where c_t^v and h_t^v denote individual consumption and labour supply. β and γ are respectively the intertemporal discount factor and a weight controlling the relative importance of consumption and leisure.

[9] For a brief description of the model structure: in each country, households make decisions on consumption, portfolio and labour supply. Domestic capital and labour cannot be traded internationally. They are used within the border by firms to produce a country-specific intermediate good, with their production technologies being hit by stochastic shocks. The two intermediate goods are then traded internationally to produce the final goods that are ready for use. In terms of financial markets, two equity-style assets are traded, respectively representing claims on the profit made by the intermediate-good producers in each country.

[10] The differing country development is used to explain global imbalances. The OLG structure is a technical device that is used to ensure model stationarity in the asymmetric international economy.

They face the budget constraint

$$\alpha_{1t+1}^{v}+\alpha_{2t+1}^{v}=r_{1t}\alpha_{1t}^{v}+r_{2t}\alpha_{2t}^{v}+l_{t}^{v}-c_{t}^{v}$$

where generation v's labour/human income l_t^v equals the product of labour supply h_t^v and real wage (nominal wage g_t over CPI, p_t): $l_t^v=\frac{g_t}{p_t}h_t^v$. α_{1t}^v and α_{2t}^v are their net holding of home and foreign assets. r_{1t} and r_{2t} constitute two assets' gross rate of return (defined later). Let the gross wealth $w_t^v\equiv\alpha_{1t}^v+\alpha_{2t}^v$. The constraint reads

$$w_{t+1}^{v}=r_{2t}w_{t}^{v}+\alpha_{1t}^{v}r_{xt}+l_{t}^{v}-c_{t}^{v}$$

where $r_{xt}=r_{1t}-r_{2t}$ represents the excess return of asset 1 over asset 2.

The household's problem is to choose optimal c_t^v, l_t^v, α_t^vs to maximize U_t^v, subject to the budget constraints. The associated first-order conditions are

$$\lambda_t^v=\left(c_t^v\right)^{-1}$$

$$\left(c_t^v\right)^{-1}=\beta E_t\left[r_{1t+1}\left(c_{t+1}^v\right)^{-1}\right]$$

$$\left(c_t^v\right)^{-1}=\beta E_t\left[r_{2t+1}\left(c_{t+1}^v\right)^{-1}\right]$$

$$h_t^v=1-\gamma\frac{p_t}{g_t}c_t^v$$

where λ_t^v is the related Lagrangian multiplier.

Foreign households maximize the utility function of the same form, however, subject to

$$s_t\left(\alpha_{1t+1}^{*v}+\alpha_{2t+1}^{*v}\right)=s_t\left(r_{1t}\alpha_{1t}^{*v}+r_{2t}\alpha_{2t}^{*v}\right)+l_t^{*v}-c_t^{*v}$$

where s_t denotes the real exchange rate at time t, i.e. the price of the home consumption basket in terms of the foreign basket. It appears in the constraint because, apart from the asset-related variables (including the foreign asset holding α_t^{*v} and return r_{2t}) which are denoted in terms of the home basket, all other variables are in terms of their local basket in the model. The related first-order conditions are similar to those of the home country.

By the demographic structure, all other equations than Euler equations are linear and can hence be easily aggregated.[11] In particular, per-capita budget constraints read

$$\tilde{n}\left(\alpha_{1t+1}+\alpha_{2t+1}\right)=r_{1t}\alpha_{1t}+r_{2t}\alpha_{2t}+l_t-c_t$$

[11] For example, per-capita labour income is the product of real wage and per-capita labour supply, $l_t=\frac{g_t}{p_t}h_t$.

$$s_t\tilde{n}\left(\alpha^*_{1t+1}+\alpha^*_{2t+1}\right)=s_t\left(r_{1t}\alpha^*_{1t}+r_{2t}\alpha^*_{2t}\right)+l^*_t-c^*_t$$

$\tilde{n}$ emerges because, following Weil (1989), new generations are assumed to be born with no assets, i.e. $\alpha^t_t=0$. For the Euler equations, we log-linearize them first and then aggregate (Appendix C).

The asset returns r_{1t} and r_{2t} are

$$r_{1t}=\frac{d_t+\tilde{n}z_{1t+1}}{z_{1t}},\ \ r_{2t}=\frac{(d^*_t/s_t)+\tilde{n}z_{2t+1}}{z_{2t}}$$

where z_{1t} and z_{2t} denote the prices of asset 1 and 2 (both in terms of the home basket) at the end of period $t-1$. d_t and d^*_t are the dividends paid by the home and foreign firms (specified below). s_t converts the d^*_t into the home basket.

3.2 Firm's problem

A Cobb-Douglas technology is used to produce the intermediate good

$$x_t=e^{\varepsilon_t}\left(k_t\right)^{\delta}\left(h_t\right)^{1-\delta},\ \ x^*_t=e^{\varepsilon^*_t}\left(k^*_t\right)^{\delta^*}\left(h^*_t\right)^{1-\delta^*}$$

Here ε_t and ε^*_t represent technology shocks following

$$\varepsilon_t=\mu\varepsilon_{t-1}+\epsilon_t,\ \ \varepsilon^*_t=\mu\varepsilon^*_{t-1}+\epsilon^*_t$$

where $0<\mu<1$. The innovations ϵ and ϵ^* are zero-mean $i.i.d$ processes with the property of $var\left(\epsilon\right)=var\left(\epsilon^*\right)=\sigma^2$ and $cov\left(\epsilon\epsilon^*\right)=0$.

With this type of production function, δ and $1-\delta$ represent the shares of financial (non-human) and labour (human) wealth. We assume the home country to be more developed: $\delta>\delta^*$. At the most basic level, the δs denote the capital shares in production. So this asymmetry is related to any factor, both physical (e.g. natural resource and technology stock) and institutional (e.g. education, law, political system or/and particular industrial policies), that restricts an underdeveloped country from substituting labour with more use of machines when producing. As explained by Caballero et al. (2008, 2017), δ's level also depends on one country's ability to capitalize future income or, in their words, its ability in generating a storage of value, which also links it to a society's financial developments (and social institutions such as law systems). The question of which particular one or mix of these deep characteristics of country drives the asymmetric δs is interesting but outside the scope of this study. We use a lower δ^* as a simple way of capturing these underdevelopments of the foreign country and then investigate how this feature impacts international portfolios.

The firm maximizes the sum of the present value of all future dividends. The dividend is given by the difference between the revenue and the sum of input costs

$$d_t = \frac{q_t}{p_t} x_t - l_t - i_t.$$

Here q_t denotes the price of the home intermediate good. q_t/p_t is thus its price in terms of the home final good. Investment is given by $i_t = \tilde{n} k_{t+1} - k_t$.

The first-order condition of optimal choices of labour and capital demand is

$$MPL_t = \frac{g_t}{q_t}$$

$$r_{kt} = \frac{q_t}{p_t} MPK_t + 1.$$

The two intermediate goods are combined to form final goods y and y^* through

$$y_t = \left[\kappa^{\frac{1}{\phi}} \left(x_{ht} \right)^{\frac{\phi-1}{\phi}} + (1-\kappa)^{\frac{1}{\phi}} \left(x_{ft} \right)^{\frac{\phi-1}{\phi}} \right]^{\frac{\phi}{\phi-1}}$$

$$y_t^* = \left[(1-\kappa)^{\frac{1}{\phi}} \left(x_{ht}^* \right)^{\frac{\phi-1}{\phi}} + \kappa^{\frac{1}{\phi}} \left(x_{ft}^* \right)^{\frac{\phi-1}{\phi}} \right]^{\frac{\phi}{\phi-1}}$$

where x_{ht} and x_{ft} denote home demands for home and foreign intermediate goods. x_{ht}^* and x_{ft}^* denote the corresponding foreign demands. ϕ is the elasticity of substitution between the home and foreign intermediate goods. Following the literature, we assume a consumption home bias, $1/2 < \kappa < 1$.

Given this technology, the related consumption-based price indices read

$$p_t = \left[\kappa \left(q_t \right)^{1-\phi} + (1-\kappa) \left(\frac{q_t^*}{s_t} \right)^{1-\phi} \right]^{\frac{1}{1-\phi}}$$

$$p_t^* = \left[(1-\kappa) \left(s_t q_t \right)^{1-\phi} + \kappa \left(q_t^* \right)^{1-\phi} \right]^{\frac{1}{1-\phi}}$$

where q_t^* is the price of the foreign good. The law of one price holds for the two internationally traded goods, so the foreign price of the home good is given by $s_t q_t$ and the home

	Home holdings	Foreign holdings
Asset 1-Home equity	α_1	α_1^*
Asset 2-Foreign equity	$\alpha_2 = w - \alpha_1$	$\alpha_2^* = w^* - \alpha_1^*$

Table 3: Net asset holdings across countries

price of the foreign good $\frac{q_t^*}{s_t}$. The demands for the intermediate goods are

$$x_{ht} = \kappa \left(\frac{q_t}{p_t}\right)^{-\phi} y_t, \quad x_{ft} = (1-\kappa)\left(\frac{q_t^*}{s_t p_t}\right)^{-\phi} y_t$$

$$x_{ht}^* = (1-\kappa)\left(\frac{s_t q_t}{p_t^*}\right)^{-\phi} y_t^*, \quad x_{ft}^* = \kappa \left(\frac{q_t^*}{p_t^*}\right)^{-\phi} y_t^*$$

3.3 Market clearing

In equilibrium, all markets clear. In the intermediate goods market, we have $x_{ht} + x_{ht}^* = x_t, \; x_{ft} + x_{ft}^* = x_t^*$, while in the final goods market, $c_t + i_t = y_t$, $c_t^* + i_t^* = y_t^*$. For the asset market, see Table 3, the market clearing requires $\alpha_{1t} + \alpha_{1t}^* = z_{1t}, \; \alpha_{2t} + \alpha_{2t}^* = z_{2t}$, which are equivalent to $\alpha_{1t} = z_{1t} - \alpha_{1t}^*, \; w_t - z_{1t} = -\left(w_t^* - z_{2t}\right)$. While the interpretation of the first formula is obvious, the second formula states that the net external positions of home and foreign countries are of the same size but have the opposite sign. Let f_t be the net foreign asset at the end of time $t-1$. This formula reduces to $f_t = -f_t^*$. Note that, with the asset market clearing conditions, we only need to compute any of the four asset holdings. Next, we choose to first compute $\alpha_{1t} - z_{1t} = -\alpha_{1t}^*$, i.e. the home gross holding of the home asset.

