Country portfolios under global imbalances

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Abstract

This paper studies the composition of country portfolios under global imbalances. When countries are identical, optimal portfolio is fully diversified, which reflects the cross-country symmetric self-hedging (Lucas, 1982). Under global imbalances, an asymmetric hedging of net portfolio return emerges, implying a short (long) position of local asset in the debtor (creditor) country. The resulting portfolio is home biased. We calibrate our model to the US and China data over $1987 - 2007$ and show that it matches well the portfolio data for countries of unbalanced net external position.

Keywords: Financial globalisation, Global imbalances, International portfolio choices, Asset home bias, External adjustment.

JEL Codes: F32, F41

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1 Introduction

Financial globalization has been accompanied by global imbalances.[1] By the end of 2016, more than 75% of the countries have a net foreign asset (NFA) position that exceeds 20% of GDP.[2] In the countries that are considered to be the most important contributors of global imbalances, the NFA/GDP ratio is even higher, over 25% in China, -40% in the US and 60% in Japan and Germany and is expected to continue to diverge in the future.[3] This implies a correspondingly sizeable and growing gap between gross external asset and liability of these countries. However, in standard country portfolio models, countries are assumed to be identical. We therefore ask in this paper how country portfolios are composed when countries possess an unbalanced net external position.

The presence of non-zero NFA positions implies that consumption in each country is given by its GNP instead of its GDP. Given households' incentive to smooth consumption through holding portfolios, this change in the composition of national incomes translates into the change in the composition of gross portfolio holdings. In a world where countries are identical (Lucas, 1982), optimal portfolio positions only consist of a cross-country symmetric GDP hedging.[4] In this paper, we argue that under global imbalances, optimal portfolio positions do not only consist of this GDP hedging but also a hedging associated with the difference between GNP and GDP, i.e. the hedging of net portfolio return, which subsequently influences international diversification of capital and external adjustment of country.

[1] Lane and Milesi-Ferretti (2007) document the data patterns of the accelerating financial globalization alongside the persistent current account global imbalances. Gourinchas and Rey (2013) highlight these patterns as the stylized facts of international financial market over the last few decades.

[2] These numbers are computed by the author based on the GDP data from the IMF's World Economic Outlook Database (WEOD) that was updated on 10/10/2017 and the country portfolio's data from the Balance of Payment and International Investment Position Statistics (BOP/IIPS) that **was** updated on 09/25/2017. Depending on the availability of consistent GDP and portfolio data, 111 countries are included. This figure, NFA/GDP, is 76.47% for advanced countries and 75.32% for emerging/developing countries, respectively.

[3] See the time trends predicted by the International Monetary Fund's (IMF) 2017 External sector report (page 20).

[4] Because the relative return of domestic assets co-moves positively with domestic GDP, a short position of domestic assets is required by the risk-sharing in both countries. Due to country symmetry, the size of this position is 1/2.

To formalize this idea, we build a model of global imbalances and country portfolios. In our baseline two-country open economy model, first, we borrow a country asymmetry in patience from Buiter (1981) to obtain global imbalances. Second, to introduce international portfolio choices, we allow for trade in two equity-style assets as in symmetric models, e.g. Devereux and Sutherland (2011) and Heathcote and Perri (2013). Third, we assume an overlapping generation (OLG) structure à la Weil (1989) to ensure model stability in this asymmetric environment.

Specifically, we assume the households in the home country are less patient than the households in the foreign country, which drives the net capital flows from the foreign to the home country. Interpreted as vehicles of hedging against (relative) national income risks, optimal portfolios are hence composed of the portfolio self-hedging and a hedging associated with the return on unbalanced net external positions.[5] As in a symmetric model, the self-hedging entails a cross-country symmetrically short position of local assets. However, because under global imbalances the two countries have opposite status on international payment, the hedging of net portfolio return works in different ways in the two countries.[6] Taking local asset holding as an example, this hedging is negative in the home country while positive in the foreign country. To understand, as a net borrower (lender), the home (foreign) country pays (receives) interest on its net external position. In response to a local income windfall, the interest payment is relatively low. National income and consumption are relatively high (low) while the relative return to the local asset is high. The local asset, therefore, is a bad (good) hedge against the current return to net portfolio of the home (foreign) country, which delivers a short (long) position of local asset.

The relative size of this asymmetric hedging has important implications for the pattern of international diversification. By model calibration, we find that the short (long) position of local asset implied by this hedging is less (more) sizeable in the home (foreign) country, i.e. the home country prefers to sell less home asset to the foreign country while the foreign country holds more local asset domestically. International portfolio allocation

[5] In our model, there is a minor adjustment term due to the demographic structure.

[6] We distinguish between the hedging of current net portfolio return and that of future returns. Here we focus on the hedging of current net portfolio return. As will be detailed in the main text, there will be a minor hedging of future net portfolio returns which implies a symmetric and long position of local asset in both countries.

therefore must exhibit an equity home bias in the sense that both countries hold more local asset in their own portfolio. This result is relevant when looking at the past few decades of financial globalization in which cross-border financial transactions have grown at a fast rate while the level of asset home bias has fallen slowly.[7] Through the lens of Lucas's (1982) model, it is natural to conjecture that as the world becomes more open, country portfolios should converge toward a full diversification. This conjecture, however, relies on the strong assumption of identical countries and is not necessarily true when facing a world of NFA imbalances. According to our result, the optimal portfolios in such a world are in fact characterized by a home-biased allocation, instead of a fully-diversified (or a foreign-biased) one.

We demonstrate how the baseline model can be extended to better explain the observed portfolios in the countries with large unbalanced NFA positions. In the baseline model, we maintain the assumption that all incomes are capitalizable as Lucas (1982) and only consider the asymmetry in patience. In an extended model, we incorporate non-financial income and adopt a different asymmetry of financial development following Caballero et al. (2008, 2017). We calibrate the model and find it produces portfolio positions that are broadly consistent with the US and China's data between $1987-2007$. Through this experiment, we emphasize that, first, the emergence of the hedging of net portfolio return does not hinge on the particular asymmetry that used. Once an asymmetry opens non-zero NFA positions, it simultaneously creates the need to hedge against the risk associated with net external income. Second, by introducing the non-financial income, the magnitude of net and gross portfolios reduces substantially and approaches its empirical counterpart. However, again, the gap between the gross positions can only be justified in light of the new hedging under global imbalances. In addition, the degrees of international portfolio diversification feature a heterogeneity that corroborates the following fact (Coeurdacier and Rey, 2012): In the advanced borrowing country, the asset home bias is less significant than in the emerging lending country, which is because, as before, the hedging of net portfolio return requires a short (long) position of local asset in the home (foreign) country and hence tends to dampen (strengthen) the asset home bias there.

[7] Since the classic paper of French and Poterba (1991), equity home bias has long been a puzzle and been studied in the literature. Lewis (1999) is an early literature survey. Sercu and Vanpee (2007) provide extensive evidence for this trend before the financial crash while Coeurdacier and Rey's (2012) paper represents a recent survey of the literature.

Our work is related to a vast literature on global imbalances that uses different types of country asymmetry to account for the persistent non-zero NFA positions between the North and South countries.[8] This line of literature shares one common feature: while focusing on the determination of net positions of external assets they do not touch on the issue of portfolio choices.

This paper contributes to another large body of literature on the determination of gross portfolios, most of which aims to reconcile the puzzle of asset home bias with various types of hedging motive.[9] While this literature considers symmetric models, we analyze model of asymmetric countries. With the methodological developments,[10] there has been also a growing literature analyzing asymmetric portfolio models, such as Devereux and Sutherland (2009), Stepanchuk and Tsyrennikov (2015) and Mukherjee (2015).[11] Our key difference is that we focus on how, in general, non-zero NFA positions affect gross portfolio composition via the hedging of net portfolio return. Besides, the model with OLG structure enables us to obtain a fully analytical solution of both net and gross portfolios, which allows us to gain a better understanding of the nexus between households' intertemporal decision of saving and their intratemporal decision of portfolio choices in a financially-integrated global economy.

Our model also sheds light on NFA dynamics and relates to the literature on external adjustment. In a model that focuses on trade in one asset,[12] country's external adjustment

[8] The explanations along this literature include country asymmetries in terms of financial development (Mendoza et al., 2009, Caballero et al., 2008, Angeletos and Panousi, 2011, Coeurdacier et al., 2015), productivity growth (Engle and Rogers, 2006), demographic dynamics (Henriksen, 2005, Attanasio et al., 2006), business cycle volatility (Fogli and Perri, 2015), industrial structure (Jin, 2012), resource relocation (Song et al., 2011), social security system (Eugeni, 2015) and sex imbalance (Wei and Zhang, 2011) among others.

[9] See, e.g. Baxter and Jermann (1997), Coeurdacier et al. (2010) and Heathcote and Perri (2013) that focus on labour income, Kollmann (2006) on real exchange rate risk, Coeurdacier et al. (2007), Bretscher et al. (2016) on redistributive shocks and Berriel and Bhattarai (2013) on government spending shocks, etc.

[10] See Tille and Wincoop (2010), Devereux and Sutherland (2011), Evans and Hnatkovska (2012) and Rabitsch et al. (2015), etc.

[11] Devereux and Sutherland (2009) and Stepanchuk and Tsyrennikov (2015) rely on the asymmetries associated with the specification of international financial market. Mukherjee (2015) emphasizes differing quality of corporate governance across countries.