4 Qualitative analysis

We first show that in steady state, global imbalances emerge. Then, we discuss its implications for the degree of portfolio diversification in differing countries.

4.1 Global imbalances

Appendix C derives the steady-state level for all non-portfolio variables, see Table 4.

Normalising the $GDPs$ to 1, the following relations hold in steady state:
(1) $i = \frac{n\delta}{(r-1)}$, $l = (1-\delta)$, $d = \frac{(r-\tilde{n})}{(r-1)}\delta$, $i^* = \frac{n\delta^*}{(r-1)}$, $l^* = (1-\delta^*)$, $d^* = \frac{(r-\tilde{n})}{(r-1)}\delta^*$;
(2) $w = \frac{(r\beta-1)(1-\delta)}{(\tilde{n}-r\beta)(r-1)}$, $z_1 = k = \frac{\delta}{(r-1)}$, $w^* = \frac{(r\beta-1)(1-\delta^*)}{(\tilde{n}-r\beta)(r-1)s}$, $z_2 = \frac{k^*}{s} = \frac{\delta^*}{(r-1)s}$;
(3) $f = w - z_1 = \frac{r\beta-1-n\delta}{(\tilde{n}-r\beta)(r-1)} < 0$, $f^* = \frac{1}{s}\frac{r\beta-1-n\delta^*}{(\tilde{n}-r\beta)(r-1)} > 0$;
(4) $r = \frac{1+\bar{\delta}n}{\beta}$ where $\bar{\delta} \equiv \frac{(\delta^*+s\delta)}{(1+s)}$;
(5) $c = \left[1-\frac{n\bar{\delta}}{r-1}\right]\left[1+\frac{\bar{\delta}-\delta}{1-\delta}\right] < c^* = \left[1-\frac{n\bar{\delta}}{r-1}\right]\left[1+\frac{\bar{\delta}-\delta^*}{1-\bar{\delta}}\right]$.

Table 4: Non-portfolio variables in steady state

The total income of a country consists of labour and dividend incomes aside from investment, see line (1). The more developed is a country, the higher is the share of dividend income while the lower is the share of labour income. This will impact the total asset demand and supply of each country.

Making use of the aggregate budget constraint and consumption function, we obtain the law of motion of asset demand in the two countries. For instance, in the home country, it is $w_{t+1} = \frac{r\beta}{\tilde{n}}w_t + \frac{(r\beta-1)}{\tilde{n}(r-1)}l_t$. Under the condition $r < \tilde{n}/\beta$, we obtain the steady-state w_t, see line (2). If $r > 1/\beta$, which is verified below, w is an increasing function of the labour income share: households save by holding assets. The asset supply is increasing in the financial income share.

Moreover, intuitively, when the asset yields a slightly higher return, the asset demand will rise while the asset supply will decrease

$$\frac{\partial w}{\partial r} = \frac{(r\beta-1)^2 + n(1-\beta)}{[(\tilde{n}-r\beta)(r-1)]^2}(1-\delta) > 0, \quad \frac{\partial z}{\partial r} = -\frac{\delta}{(r-1)^2} < 0$$

This implies a upward-sloping asset demand schedule and a downward-sloping asset supply schedule in a conventional Metzler diagram (Figure 3). In autarky, NFA equals zero, which determines the steady-state interest rate at

$$r^a = \frac{1+\delta n}{\beta}.$$

It positively depends on time preference $\frac{1}{\beta}$, population growth n and, in particular, country development δ. Therefore, with time preference and population growth being equal, a developing country of low δ will feature excess savings and a relatively lower autarky interest rate, which drives its net capital outflows in an open global economy.

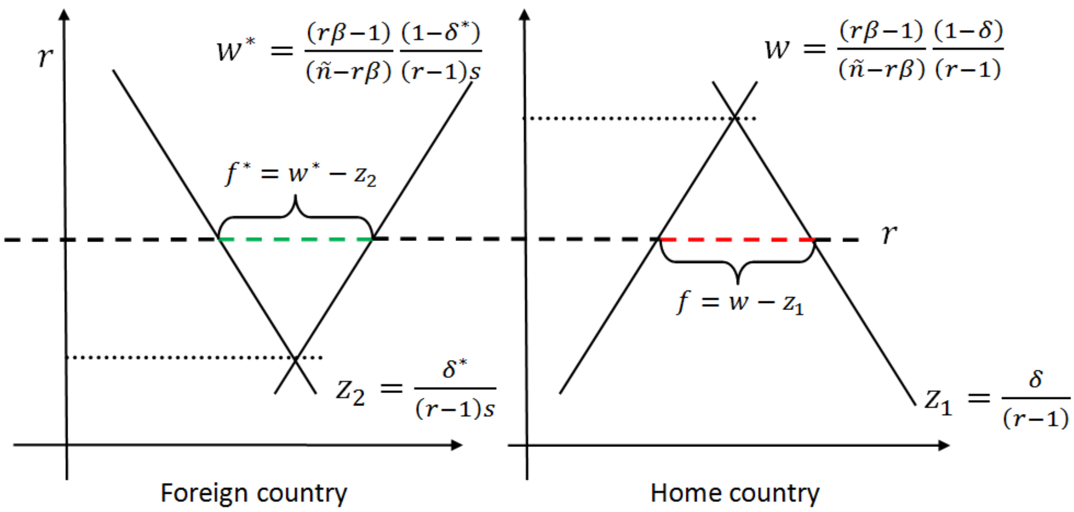

Figure 3: The Metzler diagram of global imbalances

To see this, the international interest rate is determined by $f + f^* = 0$, $r = \frac{1+\bar{\delta}n}{\beta}$ where $\bar{\delta} \equiv \frac{(\delta^*+s\delta)}{(1+s)} \in (\delta^*, \delta)$. First, $\frac{1}{\beta} < r < \frac{\tilde{n}}{\beta}$ is verified. Second, r lies in between the autarky interest rates of the two countries $r^{a*} < r < r^a$, which means $f = \frac{(r-r^a)}{\beta(\tilde{n}-r\beta)(r-1)} < 0$ and $f^* = \frac{1}{s}\frac{(r-r^{a*})}{\beta(\tilde{n}-r\beta)(r-1)} > 0$. Capital flows from the foreign to the home country in net terms.[12]

4.2 Globally asymmetric home bias

Below, we compute the steady-state portfolio. We compare our results to those in the literature and highlight the role of global imbalances in generating the hedging of net external payment and hence, the asymmetric asset home bias.

As a standard procedure, we approximate the model to the first-order accuracy (Ap-

[12]For line (5) of Table 5, we obtain the steady-state consumptions from the budget constraints or, equivalently, $c = 1 - i + (r - \tilde{n})\, f$, $c^* = 1 - i^* + s\,(r - \tilde{n})\, f^*$. The final good demands are therefore $y = c + i = 1 + (r - \tilde{n})\, f$, $y^* = c^* + i^* = 1 + s\,(r - \tilde{n})\, f^*$. One country's total spending is given by its total income or *GNP*: the sum of its *GDP* (that is normalised to 1) and net external income. If, as a dynamically efficient case for instance, $r > \tilde{n}$, the debtor (creditor) country's disposable expenditure will be less (more) than its average *GDP*. Because the debtor country has a higher capital stock and will invest more on average anyway, i.e. $i > i^*$, the international payment effect is reinforced in leading to a higher consumption level in the debtor country. If, however, $r < \tilde{n}$, the two effects are offsetting each other but the investment effect dominates. So in any case of the model, the consumption of the debtor home country will be lower as compared to the creditor foreign country.

pendix D).[13] We define and focus on solving for $\alpha \equiv \alpha_1 - z_1$, i.e. the home gross holding of the home asset. Because the home country is the default supplier of the home asset, a realistic α satisfies $-z_1 < \alpha < 0$.[14] Appendix E shows that α is determined by the model's first-order behaviours (variables with a hat)

$$E_{t-1}\left[\hat{c}_t^D \hat{r}_{xt}\right] = 0$$

$\hat{c}_t^D = \hat{c}_t - \hat{c}_t^* + \hat{s}_t - (1-\tau)\left(\hat{c}_t^n - \hat{c}_t^{n*} + \hat{s}_t\right)$ stands for the portfolio-relevant cross-country consumption differential. $\tau \equiv r\beta/\tilde{n} < 1$ equals the steady-state share of consumption by the existing population in this model.[15] $\hat{r}_{xt} \equiv \hat{r}_{1t} - \hat{r}_{2t}$ is the excess return of asset 1 relative to asset 2. The above condition states that households choose a portfolio to achieve optimal risk sharing. Depending on the income risks involved in $\hat{c}_t^D$, α is built up by a series of hedging motives. Appendix F shows that $\hat{c}_t^D$ is

$$(r - \tau\tilde{n})\left(\frac{1}{c} + \frac{s}{c^*}\right)\alpha\hat{r}_{xt} + \frac{r - \tau\tilde{n}}{r}\left[\Delta d_t + \Delta l_t + \left(\frac{1}{c} + \frac{s}{c^*}\right) rf\Sigma_{2t}^{rn}\right] - (1-\tau)\,\Delta c_t^n$$

where Δd_t, Δl_t, $rf\Sigma_{2t}^{rn} = rf\Sigma_{i=0}^{\infty}\left[\frac{\tilde{n}}{r}\right]^i \hat{r}_{2t+i}$ and Δc_t^n respectively represents the home country's relative financial income, relative labour income, external interest payment and the relative consumption of newborns.[16]

A partial equilibrium α is therefore

$$\begin{aligned}\alpha \quad = \quad & \underbrace{-\frac{cc^*}{(cs + c^*)\,r}\frac{cov\left(\Delta d_t, \hat{r}_{xt}\right)}{var\left(\hat{r}_{xt}\right)}}_{\text{Self-hedging }(-)} \underbrace{-\frac{cc^*}{(cs + c^*)\,r}\frac{cov\left(\Delta l_t, \hat{r}_{xt}\right)}{var\left(\hat{r}_{xt}\right)}}_{\text{Hedging labour income }(+)} \\ & \underbrace{-f\frac{cov\left(\Sigma_{2t}^{rn}, \hat{r}_{xt}\right)}{var\left(\hat{r}_{xt}\right)}}_{\text{Hedging interest payment }(-)} + \underbrace{\frac{cc^*}{(cs + c^*)}\frac{(1-\tau)}{(r - \tau\tilde{n})}\frac{cov\left(\Delta c_t^n, \hat{r}_{xt}\right)}{var\left(\hat{r}_{xt}\right)}}_{\text{Hedging newborn's consumption}}\end{aligned}$$

α is composed by:

1. The hedging of financial income (or self-hedging) which is negative. By the asset pricing relation, the (relative) rate of return on the asset is an increasing function of

[13] See, e.g. Devereux and Sutherland (2011) and Tille and Wincoop (2010).

[14] The absolute value of α is viewed as the level of gross external liability by the home country while it is seen as the level of gross external asset by the foreign country.

[15] The remainder $1-\tau$ is hence the share of consumption of the newly-born population, see Appendix C.

[16] Their exact expressions are in Appendix F.

(relative) dividend, i.e. $cov(\Delta d_t, \hat{r}_{xt}) > 0$. The domestic asset is shorted as a bad hedge against the associated risk.

In an endowment model where all wealth is capitalizable and countries are identical (Lucas, 1982), the relative financial income represents the whole source of risk in the $\hat{c}_t^D$ so only the self-hedging term remains in $\tilde{\alpha}$. Because $\Delta d_t = \frac{r}{(r-1)}\hat{r}_{xt}$ and $c = c^* = s = 1$, we have $\alpha = \frac{1}{2}z_1$, i.e. the full diversification of portfolios.

2. The hedging of labour income which appears because we distinguish between financial and labour incomes.[17] The current model follows Heathcote and Perri (2013) in obtaining a positive labour hedging and otherwise a symmetric portfolio home bias: Suppose that the home country is hit by a positive productivity shock, the home terms of trade deteriorate. This stimulates (relative) home investment (due to the goods home preference) and reduces the home dividend. Given that labour income always increases in response to positive supply shocks, the dividend and labour incomes move in opposite directions, i.e. a positive labour hedging that partially offsets the negative self-hedging. By "relative" labour income, this mechanism works in the same way across countries, which explains a symmetric home bias.

3. The hedging of international interest payment that we would like to highlight in this paper. It appears because, as explained, the differing country development results in persistent NFA imbalances and hence, the associated hedging motive. This hedging is negative in the home country. With $f < 0$, the home country has to pay an external interest payment. When the home asset's excess return is low (the home country experiences a positive productivity shock), the amount of interest payment, as a function of $\hat{r}_{2t}$, is relatively high (compared to if the foreign country is shocked). So the home country's disposable income and consumption become relatively low. That is, for a debtor country, when home consumption is low, the home asset's return is also low, which undermines the home asset as a good investment facing the risk of net external income. Instead, it

[17] The sign of this hedging depends on the comovement between the two types of income. If they comove positively, holding less domestic asset is required to hedge local labour income risk, which implies a further short term of the domestic asset on top of the above self-hedging. Portfolio allocation should be foreign biased (Baxtor and Jermann, 1997). If, however, they co-move negatively, the domestic asset offers a better hedge against local labour income risk. The positive labour hedging hence partially offsets the effect of a negative self-hedging, which delivers a portfolio home bias (Coeurdacier et al., 2010, Heathcote and Perri, 2013).

makes the foreign asset more preferred and tends to reduce the degree of home bias.[18]

Appendix G derives the foreign holding of the foreign asset, $\alpha^* \equiv \alpha_2^* - z_2$, from the fact of $\alpha^* = \alpha + f^*$

$$\alpha^* = \underbrace{-\frac{cc^*}{(cs+c^*)\,r}\frac{cov\left(\Delta d_t^*, \hat{r}_{xt}^*\right)}{var\left(\hat{r}_{xt}^*\right)}}_{\text{Self-hedging } (-)} \underbrace{-\frac{cc^*}{(cs+c^*)\,r}\frac{cov\left(\Delta l_t^*, \hat{r}_{xt}^*\right)}{var\left(\hat{r}_{xt}^*\right)}}_{\text{Hedging labour income } (+)}$$
$$\underbrace{-f^*\frac{cov\left(\Sigma_{1t}^{rn}, \hat{r}_{xt}^*\right)}{var\left(\hat{r}_{xt}^*\right)}}_{\text{Hedging interest payment } (+)} + \underbrace{\frac{cc^*}{(cs+c^*)}\frac{(1-\tau)}{(r-\tau\tilde{n})}\frac{cov\left(\Delta c_t^{n*}, \hat{r}_{xt}^*\right)}{var\left(\hat{r}_{xt}^*\right)}}_{\text{Hedging newborn's consumption}}$$

where $\Delta d_t^* = -\Delta d_t$, $\Delta l_t^* = -\Delta l_t$, $\Delta c_t^{n*} = -\Delta c_t^n$, $\hat{r}_{xt}^* = -\hat{r}_{xt}$ respectively denote the relative financial income, labour income, the newlyborn's consumption from the perspective of the foreign country and excess return of the foreign asset over the home asset. $\Sigma_{1t}^{rn} = \Sigma_{i=0}^{\infty}\left[\frac{\tilde{n}}{r}\right]^i \hat{r}_{1t+i}$ denotes the sum of the present value of asset 1's future rates of return.

The components of α^* have the same interpretation as those of α. And, except for the hedging of the international interest payment, all of them equal their counterpart in α.

The hedging of the interest payment in α^*, however, has a different sign than in α. With $f^* > 0$, the foreign country receives an international interest revenue. When the foreign asset's excess return is high (the home country experiences a positive shock), the amount of the revenue, as a function of $\hat{r}_{1t}$, is relatively low and thus, the foreign country's disposable income and consumption will be low. The foreign asset is hence a good hedge of this risk of interest payment, which requires the foreign country to hold more domestic asset and strengthens the degree of home bias.

In short, if identical, the two countries will hold identical portfolios, $\alpha = \alpha^*$. A differing country development, $\delta > \delta^*$, breaks down this symmetry to the extent that the hedging of return on net external position differs. It lowers the demand for the domestic asset in the home (debtor) country while it increases it in the foreign (creditor) country, so $\alpha < \alpha^* < 0$.

[18] There is an adjustment term due to the newborn's consumption. It appears because we assume the OLG structure and that agents are born with no assets. Therefore, only the existing population's decision matters in determining portfolios. The presence of this term then corresponds to the deduction of the newborn's consumption, $-(1-\tau)\,\Delta c_t^n$ in $\hat{c}_t^D$.

The degrees of home bias are[19]

$$\pi \equiv \frac{z_1 + \alpha}{z_1} = 1 + \frac{\alpha}{z_1}, \;\; \pi^* = \frac{z_2 + \alpha^*}{z_2} = 1 + \frac{\alpha^*}{z_2}$$

As implied by the presence of z_1 and z_2, this $CAPM$-based measurement admits that the country with higher capitalisation should also hold more of the domestic asset. Because the differing δs also cause unequal capitalisation levels, country developments operate through two channels in affecting the bias levels. While the above hedging of international interest payment lowers (increases) π in the home (foreign) country, the unequal capitalisation levels have the opposite effect. Below, we show numerically that, under a reasonable parameterization, the hedging channel dominates the market capitalisation channel and therefore will yield a lower (higher) π in the home (foreign) country.