[12] This approach is taken by the standard textbook treatment of this issue, for instance, in Obstfeld

contains a trade balance effect and an intertemporal terms-of-trade effect (or valuation effect through net external positions). However, a portfolio valuation effect (on gross positions) is absent because it is not possible to distinguish gross portfolios from net portfolios. In the models with portfolio choices but without global imbalances[13], however, external adjustment takes through the trade balance effect and the valuation effect (on gross positions). The intertemporal terms-of-trade effect is absent because net portfolios are zero in these symmetric models. Some other studies, e.g. Blanchard et al. (2005) and Gourinchas and Rey (2007), accommodate the two aspects but generally use an approach which lacks microeconomic foundations. Embedded with both country asymmetry and portfolio choices, our model captures all three channels of external adjustment and is potentially more suitable for evaluating the implications of related shocks and policies.

We present the baseline model in Section 2. Sections 3 and 4 analyse the portfolio composition under the global imbalances and its implications for international diversification and external adjustment. In Section 5, we calibrate the baseline model, consider one of its extension and contrast the model with data. Section 6 concludes.

2 The baseline model

The model is essentially Weil (1989) extended to a two-country world with a country asymmetry and international portfolios.[14] Specifically, this is a one-good, two-country

and Rogoff (1996). Most of the literature on global imbalances, for instance those surveyed above, also belongs to this category.

[13]The literature on the portfolio approach to external adjustment include, for example, Devereux and Sutherland (2010), Tille and Wincoop (2010) and Ghironi et al. (2015) who study the process of external adjustment between two identical countries and highlight the role of portfolio valuation effects in the process. They analyze the gross portfolio valuation effect on top of the traditional trade balance effect, but within the symmetric set-up, the terms-of-trade effect is missing. The current work generalizes this approach to asymmetric situations.

[14]The Weil's (1989) *OLG* structure is here used to induce stationarity for the asymmetric open economy macro model. There is no steady state for individual variables while there is a steady state for per-capita variables with the assumed *OLG* structure. In the literature, there are some other techniques of closing such models as analyzed in, for instance, Schmitt-Grohe and Uribe (2003) and Bodenstein (2011) where additional ad hoc assumptions are required. However, **we** are more interested in describing global imbalances in a structural way, i.e. as a result of first principles, and show how net and gross country portfolios are determined by (possibly different types of) country asymmetries. With this device, we find

endowment economy. Except for the asymmetric patience defined below, all other aspects of the two countries are the same. In each country, at time $t = 0$, the population is normalized to 1. It grows at a constant gross rate of $\tilde{n} \equiv 1 + n > 1$ afterwards and no one dies. A household born at time v maximizes an additive logarithmic utility function of the following form in the period $t > v$

$$U_t^v = E_t \sum_{s=t}^{\infty} \beta^{s-t} \log \left(c_s^v\right) \tag{1}$$

where β and c_s^v are the discount factor and individual consumption, respectively. Superscripts are used to denote vintage and subscripts for time.

The budget constraint for vintage v household at time t is

$$\alpha_{1t+1}^v + \alpha_{2t+1}^v = \alpha_{1t}^v r_{1t} + \alpha_{2t}^v r_{2t} + y_t^v - c_t^v \tag{2}$$

where α_{1t+1}^v and α_{2t+1}^v denote the household's gross holdings of the two assets, defined below, at the end of time t. r_{1t} and r_{2t} are gross rates of return of assets from time $t-1$ to t. The individual endowment and consumption are y_t^v and c_t^v. Eq.(2) states that the net wealth of a household at the end of time t equals the portfolio returns from the last period plus the net saving.

Maximisation of Eq.(1) subject to Eq.(2) yields the individual Euler equations

$$\left(c_t^v\right)^{-1} = \beta E_t \left[\left(c_{t+1}^v\right)^{-1} r_{jt+1}\right] \tag{3}$$

for $j = 1$, 2 and $v = 1$, 2, ..., t. Similar conditions apply for the foreign country.

By asymmetric patience, $\beta < \beta^*$ is assumed.[15] There are three reasons for this. First, as shown by Buiter (1981), differing patience leads to unbalanced NFA positions of country in an open economy. Second, we use the different βs as a catch-all for factors underlying global imbalances.[16] According to Bernanke (2005), Gourinchas and Jeanne

that steady-state per-capita NFA positions are explicit functions of the fundamental parameters, i.e. differing discount rates across countries, which makes this possible.

[15] We use an asterisk to denote foreign (except for asset-related) variables.