5 Numerical analysis

5.1 A baseline calibration

Let a year be the model frequency. The top section of Table 5 shows the parameterization of our baseline calibration. Following the literature, we set $\beta = 0.97$. The OLG structure in the model is only used to ensure model stability. We choose a small number of $n = 10^{-5}$ here. Together with the choice of β, this value implies a real interest rate of around 3 percent, consistent with the calibration target that appears in the existing literature of modelling both developed and developing countries, for instance, Uribe and Yue (2006), Caballero et al. (2008) and Hnatkovska et al. (2016).[20][21] Like Caballero et

[19] As explained in Section 2, there is a home bias when π is higher than $1/N$ where N denotes the total number of countries in the world, i.e. when $\pi > 1/2$ in our two-country model.

[20] Besides, as mentioned by the footnote 18, the presence of population growth generates an adjustment term associated with the newborns' consumption in α. By choosing a small n, we ensure that the size of this adjustment term is small and does not drive our result.

[21] Under the baseline calibration, r is given by 1.031 while the exchange rate is below unity, $s = 0.996$. The latter is because the foreign country maintains a higher level of GNP and consumption by receiving external interest revenues. With the same degree of home goods preference in the two countries, there must be a higher demand for foreign goods x^*. Therefore, to clear the market, the relative price of home goods and thus, that of the home basket, must be cheaper. (For convenience of exposition, when computing steady-state relative prices, we normalize the home price of the foreign good to unity, i.e.

Variable	Description	Value	
β	Discount factor	0.97	
n	Net population growth rate	10^{-5}	
δ	Wealth division parameter in the home country	0.12	
μ	Persistence of productivity shocks	0.95	
ϕ	Elasticity of substitution between intermediate goods	0.9	
κ	Share of local intermediate goods in final goods	0.65	
		$\delta^*= 0.11$	$\delta^*= 0.1$
z_1	Home market capitalization	3.8799	3.8799
z_2	Foreign market capitalization	3.5713	3.2592
f	Home NFA (GDP is normalised to 1)	0.1830	0.3647
α	Gross holding of home asset by home households	−0.7220	−0.7214
	α [1] Self-hedging	−1.8159	−1.6876
	α [2] Hedging of labour income	1.2328	1.2480
	α [3] Hedging of international payment	−0.1390	−0.2819
	α [4] Adjustment to newborns' consumption	0	0
α^*	Gross holding of foreign asset by foreign households	−0.5390	−0.3567
	α^* [1] Self-hedging	−1.8159	−1.6876
	α^* [2] Hedging of labour income	1.2328	1.2480
	α^* [3] Hedging of international payment	0.0440	0.0828
	α^* [4] Adjustment to newborns' consumption	0	0
$\alpha_1= z_1+\alpha$	Home holding of home asset	3.1578	3.1584
$\alpha_2= w - \alpha_1$	Home holding of foreign asset	0.5390	0.3567
$\alpha_1^*= -\alpha$	Foreign holding of home asset	0.7220	0.7214
$\alpha_2^*= w^*-\alpha_1^*$	Foreign holding of foreign asset	3.0324	2.9025
$\pi = \alpha_1/z_1$	Asset home bias in the home country	0.8139	0.8141
$\pi^*= \alpha_2^*/z_2$	Asset home bias in the foreign country	0.8491	0.8906

Table 5: Benchmark calibration

al. (2008, 2017), we interpret the δs as the share of non-human wealth first. We follow them in choosing the value of δ at 0.12.[22] Combined with our assumption of zero capital depreciation, this yields a value of capital stock around 3 to 4 times of average GDP for the two countries.[23] $\delta^* = 0.11$ is first selected to target a steady-state negative NFA of around 18% of GDP in the home country, based on $U.S.$ data during $1999-2010$. The persistence of the productivity shock is set at 0.95, its median estimate by Smets and Wouters (2007). ϕ is chosen to be 0.9 (Heathcote and Perri, 2013). κ is set such that the local goods account for 65% of the input of final goods.[24]

The bottom section of Table 5 reports the portfolio choices and the implied bias degree in the two countries. As analysed, the self-hedging is negative while the hedging of labour income is positive.[25] They are symmetric for the two countries. The hedging of international interest payment is, however, negative in the home country while positive in the foreign country, thereby generating a lower degree of home bias in the home country.

Figure 4 depicts the portfolio allocation. In the middle are the four portfolio net holdings. To see the global imbalances, note that the foreign holding of the home asset outweighs the home holding of the foreign asset, $\alpha_1^* > \alpha_2$. To see the asymmetric home bias, note that a lower share of the domestic asset remains domestically in the home country, $\pi = \frac{\alpha_1}{\alpha_1+\alpha_1^*} < \pi^* = \frac{\alpha_2^*}{\alpha_2^*+\alpha_2}$. On the left and right-hand sides, we decompose the portfolio gross holdings α and α^* into self-hedging, labour hedging and the hedging of international interest payment. Because the other two hedging terms are symmetric across countries, the heterogeneity of the bias degree is associated with global imbalances through the asymmetric distribution of the hedging of international interest payment.

$q^*/s = 1$, so the terms of trade of the home country, defined as the price of exports in terms of imports is equal to $q/(q^*/s) = q$ in the model.)

[22]Coeurdacier and Gourinchas (2016) estimate a close value for the US financial wealth share at 0.13.

[23]Under the parameterization, in steady state, in the home country, we have $z_1 = 3.8799$ and $w = 3.6968$. In the foreign country, we have $z_2 = 3.5713$ and $w^* = 3.7544$. In other words, the total wealth of a country is about 3.8 times of GDP. As a reference, Caballero et al. (2008) target a value of country wealth of 4 times GDP for the advanced country. According to the dataset collated by Heathcote and Perri (2013), however, this ratio averages at around 2.5 over the period $1970-2010$ in the $U.S.$ A positive capital depreciation reduces this ratio. We allow for this below when conducting robustness checks.

[24]Given that δs are chosen to be relatively low, we choose ϕ and κ to also be low relative to their typical estimates in the literature so as to ensure **a** home bias in both countries (Heathcote and Perri, 2013). We will relax this in the robustness checks.

[25]The hedging of newborn's consumptions is negligibly small due to our choice of n.

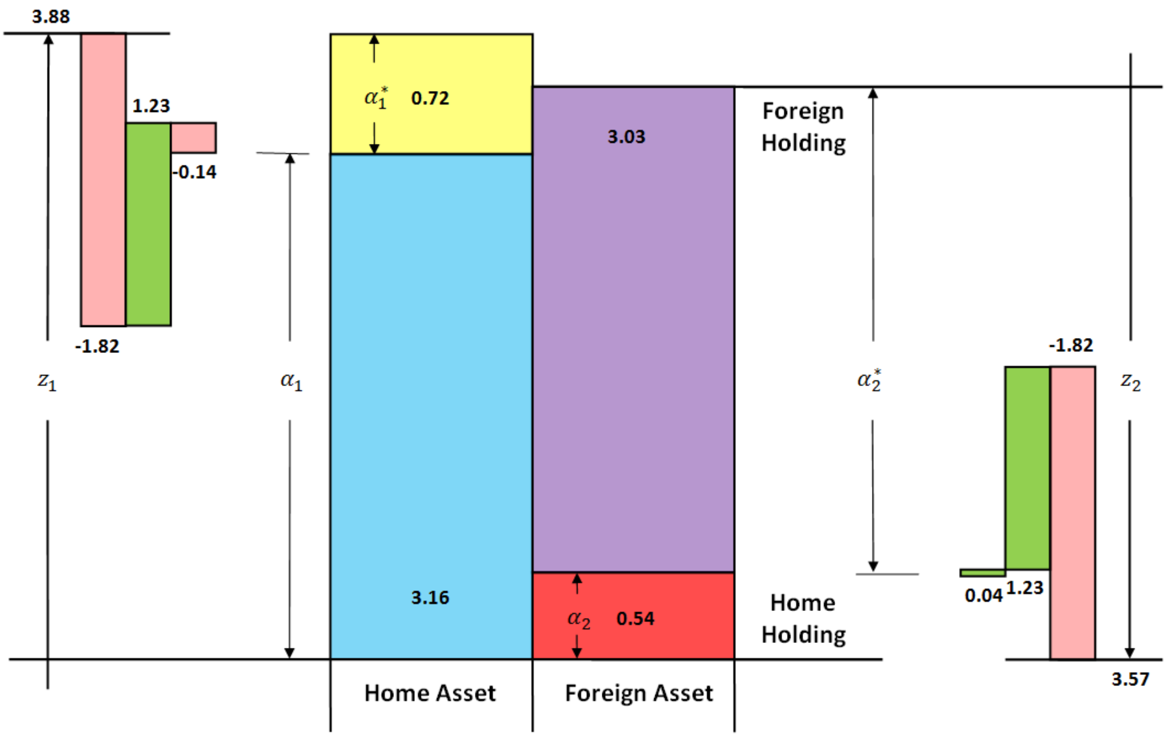

Figure 4: Portfolio allocation under the baseline calibration ($\delta = 0.12$, $\delta^* = 0.11$)

Unsurprisingly, these results will become more salient when the δ-gap widens. As another experiment, we set a lower $\delta^* = 0.1$ to target larger NFA imbalances at around 36% of GDP, see also Table 5.[26] When the size of the δ-gap doubles, the magnitude of the excess home bias in the foreign country roughly doubles as well. That is, as the global imbalances diverge, the excess home bias in the foreign country is sustained, in line with Coeurdacier and Rey's (2013) observation that developing countries "do not exhibit any clear downward trend in home bias".