[16] Ferrero et al. (2007) use a similar strategy, using asymmetric βs as a catch-all in generating net external imbalances, when investigating the impacts of current account dynamics on monetary policy (while the problem of portfolio choices is absent by assuming a single bond in the international financial market). The difference between Ferrero et al. (2007) and our paper is that they assume that the βs are hit by asymmetric preference shocks so that global imbalances are contemporary instead of being persistent.

(2013), Gourinchas and Rey (2013), etc., to explain the global imbalances, these factors also operate through generating an excess saving and a depressed autarky interest rate in the South countries. The asymmetry in βs is therefore viewed as a reduced-form representation of these complementary explanations of net capital flows. For instance, according to the related studies, a restricted access to a well-functioning credit market, a quality social security system, (or even) a balanced marriage market or/and free fertility choices[17] will make agents act in a more patient way by saving more.[18] Finally, it simplifies the model solution. We try to answer our questions in a simple framework, a model similar to Lucas's (1982) benchmark. As an alternative way of modelling global imbalances, the other country asymmetries require additional assumptions and therefore create an increased complexity while there is no essential change to the key result of the baseline model. In Section 5, we consider a different asymmetry of financial development à la Caballero et al. (2008, 2017).[19]

We assume that two assets, home and foreign equities, are traded internationally and

[17]See Coeurdacier et al. (2015) on credit constraints, Chamon and Prasad (2010) on expenditure burden and precautionary savings, Eugeni (2015) on the social pension system, Wei and Zhang (2011) on sex imbalances and Curtis et al. (2011) and Banerjee et al (2014) on structural demographic changes, etc. Following the literature, these institutions and factors, pensions, spouses and children, can all be viewed as substitutes for savings.

[18]While we agree that identifying the relative importance of these factors in contributing to the global imbalances in practice is interesting and very important, it is outside the scope of this work. Instead of proposing a new theory of global imbalances, the focus of this paper is to understand the composition of a country's portfolio choices as well as its implications for international diversification and NFA's adjustments when NFAs are persistently unbalanced due to structural cross-country asymmetries.

[19]As mentioned, most of the existing literature on global imbalances takes a similar approach when accounting for the global imbalances, i.e. emphasizing the role of a country asymmetry that generates a relatively high saving while a relatively low autarky interest rate in the North countries (Bernanke, 2005, Gourinchas and Jeanne, 2013, Gourinchas and Rey, 2013). Many factors that are able to affect the saving behaviour and the autarky interest rate can therefore be the potential candidate of explanation. The time preference of agents is the most fundamental determinant of the autarky interest rate as can be shown in a standard Ramsey model, which leads us to select the asymmetry associated with β as a catch-all in this paper. Countries may differ in the other aspects. We argue that, as in the current model, once these alternative asymmetries open a non-zero NFA position, so that a country's consumption will be given by GNP rather than GDP, this will create the motive to hedge NFA returns.

represent claims on the endowment of the issuing country with returns defined by

$$r_{1t} = \frac{y_t + z_{1t}}{z_{1t-1}}, \;\; r_{2t} = \frac{y_t^* + z_{2t}}{z_{2t-1}} \tag{4}$$

where z_{1t} and z_{2t} are equity prices.

Following Weil (1989), we assume that $y_t^v = y_t$, $y_t^{v*} = y_t^*$ for all v and t where y_ts represent per-capita aggregate incomes that are shocked:

$$\log\left(y_t/y\right) = \mu \log\left(y_{t-1}/y\right) + \varepsilon_t, \;\; \log\left(y_t^*/y^*\right) = \mu \log\left(y_{t-1}^*/y^*\right) + \varepsilon_t^* \tag{5}$$

In this paper, a per-capita variable without a time subscript denotes its steady-state value. We normalize $y = y^* = 1$ and assume that $0 \leq \mu \leq 1$ and ε and ε^* are zero-mean $i.i.d$ shocks with $var\left(\varepsilon\right) = var\left(\varepsilon^*\right) = \sigma^2$ and $cov\left(\varepsilon\varepsilon^*\right) = 0$.

2.1 Global imbalances in steady state

As shown below, the international interest rate of non-stochastic steady state $r_1 = r_2 = r$ will lie in between $1/\beta^*$ and $1/\beta$ in the asymmetric model. From the Euler equations, individual consumption is hence tilted downwards in the home country and upwards in the foreign country. There is no steady state for individual variables.[20] However, with the assumed demographic structure, the aggregate per-capita steady state is available and features NFA global imbalances. Below, we present this steady state around which the model is log-linearised.