5.2 Robustness checks

We focus on the following cases where we allow for: (1) varying parameter values; (2) capital depreciation and an alternative interpretation of the δ-asymmetry; (3) additional

[26]The U.S. net external financial position kept deteriorating after the 2007 crisis. The NFA/GDP ratio (in absolute value) has reached over 40%. The global imbalances are expected to continue diverging, see, e.g. International Monetary Fund's 2017 External sector report.

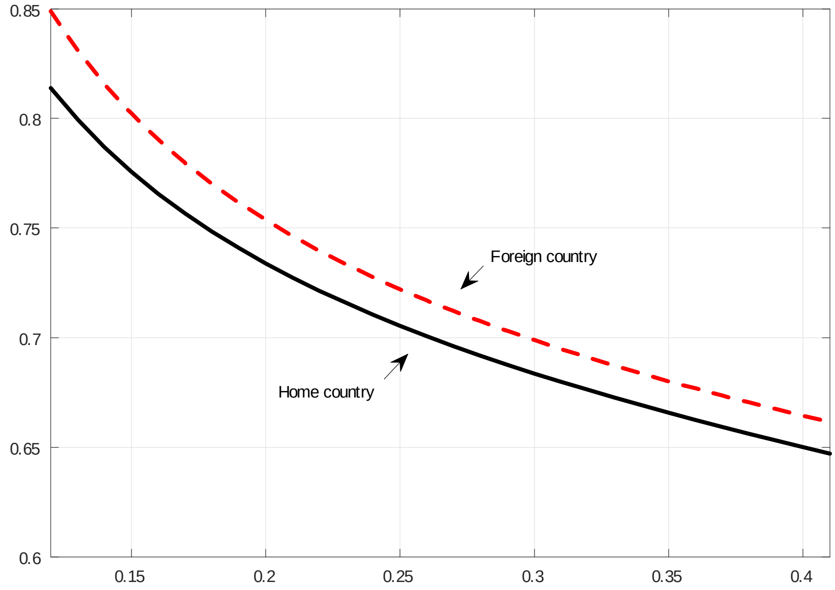

Figure 5: Asset home bias (vertical axis) and Wealth division δ (horizontal axis)

hedging motive of exchange rate risk; and (4) alternative country asymmetry of household patience.

5.2.1 Parameter values

Wealth division parameters, the δs So far, we have relied on Caballero et al.'s (2008, 2017) interpretation of δ as the non-human wealth share. Some literature suggests that this share can be as high as around 1/3, e.g. Lettau (2001) estimates it at 0.31. This is similar to the case where δs are interpreted as the capital share of income.[27] To see if our result remains, we change the value of δ, while keeping constant the δ-gap, from the current value of 0.12 up to around 0.4. Figure 5 shows that the portfolio in the home country is always less home-biased.

When the δs increase, both lines decline. This is economically sensible because, when the δs increase, there is less labour income risk to be hedged by more available hedging vehicles. The portfolios can be less home-biased in both countries.

So far, we also assumed zero capital depreciation in the model and chose a low value

[27] Therefore, the asymmetry is more related to industrial structure as argued by Jin (2012).

of δs to target a reasonable value of asset supply, which corresponds to Caballero et al.'s (2008) endowment-economy model. Interpreting δs as capital shares of income, we extend our model to allow for positive capital depreciation.[28] Repeating the above experiment, we find that the results are quite similar to those displayed in Figure 5 except that portfolios are slightly more biased in both countries.[29] The asymmetric home bias remains because the inclusion of capital depreciation does not affect the working of the hedging mechanism. The bias is enhanced because a higher level of the depreciation rate implies a lower level of equity stock. In order to hedge against the same amount of labour income risk, a larger share of domestic assets should be held domestically.[30]

Elasticity of substitution between goods, ϕ One implication of the choice of ϕ is that, the higher is ϕ, the higher are the πs. This is due to the fact that when the two goods are more substitutable, in response to a positive shock to home-country productivity, the resulting price responses are moderated (Cole and Obstfeld, 1991). The weakening of the stabilizing terms-of-trade effect leaves a heavier load of risk-sharing to be achieved through portfolio diversification. This requires the domestic assets to be outweighed.

For the purpose of the robustness check, we do not need to worry too much about the left-hand side of ϕ because given a very low value of δs that has been chosen, we have also selected a very low $\phi = 0.9$ to avoid the counterfactual case of πs being greater than 1. According to the literature, these extremely low values of ϕ are less likely to be relevant. In the literature, ϕ is usually set at around or higher than unity, e.g. Stockman and Tesar (1995) and Backus et al. (1995). Feenstra et al. (2014) estimate a median of the "macro" elasticity to be close to (but higher than) 1 and the "micro" one to be even higher (up to 2 times larger). In Figure 6, we vary ϕ in the neighbourhood of 0.9. As long as the asset home bias takes place in both countries, $\pi < \pi^*$ is always observed for differing levels of

[28] The extension is straightforward. The note for the extended model with a positive capital depreciation is available upon request.

[29] When we set $\delta = 0.33$, $\delta^* = 0.9\delta$ such that NFA is again (around) 18% of GDP, $f = 0.1839$, the annual depreciation rate of 0.1 as usually used/estimated in the literature (e.g. Backus et al., 1994, Smets and Wouters, 2007), the other parameter values as in the baseline calibration, the degrees of home bias in the two countries are: $\pi = 0.6820$ vs $\pi^* = 0.7288$. Abstracting from the capital depreciation, the degrees are: $\pi = 0.6683$ and $\pi^* = 0.7180$.

[30] We return to the baseline model of zero capital depreciation in the following checks, unless otherwise stated.

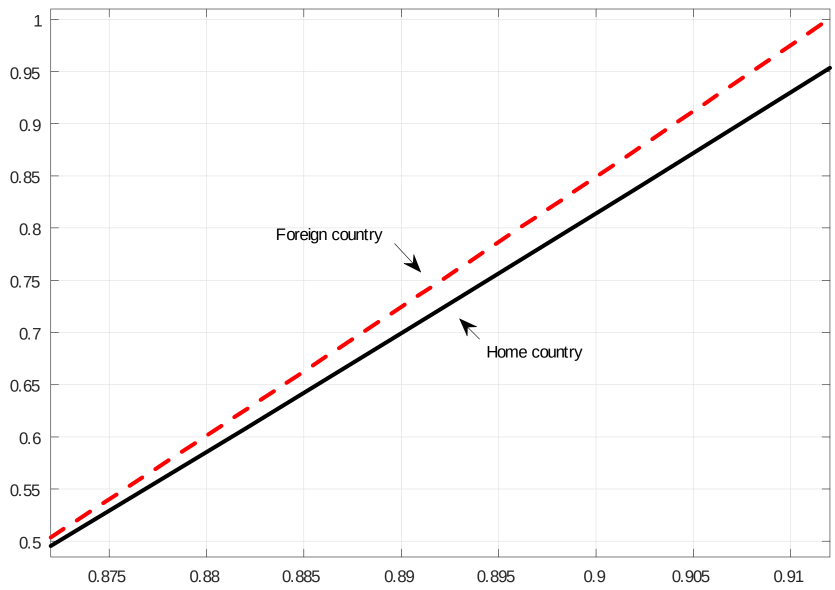

Figure 6: Asset home bias (vertical axis) and Trade elasticity ϕ (horizontal axis)

trade substitutability.

The gap between π and π^* increases as ϕ increases. This is because, given the δs, asset supplies (the zs) are mainly determined by an r that is insensitive to ϕ. However, a rise in ϕ drives up the net holdings of the domestic assets. π^* hence grows faster than π because the foreign country has a lower asset supply.[31]

Degree of home goods preference, κ Similar to the case of ϕ, a higher κ implies higher πs in both countries. The change of κ affects the magnitude of the terms-of-trade effect as well. Consider, for instance, that the home country experiences a positive productivity shock. On the supply side, this shock leads to a terms-of-trade deterioration, which partially offers risk-sharing. However, on the demand side, a higher κ implies an increased demand for the home good, which counteracts the terms-of-trade effect. Portfolio hedging becomes more important in terms of sharing risks. The portfolio home bias will therefore be enhanced. However, our result of an asymmetric home bias is not

[31] In other words, the hedging channel of determination of π is more elastic than the market capitalisation channel in response to ϕ.

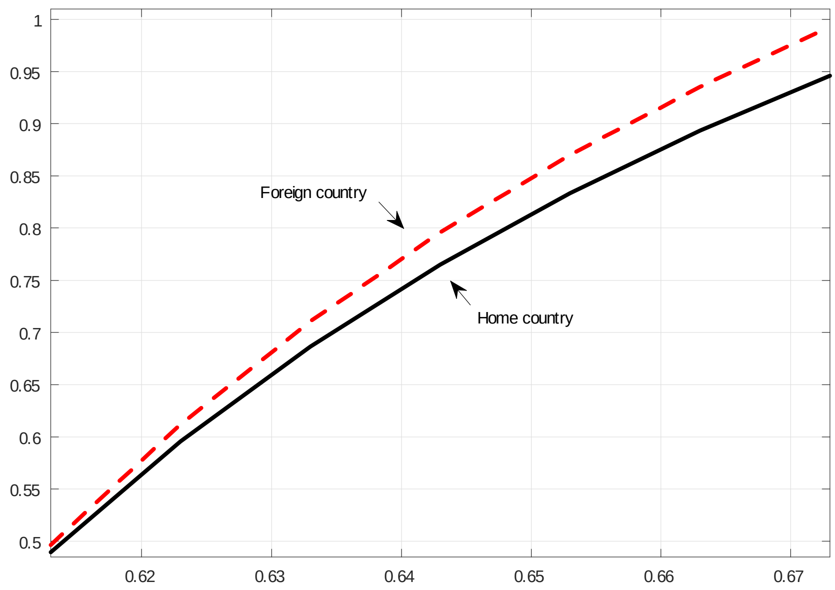

Figure 7: Asset home bias (vertical axis) and Local good preference κ (horizontal axis)

affected, see Figure 7. As long as the portfolios in both countries exhibit a home bias, π is lower in the home country.