Net foreign assets To find the per-capita NFA of the home country in steady state, we rewrite Eq. (2) as $w_{t+1}^v = w_t^v r_{2t} + \alpha_{1t}^v r_{xt} + y_t^v - c_t^v$ by defining $w_{t+1}^v = \alpha_{1t+1}^v + \alpha_{2t+1}^v$ as the household net wealth and $r_{xt} = r_{1t} - r_{2t}$ the excess return of equity 1 over equity 2. Using this budget constraint and Euler equations, we obtain the individual consumption function

$$c_t^v = (1-\beta)\left[r w_t^v + \sum_{i=0}^{\infty} \frac{1}{r^i} y_{t+i}\right] \tag{6}$$

[20]Given that $1/\beta^* < r < 1/\beta$, in the home country we have $r\beta < 1$. From Eq. (3), households consume less and less as they grow old. In contrast, in the foreign country, we have $r\beta^* > 1$. Individual consumption keeps growing. Because individual consumptions are not stable, individual wealth and portfolios are not stable either due to the budget constraints.

	Home holdings	Foreign holdings
Asset 1-Home equity	$\alpha_1 + z_1$	α_1^*
Asset 2-Foreign equity	$\alpha_2 = w - \alpha_1$	$\alpha_2^* + z_2 = w^* - \alpha_1^* + z_2$

Table 1: Net asset holdings across countries

Following Weil (1989), we assume that households are born with no wealth. Therefore,

$$c_t^n \equiv c_t^t = (1-\beta)\sum_{i=0}^{\infty}\frac{1}{r^i}y_{t+i} \tag{7}$$

where we introduce c_t^n with a superscript n to denote the consumption of new-borns.

We aggregate the individual budget constraint and consumption function to yield $w_{t+1} = \frac{r\beta}{\tilde{n}}w_t + \frac{r\beta-1}{\tilde{n}(r-1)}y_t$.[21] Assuming a stability condition $\tau \equiv r\beta/\tilde{n} < 1$, we obtain

$$w = \alpha_1 + \alpha_2 = \frac{r\beta - 1}{(\tilde{n} - r\beta)(r-1)} < 0 \tag{8}$$

Since $(r\beta - 1) < 0$, the home country will be in a position of net debt. In contrast, the foreign country will be in a position of net credit, $w^* = \frac{r\beta^* - 1}{(\tilde{n} - r\beta^*)(r-1)} > 0$. These results confirm the intuition that the impatient country consumes by borrowing while the patient country saves by lending.

International interest rate The net holdings of assets in the two countries are shown in Table 1.[22] A market clearing of the two assets implies $z_1 + \alpha_1 + \alpha_1^* = z_1$ and $w - \alpha_1 + z_2 + w^* - \alpha_1^* = z_2$, which is equivalent to $\alpha_1^* = -\alpha_1$ and $w^* = -w$.

The first equation implies that in solving portfolio allocations, we only need to solve for α_1. The other three αs are linked to α_1 through w and z. Denoting $\alpha \equiv \alpha_1$, we focus

[21] Due to the demographic structure, a per-capita variable, for instance consumption, is obtained from

$$c_t = \frac{c_t^0 + nc_t^1 + n\tilde{n}c_t^2 + \cdots + n\tilde{n}^{t-1}c_t^t}{\tilde{n}^t}$$

where c_t without superscript v denotes per-capita aggregate consumption. The per-capita aggregate budget constraint reads $\tilde{n}w_{t+1} = rw_t + y_t - c_t$ where $\tilde{n}$ emerges because we assumed that the households are born with no wealth (See Weil, 1989 or/and Chapter 3 of Obstfeld and Rogoff, 1996) .

[22] Two facts are used here. First, the home country is the default owner of home equity whose value is given by z_1. The home country's net holding of home equity is therefore given by the sum of the asset endowment and the gross holding $z_1 + \alpha_1$. Second, through the definition of $w = \alpha_1 + \alpha_2$, the home holding of foreign equity is given by $w - \alpha_1$. Foreign holdings follow from the same logic.

on solving for α in Section 3. The second equation states that the positions of home deficit and foreign surplus should be equal, which determines r

$$r=\frac{(1+\tilde{n})(\beta+\beta^{*})-\sqrt{(1+\tilde{n})^{2}(\beta+\beta^{*})^{2}-16\tilde{n}\beta\beta^{*}}}{4\beta\beta^{*}} \tag{9}$$

This verifies our previous assertion that $1/\beta^{*}<r<1/\beta$.[23] In addition, r is decreasing in the βs and increasing in $\tilde{n}$.

Consumption According to the aggregate Eq.(2), we obtain $c=1+(r-\tilde{n})w$. We assume $r>\tilde{n}$ and focus on the case of a dynamically efficient steady state. In this case, we have $w<0$ and $c<1$ for the home country while we have $w^{*}>0$ and $c^{*}>1$ for the foreign country. Note that in the symmetric case of $\beta=\beta^{*}$, we would have $w=w^{*}=0$ and $c=c^{*}=1$. Global imbalances disappear and the two countries consume their average resources, neither more nor less. When $\beta<\beta^{*}$, the impatient country consumes less than its average income, which reflects the fact that the country runs a trade deficit in steady state and some domestic resources are used to service international interest payments. Correspondingly, with a relatively higher β, the foreign country as a whole consumes more than its average income because per-capita GNP is higher than GDP and there is a positive international interest income.

For later use, we derive a relation between c and c^{n}, $c=\frac{n}{(\tilde{n}-r\beta)}c^{n}$.[24] Because in each period s, the new-born cohort only accounts for $n\tilde{n}^{s-1}/\tilde{n}^{s}=n/\tilde{n}$ of the total population, the steady-state fraction of consumption that is due to new-borns in total c is given by $\frac{n}{\tilde{n}}\frac{(\tilde{n}-r\beta)}{n}\equiv 1-\tau$. The remainder, τ, represents the steady-state fraction of consumption that is due to old generations.[25] Note that because $\beta<\beta^{*}$, in the foreign country,

[23] The proof is straightforward. Note that from $w=w^{*}$, we obtain the above r as the smaller root of the equation $F(r)\equiv 2\beta\beta^{*}r^{2}-(\tilde{n}+1)(\beta+\beta^{*})r+2\tilde{n}=0$. It is easy to verify that $F(1/\beta^{*})=n(1-\beta/\beta^{*})>0$ and $F(1/\beta)=n(1-\beta^{*}/\beta)<0$, which proves that $1/\beta^{*}<r<1/\beta$. To understand why the greater root for r is excluded, note that from the last subsection, it is required that $r<\tilde{n}/\beta^{*}<\tilde{n}/\beta$ to obtain stable NFAs. However, $F(\tilde{n}/\beta^{*})=(\beta/\beta^{*}-1)\left(\tilde{n}^{2}-\tilde{n}\right)<0$. The greater root violates the condition of $r<\tilde{n}/\beta^{*}$.

[24] From the new-borns' consumption function, $c^{n}=r(1-\beta)/(r-1)$. From $c=1+(r-\tilde{n})w$, $c=rn(1-\beta)/[(\tilde{n}-r\beta)(r-1)]$. $c=\frac{n}{(\tilde{n}-r\beta)}c^{n}$ hence follows. Or note that, according to the per-capita aggregation relation, we have $c_{t}=\frac{r\beta}{\tilde{n}}c_{t-1}+\frac{n}{\tilde{n}}c_{t}^{n}$ along the non-stochastic path.

[25] So our previous assumption of model stability is equivalent to the assumption of a positive share of old generations' consumption $\tau>0$.

$\tau^* = \frac{r\beta^*}{\tilde{n}} > \tau$.

We log-linearise the model around the above steady state. With unbalanced NFAs and population growth, the current model produces income risks and optimal asset holdings that are different from a symmetric model.[26] We analyse them now.

3 Optimal portfolios under global imbalances

In Appendix C, we show that the optimal condition for α is given by[27]

$$E_{t-1}\left[\hat{c}_t^D \hat{r}_{xt}\right] = 0 \qquad (10)$$

where $\hat{c}_t^D \equiv \left[\frac{1}{\tau}\left(\hat{c}_t - (1-\tau)\,\hat{c}_t^n\right) - \frac{1}{\tau^*}\left(\hat{c}_t^* - (1-\tau^*)\,\hat{c}_t^{n*}\right)\right]$ can be referred to as the cross-country portfolio-relevant consumption differential.

According to this condition, α is determined by first-order behaviours of the excess return $\hat{r}_{xt}$ and $\hat{c}_t^D$. The excess return $\hat{r}_{xt}$ has the same form as in a standard symmetric model, $\hat{r}_{xt} = \frac{(r-1)}{(r-\mu)}\left(\varepsilon_t - \varepsilon_t^*\right)$. For $\hat{c}_t^D$, apart from τ, $\tau^* \neq 1$, it differs from that of a symmetric model, i.e. $\left(\hat{c}_t - \hat{c}_t^*\right)$ as shown in Appendix A, by subtracting the relative consumption of new-borns. This is because we assumed that new-borns are born with zero assets and therefore do not make portfolio choices.

Eq. (10) also tells us how to interpret α. In the uncertain environment, households have an incentive to trade assets in the international financial market. Given the concave utility function, it is always desirable for the households to ensure a relatively smooth pattern of consumption across states. Given that consumption is fluctuating due to volatile incomes, this is achieved by investing in assets with payoffs that are themselves also volatile, but tend to yield a relatively high return while households' income and consumption are relatively low. α can therefore be viewed as a hedging of the relative national income risks that underlie the consumption differential $\hat{c}_t^D$.