For a similar reason to that of ϕ, when κ increases, the discrepancy between π and π^* becomes larger. Given that κ is usually considered to be higher than 0.65, e.g. around 0.85 as in Backus et al., 1994, Corsetti et al., 2008, Heathcote and Perri, 2013, the pattern of $\pi < \pi^*$ will only become more significant for such a higher κ.

Shock persistence, μ We vary μ from 0 to 0.99 in the model and always find a higher π^* than π. Figure 8 reports the result where μ varies from 0.8 to 0.99. Similar to the above results, $\pi < \pi^*$ survives while the πs increase as the shocks become more persistent. This is because, the higher is μ, the more volatile are all income streams, in particular, Δd_t and Δl_t. Nevertheless, because non-financial wealth in the model accounts for a relatively larger share of total wealth, $\delta < 1/2$, the increase in volatility of Δl_t is more significant than that of Δd_t. This enhances the role of hedging of labour income relative to that of self-hedging in α, which leads to a less diversified portfolio in both countries. Otherwise, if financial wealth were to account for a relatively large share of total wealth, its volatility

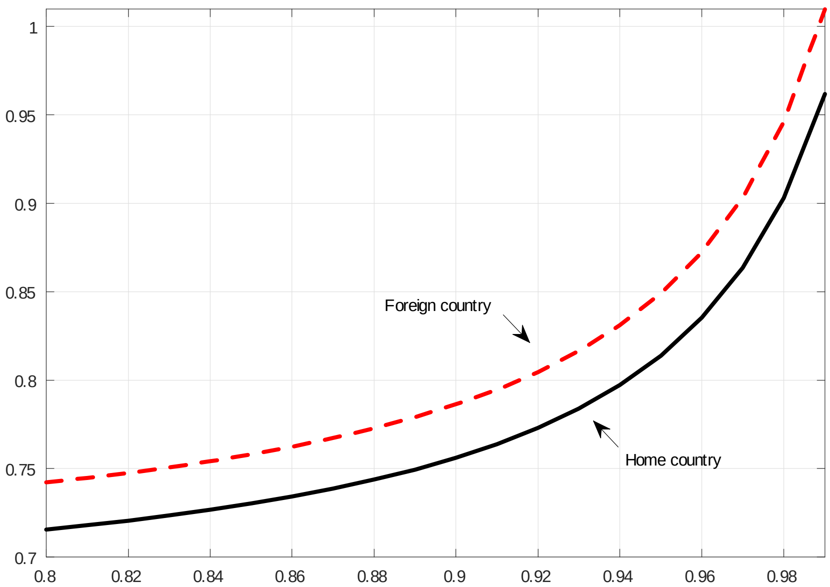

Figure 8: Asset home bias (vertical axis) and Shock persistence μ (horizontal axis)

would grow relatively fast when μ increases, which would result in a reversed effect on the πs. In either case, the differing hedging of international interest payment dominates and the result of $\pi < \pi^*$ remains.

5.2.2 Hedging exchange-rate risk

Taking into account additional hedging motives will not change our result as long as they are symmetric. We illustrate this point by extending our model with a hedging of the exchange-rate risk. For this purpose, we replace the logarithmic utility function of our baseline model with a more commonly-used $CRRA$ function

$$U_t^v = \sum_{i=0}^{\infty} \beta^i \left[\frac{\left(c_{t+i}^v\right)^{1-1/\rho}}{1-1/\rho} - \gamma \frac{\left(h_{t+i}^v\right)^{1+\eta}}{1+\eta} \right]$$

where ρ denotes the elasticity of intertemporal substitution and η the (inverse) elasticity of substitution of labour supply.

As explained in Appendix I, we can find the optimal portfolio of this extended model

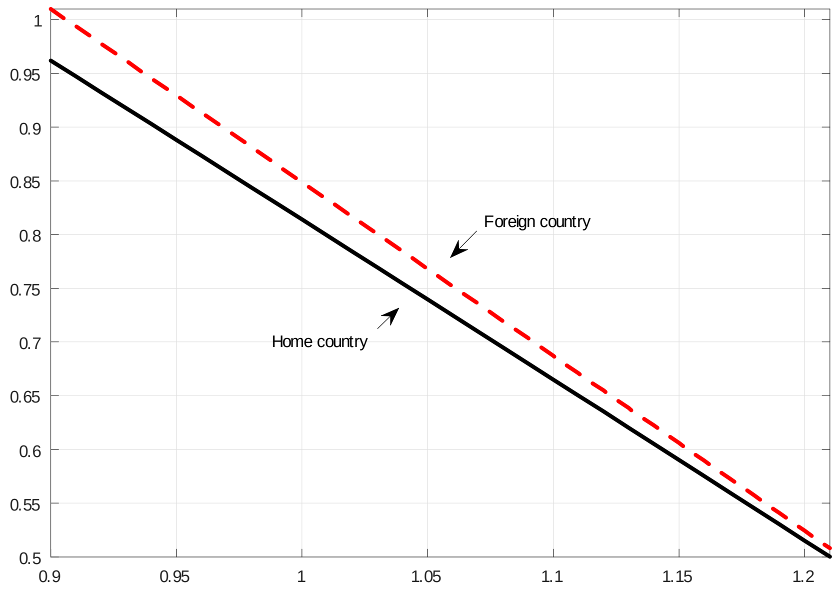

Figure 9: Asset home bias (vertical axis) and Intertemporal elasticity of substitution ρ (horizontal axis)

as the sum of the existing hedging terms and an additional hedging of exchange-rate risk

$$\begin{aligned}\alpha &= -\frac{cc^*}{(cs+c^*)\,r}\frac{cov\,(\Delta d_t,\hat{r}_{xt})}{var\,(\hat{r}_{xt})}-\frac{cc^*}{(cs+c^*)\,r}\frac{cov\,(\Delta l_t,\hat{r}_{xt})}{var\,(\hat{r}_{xt})}-f\frac{cov\,(\Sigma^{rn}_{2t},\hat{r}_{xt})}{var\,(\hat{r}_{xt})}\\ &\quad+\frac{cc^*}{cs+c^*}\frac{(1-\tau)}{(r-\tau\tilde{n})}\frac{cov\,(\Delta c^n_t,\hat{r}_{xt})}{var\,(\hat{r}_{xt})}\underbrace{-\frac{cc^*}{(cs+c^*)\,r}\frac{\tau\,(r-\tilde{n})}{(r-\tau\tilde{n})}(\rho-1)\frac{cov\,(\Sigma^s_t,\hat{r}_{xt})}{var\,(\hat{r}_{xt})}}_{\text{Hedging exchange rate}}\end{aligned}$$

where $\Sigma^s_t = \Sigma^{\infty}_{i=0}\left[\frac{\tilde{n}}{r}\right]^i \hat{s}_{t+i}$.

This hedging is symmetric across countries and is positive when $\rho < 1$.[32] Like the labour hedging, it will not change our result of an asymmetric home bias. To see this, we

[32] As analysed in the symmetric set-up, e.g. Coeurdacier and Rey (2012), the hedging of the exchange-rate risk depends on two forces going in opposite directions: when domestic goods are more expensive, households need to generate more income in order to stabilize their purchasing power. Or, households could delay consumption until domestic goods become cheaper. Which force wins depends on how strong is households' desire in smoothing consumption across states. For households sufficiently reluctant to adjust consumption intertemporally, $\rho < 1$, the former effect dominates and households want to increase their income when their consumption goods are more expensive. In the model, because the home asset yields a higher return when the home good becomes more expensive (a negative shock to the home

simulate the model under the previous parameterization. η is set at 1 following Heathcote and Perri (2013). Combined with $\rho = 1$, this yields πs that are close to those of the baseline model. In Figure 9, we vary ρ from 0.9 to 1.2. As long as the portfolios in the two countries exhibit an asset home bias, the pattern of $\pi < \pi^*$ is always true.

The figure shows that the lower is ρ, the higher are the πs and the bias gap. The πs are both higher because, as explained, the hedging channel will become more important when ρ decreases. The bias gap widens because, again, the hedging channel is more responsive to the change of ρ than the market capitalisation channel.

5.2.3 Alternative country asymmetry of patience

The real reason for the so-called global imbalances or uphill capital flows could be composite (see, e.g., Gourinchas and Jeanne, 2013, Gourinchas and Rey, 2014). This paper emphasizes that, once the country asymmetry opens non-zero NFA positions, it creates the need to hedge against the risk associated with the international interest payment which, in turn, leads to an asymmetric portfolio home bias globally.