[26] For the readers who are interested, in Appendix A, we compare the current asymmetric model with a symmetric portfolio model (that is based on Devereux and Sutherland, 2011).

[27] Throughout the paper, a per-capita variable with a hat denotes its log-deviation from the steady state. For instance, $\hat{c}_t = \log\left(\frac{c_t}{c}\right)$ and $\hat{r}_t = \log\left(\frac{r_t}{r}\right)$. The only exception is for $\hat{w}$. In conventional symmetric models, the steady-state w is zero. So $\hat{w}$ is usually defined as a deviation of w_t relative to steady-state GDP, i.e. $\log w_t - \log y$. We follow this so as to make the comparison between the results in our paper and those in a symmetric model more convenient.

Appendix D shows that

$$\begin{aligned}\hat{c}_t^D &= \frac{r}{r-\mu\tilde{n}}\left[\frac{1-\beta}{c\tau}\hat{y}_t - \frac{1-\beta^*}{c^*\tau^*}\hat{y}_t^*\right] - \frac{\tilde{n}}{r-\mu\tilde{n}}\left[\frac{(1-\tau)}{\tau}\hat{c}_{t+1}^n - \frac{(1-\tau^*)}{\tau^*}\hat{c}_{t+1}^{n*}\right] \\ &+r\phi w\hat{r}_{2t} + \frac{\tilde{n}}{r}r\phi w\Sigma_{t+1}^{rn} - \left[\frac{(1-\tau)}{\tau}\hat{c}_t^n - \frac{(1-\tau^*)}{\tau^*}\hat{c}_t^{n*}\right] + r\phi\alpha\hat{r}_{xt} \qquad (11)\end{aligned}$$

where $\phi \equiv \frac{(1-\beta)}{c\tau} + \frac{(1-\beta^*)}{c^*\tau^*}$ and $\Sigma_{t+1}^{rn} \equiv \Sigma_{i=0}^{\infty}\left(\frac{\tilde{n}}{r}\right)^i \hat{r}_{t+1+i}$. It follows that except for the excess return on the gross portfolio $r\phi\alpha\hat{r}_{xt}$, $\hat{c}_t^D$ consists of the following risk factors:

1. The (relative) endowment effect $\hat{c}_t^D[1]$, i.e. the first two terms on the right-hand-side (RHS). The first term, $\frac{r}{r-\mu\tilde{n}}\left[\frac{1-\beta}{c\tau}\hat{y}_t - \frac{1-\beta^*}{c^*\tau^*}\hat{y}_t^*\right]$, denotes the relative endowment movement belonging to both the existing and yet-to-be-born generations. The second term, $\frac{\tilde{n}}{(r-\mu\tilde{n})}\left[\frac{(1-\tau)}{\tau}\hat{c}_{t+1}^n - \frac{(1-\tau^*)}{\tau^*}\hat{c}_{t+1}^{n*}\right]$, denotes only those due to the yet-to-be-born generations. The difference between them can be viewed as a relative GDP effect, the only term that is present in a symmetric model.

2. The (relative) current and future net-portfolio-return effects $\hat{c}_t^D[2] = r\phi w\hat{r}_{2t}$ and $\hat{c}_t^D[3] = \frac{\tilde{n}}{r}r\phi w\Sigma_{t+1}^{rn}$. They emerge because $w \neq 0$ in the model, which implies international payments in the current and future periods. These and the above relative GDP effects taken together can be viewed as a relative GNP effect.

3. The (relative) new-borns' consumption effect $\hat{c}_t^D[4] = -\left[\frac{(1-\tau)}{\tau}\hat{c}_t^n - \frac{(1-\tau^*)}{\tau^*}\hat{c}_t^{n*}\right]$. It emerges because, as mentioned, only the old cohorts' decisions matter in order to determine the optimal portfolio. It disappears in a standard symmetric model because the OLG structure is unnecessary and absent there.[28]

Substituting $\hat{c}_t^D$ into Eq. (10), we obtain α[29]

$$\alpha = \underbrace{-\frac{cov(\Delta y_t,\ \hat{r}_{xt})}{var(\hat{r}_{xt})}}_{\alpha[1]<0}\underbrace{-w\frac{cov(\hat{r}_{2t},\ \hat{r}_{xt})}{var(\hat{r}_{xt})}}_{\alpha[2]<0}\underbrace{-\frac{\tilde{n}w}{r}\frac{cov\left(\Sigma_{t+1}^{rn},\ \hat{r}_{xt}\right)}{var(\hat{r}_{xt})}}_{\alpha[3]} + \underbrace{\frac{cov(\Delta c_t^n,\ \hat{r}_{xt})}{var(\hat{r}_{xt})}}_{\alpha[4]>0} \qquad (12)$$

[28] There should have been a relative interest-rate-tilting effect which reflects the fact that in these two countries, households potentially have a differing degree of desire to take advantage of intertemporal opportunities. We see from the above discussion that the tilting effect in the home country is relatively weaker than in the foreign country, i.e. $\beta < \beta^*$. However, when entering $\hat{c}_t^D$, it is given a relatively larger weight, i.e. $\frac{1}{\tau} > \frac{1}{\tau^*}$. These two factors offset each other, i.e. $\frac{\beta}{\tau} = \frac{\beta^*}{\tau^*}$, which results in the disappearance of an interest-rate-tilting effect after we take the country difference into account. See Appendix D for the details.