As an example, within our framework, we investigate the possibility that the households in the two countries have differing levels of patience $\beta < \beta^*$. Appendix J presents the details of such a model. Based on the baseline parameterization, we calibrate this model. Specifically, we set two δs at 0.12 and $\beta^* = 0.97$. β is selected such that the NFA/GDP ratio is, again, around 18% first and then 40%. Table 6 reports the associated results, from which the excess home bias in the foreign (creditor emerging) country re-emerges. The result in fact becomes more robust in the sense that the same level of global imbalances implies a even larger bias gap between the two countries. This is because, as discussed, in the baseline model of differing δs, there is a market capitalisation channel that moderates the effect of the hedging channel while in the current model, this market capitalisation channel collapses. Differing βs do not imply unequal asset supplies, $z_1 = z_2$, which leaves only the hedging channel alive and allows the bias gap to grow.[33]

country production), i.e. $cov\left(\Sigma_t^s, \hat{r}_{xt}\right) > 0$, the hedging of the exchange-rate risk is positive and enhances the asset home bias.

[33]This paper does not aim to identify and evaluate the contribution of each driving force of global imbalances. We use the result to emphasise that, as long as the differing δs are not the only cause of the observed global imbalances, the hedging of international interest payment highlighted here explains more of the bias gap between countries since the market capitalisation channel is not as important as in our

Variable	Value	
β^*	0.97	
	$\beta = \beta^* - 0.95\% \times n$	$\beta = \beta^* - 1.9\% \times n$
z_1	3.8798	3.8798
z_2	3.8958	3.9110
f	0.1803	0.3612
α	−0.7822	−0.8443
α_1	3.0976	3.0355
α_2	0.6019	0.4831
α_1^*	0.7822	0.8443
α_2^*	3.2938	3.4279
π	0.7984	0.7824
π^*	0.8455	0.8765

Table 6: Calibration of the model of differing patience

6 Conclusion

The uphill international capital flows and a "more severe" lack of international portfolio diversification in developing and emerging countries can be causally correlated. We developed a model of endogenous net and gross country portfolios to show that: under global NFA imbalances, agents have a motive to hedge against the interest payments that are associated with unbalanced external positions. Because the hedging has an opposite sign across countries, the portfolio allocation moves away from an otherwise symmetrically home-biased pattern: the creditor (developing) country will hold domestic assets more intensively than the debtor (developed) country, in line with the data observation.

Portfolio models that are based on hedging motives are quite successful in accounting for country portfolio facts, especially for the asset home bias of symmetric models (Coeurdacier and Rey, 2013). Our result shows that, in asymmetric situations, this type of model is consistent with the data as well. Like Heathcote and Perri (2013), we interpret the model equity as any asset that represents a claim to country output and do not distinguish between bond and equity assets. The next step can be to develop a model of

benchmark model of a single country asymmetry of differing δs.

multiple-asset type (Coeurdacier and Gourinchas, 2016) in light of the so-called two-way capital flows (Ju and Wei, 2010, Wang et al., 2015). Moreover, motivated by the literature which attempts to explain the home bias with market integration and trade costs (Tesar and Werner, 1995, Warnock, 2002), one may wonder if a model with asymmetric levels of trade openness and trade cost provides a complementary force to the channel identified in this paper.[34] There have also been many empirical studies considering the role of geography, culture and institutions (see, for instance, Portes and Rey, 2005, Chan et al., 2005, Daude and Fratzscher, 2008 among others) in explaining differences in country portfolios. Guided by our results, the country's net external balance should be taken into account in such a study.

[34]From our baseline calibration, after all, the differing hedging explains around 1/3 of the bias gap. However, for such a model to work, besides the difficulty that already exists when explaining a symmetric home bias (Coeurdacier and Rey, 2012), it may need a group of developing countries that trades in a more costly way within their group than another group of developed countries to do so.

REFERENCE

Backus, David K & Kehoe, Patrick J & Kydland, Finn E, 1994. Dynamics of the Trade Balance and the Terms of Trade: The J-Curve?, American Economic Review, American Economic Association, vol. 84(1), pages 84-103, March.

———, 1995. International Business Cycles: Theory and Evidence, Frontiers of Business Cycle Research edited by Thomas F. Cooley, 331-56. Princeton, NJ: Princeton Univ. Press

Baxter, Marianne & Jermann, Urban J, 1997. The International Diversification Puzzle Is Worse Than You Think, American Economic Review, American Economic Association, vol. 87(1), pages 170-80, March.

Caballero, Ricardo J.& Farhi, Emmanuel & Gourinchas, Pierre-Olivier, 2008. An Equilibrium Model of Global Imbalances and Low Interest Rates, American Economic Review, American Economic Association, vol. 98(1), pages 358-93, March.

Caballero, Ricardo J.& Farhi, Emmanuel & Gourinchas, Pierre-Olivier, 2017. The Safe Assets Shortage Conundrum, Journal of Economic Perspectives, (Summer): 29-46

Chan, K. & Covrig, V.M. & Ng, L.K., 2005. What Determines the Domestic and Foreign Bias? Evidence from mutual fund equity allocations worldwide. Journal of Finance 60, 1495–1534.

Coeurdacier, Nicolas & Pierre-Olivier Gourinchas, 2016. When Bonds Matter: Home Bias in Goods and Assets, Journal of Monetary Economics, vol. 82, pages 119-37, September.

Coeurdacier, Nicolas & Kollmann, Robert & Martin, Philippe, 2010. International Portfolios, Capital Accumulation and Foreign Assets Dynamics, Journal of International Economics, Elsevier, vol. 80(1), pages 100-112, January.

Coeurdacier Nicolas & Rey Hélène, 2013. Home Bias in Open Economy Financial Macroeconomics, Journal of Economic Literature, American Economic Association, vol. 51(1), pages 63-115, March.

Cole, Harold L. & Obstfeld, Maurice, 1991. Commodity Trade and International Risk Sharing: How Much Do Financial Markets Matter? Journal of Monetary Economics, 28 (August), 3-24.

Cooper, I.A. & Kaplanis, E., 1994. Home Bias in Equity Portfolios, Inflation Hedging, and International Capital Market Equilibrium. Review of Financial Studies, 7, 45–60.

Corsetti, G. & Dedola, L. & Leduc, S., 2008. International Risk Sharing and the Transmission of Productivity Shocks. Review of Economic Studies, 75, pages 443-473.

Daude, C. & Fratzscher, F., 2008. The Pecking Order of Cross-border Investment. Journal of International Economics 74 (1), 94–119.

Devereux, Michael B. & Sutherland, Alan, 2010. Valuation Effects and the Dynamics of Net External Assets, Journal of International Economics, Elsevier, vol. 80(1), pages 129-143, January.

Devereux, Michael B. & Sutherland, Alan, 2011. Country Portfolios In Open Economy Macro-Models, Journal of the European Economic Association, European Economic Association, vol. 9(2), pages 337-369, 04.

Devereux, M. & Senay, O. & Sutherland, A., 2014. Nominal Stability and Financial Globalization, Journal of Money, Credit and Banking, Blackwell Publishing, vol. 46(5), pages 921-959, 08.

Dhareshwar, Ashok & Nehru, Vikram, 1993. A New Database on Physical Capital Stock: Sources, Methodology and Results, Revista de Analisis Economica, 8(1), pp. 37-59, June 1993

Feenstra, Robert C. & Luck, Philip A. & Obstfeld Maurice & Russ, Katheryn N., 2014. In Search of the Armington Elasticity, NBER Working Papers 20063, National Bureau of Economic Research, Inc.

French, Kenneth R. & Poterba, James M., 1991. Investor Diversification and International Equity Markets, American Economic Review, vol. 81(2), pages 222-226, May.

Gourinchas, Pierre-Olivier & Jeanne Olivier, 2013, Capital Flows to Developing Countries: The Allocation Puzzle, Review of Economic Studies, 80, page 1484-1515

Gourinchas, Pierre-Olivier & Rey Helene, 2014, External Adjustment, Global imbalances, Valuation effects, Handbook of International Economics, edited by: Elhanan Helpman, Kenneth Rogoff and Gita Gopinath, Vol. 4, page 585-645

Heathcote, Jonathan & Perri, Fabrizio, 2002. Financial Autarky and International Business Cycles, Journal of Monetary Economics, Elsevier, vol. 49(3), pages 601-627, April.

Heathcote, Jonathan & Perri, Fabrizio, 2013. The International Diversification Puzzle Is Not as Bad as You Think, Journal of Political Economy, University of Chicago Press, vol. 121(6), pages 1108 - 1159.

Hnatkovska, Viktoria & Amartya, Lahiri & Carlos A. Vegh, 2016. The Exchange Rate Response to Monetary Policy Innovations, American Economic Journal: Macroeconomics, 8(2): 137-81.

Jin, Keyu, 2012. Industrial Structure and Capital Flows, American Economic Review, American Economic Association, vol. 102(5), pages 2111-46, August.

Ju, Jiandong & Shang-Jin Wei, 2010. Domestic Institutions and the Bypass Effect of Financial Globalization, American Economic Journal: Economic Policy, 2 (November 2010), pages: 173-204.

Lane, Philip R. & Milesi-Ferretti, 2007. The External Wealth of Nations Mark II: Revised and Extended Estimates of Foreign Assets and Liabilities, 1970-2004, Journal of International Economics, Elsevier, vol. 73(2), pages 223-250, November.

Lettau, Martin, 2001. Consumption, Aggregate Wealth, and Expected Stock Returns, Journal of Finance, American Finance Association, vol. 56(3), pages 815-849, 06.

Lucas, Robert E, Jr., 1982. Interest Rates and Currency Prices in a Two-country World, Journal of Monetary Economics, Elsevier, vol. 10(3), pages 335-359.

Mukherjee, Rahul, 2015. Institutions, Corporate Governance and Capital Flows, Journal of International Economics, Elsevier, vol. 96(2), pages 338-359, July.

Portes, R. & Rey, H., 2005. The Determinants of Cross-border Equity Flows. Journal of International Economics, 65, 269–296.

Schmitt-Grohe, Stephanie & Uribe, Martin, 2003. Closing Small Open Economy Models, Journal of International Economics, Elsevier, vol. 61(1), pages 163-185, October.

Smets, F. & Wouters, R., 2007. Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach. American Economic Review 97, 586-606.

Stockman, Alan C & Tesar, Linda L, 1995. Tastes and Technology in a Two-Country Model of the Business Cycle: Explaining International Comovements, American Economic Review, American Economic Association, vol. 85(1), pages 168-85, March.

Sercu, Piet & Vanpee, Rossane, 2007. Home Bias in International Equity Portfolios: A Review. Available at SSRN 1025806.

Sercu, Piet & Vanpee, Rossane, 2008. Estimating the Costs of International Equity Investments, Review of Finance, 12(4): 587-634.

Tesar, L. L., & Werner, I. M. 1995. Home Bias and High Turnover. Journal of International Money and Finance, 14(4), 467-492.

Tille, Cedric & van Wincoop, Eric, 2010. International Capital Flows, Journal of International Economics, Elsevier, Vol. 80(2) March, pages 157-175.

Uribe, Martin, & Vivian Z. Yue, 2006. Country Spreads and Emerging Countries: Who Drives Whom? Journal of International Economics, 69(1): 6-36.

Wang, Pengfei, & Yi Wen & Zhiwei Xu, 2015. Two-way Capital Flows and Global Imbalances, The Economic Journal, 127 (Feb): 229-269.

Warnock, Francis E., 2002. Home Bias and High Turnover Reconsidered. Journal of International Money and Finance, 21(6), 795-805.

Weil, Philippe, 1989. Overlapping Families of Infinitely-lived Agents, Journal of Public Economics, Elsevier, vol. 38(2), pages 183-198, March.

A Country sample for the regression of Section 2

34 countries included in the sample are:

Developing/Emerging countries: Argentina (ARG), Bangladesh (BGD), Brazil (BRA), Chile (CHL), China (CHN), India (IND), Indonesia (IDN), Korea Republic (KOR), Malaysia (MYS), Mexico (MEX), Pakistan (PAK), Peru (PER), Philippines (PHL), South Africa (ZAF), Thailand (THA), Turkey (TUR) and Venezuela (VEN).

Developed countries: Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), Finland (FIN), France (FRA), Germany (DEU), Greece (GRC), Iceland (ISL), Italy (ITA), Japan (JPN), New Zealand (NZL), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE) and United States (USA).

B Model equations in exact form

In this section, except for utility function and Euler equations (first-order condition of optimal consumption/asset holdings), all the other equations take their per-capita form.

B.1 Aggregation relation

The relation that links individual variable x_t^v and per-capita variable x_t at time t

$$x_t = \frac{x_t^0 + nx_t^1 + n\tilde{n}x_t^2 ... + n\tilde{n}^{t-1}x_t^t}{\tilde{n}^t}$$

B.2 Households' problem

Individual utility function

$$U_t^v = \sum_{i=0}^{\infty} \beta^i \left[\log\left(c_{t+i}^v\right) + \gamma \log\left(1 - h_{t+i}^v\right)\right]$$

Intertemporal budget constraints

$$\tilde{n}\left(\alpha_{1t+1} + \alpha_{2t+1}\right) = r_{1t}\alpha_{1t} + r_{2t}\alpha_{2t} + l_t - c_t$$

$$s_t\tilde{n}\left(\alpha_{1t+1}^* + \alpha_{2t+1}^*\right) = s_t\left(r_{1t}\alpha_{1t}^* + r_{2t}\alpha_{2t}^*\right) + l_t^* - c_t^*$$

Labour income

$$l_t = \frac{g_t}{p_t} h_t$$

$$l_t^* = \frac{g_t^*}{p_t^*} h_t^*$$

Asset returns and prices

$$r_{1t} z_{1t} = d_t + \tilde{n} z_{1t+1}$$

$$r_{2t} z_{2t} = \frac{d_t^*}{s_t} + \tilde{n} z_{2t+1}$$

Euler equations (optimal choices of consumption/asset holdings)

$$(c_t^v)^{-1} = \beta E_t \left[r_{1t+1} \left(c_{t+1}^v \right)^{-1} \right]$$

$$(c_t^v)^{-1} = \beta E_t \left[r_{2t+1} \left(c_{t+1}^v \right)^{-1} \right]$$

$$s_t \left(c_t^{v*} \right)^{-1} = \beta E_t \left[s_{t+1} r_{1t+1} \left(c_{t+1}^{v*} \right)^{-1} \right]$$

$$s_t \left(c_t^{v*} \right)^{-1} = \beta E_t \left[s_{t+1} r_{2t+1} \left(c_{t+1}^{v*} \right)^{-1} \right]$$

Labour supply

$$h_t = 1 - \gamma \frac{p_t}{g_t} c_t$$

$$h_t^* = 1 - \gamma \frac{p_t^*}{g_t^*} c_t^*$$

Newborn's consumption

$$c_t^n = (1 - \beta) l_t + \frac{1}{r} c_{t+1}^n$$

$$c_t^{n*} = (1 - \beta) l_t^* + \frac{1}{r} c_{t+1}^{n*}$$

B.3 Firm's problem

Technology and Marginal products (country asymmetry in δ, i.e. $\delta > \delta^*$)

$$x_t = e^{\varepsilon_t} (k_t)^{\delta} (h_t)^{1-\delta}$$

$$x_t^* = e^{\varepsilon_t^*} (k_t^*)^{\delta^*} (h_t^*)^{1-\delta^*}$$

$$MPL_t = (1 - \delta) \frac{x_t}{h_t}$$

$$MPL_t^* = (1-\delta^*)\frac{x_t^*}{h_t^*}$$

$$MPK_t = \delta\frac{x_t}{k_t}$$

$$MPK_t^* = \delta^*\frac{x_t^*}{k_t^*}$$

Objective function and Discount factor

$$\sum_{i=0}^{\infty}\Omega_{t+i}d_{t+i}$$

$$\Omega_{t+i} = \beta^i\left(c_{t+i}^v\right)^{-1}$$

Dividend

$$d_t = \frac{q_t}{p_t}x_t - l_t - i_t$$

$$d_t^* = \frac{q_t^*}{p_t^*}x_t^* - l_t^* - i_t^*$$

Investment

$$i_t = \tilde{n}k_{t+1} - k_t$$

$$i_t^* = \tilde{n}k_{t+1}^* - k_t^*$$

Optimal choices of labour and capital demand

$$MPL_t = \frac{g_t}{q_t}$$

$$MPL_t^* = \frac{g_t^*}{q_t^*}$$

$$r_{kt} = \frac{q_t}{p_t}MPK_t + 1$$

$$r_{kt}^* = \frac{q_t^*}{p_t^*}MPK_t^* + 1$$

$$\Omega_t = E_t\left[\Omega_{t+1}r_{kt+1}\right]$$

$$\Omega_t^* = E_t\left[\Omega_{t+1}^*r_{kt+1}^*\right]$$

B.4 Market clear

Assets market clear

$$\alpha_{1t} + \alpha_{1t}^* = z_{1t}$$

$$\alpha_{2t} + \alpha_{2t}^* = z_{2t}$$

which are equivalent to

$$\alpha_{1t} = z_{1t} - \alpha_{1t}^*$$

$$w_t - z_{1t} = -\left(w_t^* - z_{2t}\right)$$

Intermediate goods market clear

$$x_{ht} + x_{ht}^* = x_t$$

$$x_{ft} + x_{ft}^* = x_t^*$$

where goods demands are given by

$$x_{ht} = \kappa \left(\frac{q_t}{p_t}\right)^{-\phi} y_t$$

$$x_{ft} = (1-\kappa) \left(\frac{q_t^*}{s_t p_t}\right)^{-\phi} y_t$$

$$x_{ht}^* = (1-\kappa) \left(\frac{s_t q_t}{p_t^*}\right)^{-\phi} y_t^*$$

$$x_{ft}^* = \kappa \left(\frac{q_t^*}{p_t^*}\right)^{-\phi} y_t^*$$

Final goods market clear

$$c_t + i_t = y_t$$

$$c_t^* + i_t^* = y_t^*$$

Price indices

$$p_t = \left[\kappa \left(q_t\right)^{1-\phi} + (1-\kappa) \left(\frac{q^*}{s_t}\right)^{1-\phi}\right]^{\frac{1}{1-\phi}}$$

$$p_t^* = \left[(1-\kappa) \left(s_t q_t\right)^{1-\phi} + \kappa \left(q_t^*\right)^{1-\phi}\right]^{\frac{1}{1-\phi}}$$

$$s_t = \frac{p_t}{p_t^*}$$

Defining w_t and f_t

$$w_t = \alpha_{1t} + \alpha_{2t}$$

$$w_t^* = \alpha_{1t}^* + \alpha_{2t}^*$$

$$f_t = w_t - z_{1t}$$

$$f_t^* = w_t^* - z_{2t}$$