[29] In what follows, our exposition will proceed with a semi-closed-form solution of α. The full-closed-form solution of α and the associated MATHEMATICA file are available from the author upon request.

where $\Delta y_t \equiv \frac{1}{r\phi}\hat{c}_t^D[1]$ and $\Delta c_t^n \equiv \frac{1}{r\phi}\hat{c}_t^D[4]$ are relative income and relative new-borns' consumption.

We explain α's components in turn.

Diversification term or self-hedging term $\alpha[1] = -\frac{1}{2(r-1)}\frac{(r-\mu)}{(r-\mu\tilde{n})} + \frac{1}{2r\phi}\frac{\mu\tilde{n}}{r-\mu\tilde{n}}\left[\frac{1-\tau}{\tau} + \frac{1-\tau^*}{\tau^*}\right]$. It reflects households' motive to hedge against $\hat{c}_t^D[1]$. Imposing $\tilde{n} = 1$, $\tau = \tau^* = 1$, it collapses into the case of a symmetric model, $\alpha = -\frac{1}{2(r-1)} = -\frac{z}{2}$, which implies a full diversification of portfolios.[30] We prove in Appendix E that, in the asymmetric model, the self-hedging is identical to that of a symmetric model, i.e.

$$\alpha[1] = -\frac{1}{2(r-1)} < 0$$

α contains the following additional components due to the presence of country asymmetry and population growth in our model.

Hedging the current net portfolio return

$$\alpha[2] = -\frac{(r-\mu)(\zeta_{r2e1} - \zeta_{r2e2})w}{2(r-1)} < 0$$

where ζ_{r2e1} and ζ_{r2e2} are responses of $\hat{r}_{2t}$ to home and foreign shocks $\{\varepsilon_t, \varepsilon_t^*\}$. It reflects households' motive to hedge against $\hat{c}_t^D[2]$. In symmetric models where $w = 0$, $\alpha[2] = 0$.

The sign of $\alpha[2]$ depends on the relative magnitude of ζ_{r2e1} and ζ_{r2e2}. According to the asset pricing relations, a positive shock in either country increases the rate of return for both assets. For the abroad asset, the increase in the return arises because of lower expected future interest rates and thus higher capital gains today. For the local asset, the increase arises because of higher capital gains and also a higher dividend payment. Thus, ζ_{r2e1} and ζ_{r2e2} are both positive and $\zeta_{r2e1} < \zeta_{r2e2}$.

$\alpha[2]$ is negative. To understand this, note that the home country is a debtor country and has to pay interest on its net foreign liability. Home and foreign (positive) shocks both boost the current interest rate and thus also the interest payment to the foreign country. Since $\zeta_{r2e1} < \zeta_{r2e2}$, the increase in the interest payment is smaller in response to the home shock. In other words, when home consumption is high, the excess return

[30] See, for instance, Lucas (1982), Devereux and Sutherland (2011), Coeurdacier and Rey's (2013) survey.

is also high, so asset 1 is a bad hedge against the risk of this income stream. The home country therefore chooses to short asset 1.

Hedging the future net portfolio returns

$$\alpha\left[3\right]=-\frac{\left(r-\mu\right)\left(\zeta_{sre1}-\zeta_{sre2}\right)}{2\left(r-1\right)}\frac{\tilde{n}w}{r}$$

where ζ_{sre1} and ζ_{sre2} are the responses of Σ_{t+1}^{rn} to home and foreign shocks $\{\varepsilon_t, \varepsilon_t^*\}$. Because, as a supply shock, the endowment increase in either country tends to reduce expected future interest rates, ζ_{sre1} and ζ_{sre2} are both negative.

The sign of $\alpha\left[3\right]$ depends on the relative magnitude of ζ_{sre1} and ζ_{sre2}. In other words, it depends on the answer to the following question: with the country asymmetry, in which country does an income rise depress the expected future interest rate more efficiently? If the foreign income shock is more powerful in this regard, i.e. $\zeta_{sre1} > \zeta_{sre2}$, then $\alpha\left[3\right]$ is positive. To understand, note that the home country also has to pay interest on its net foreign liability in subsequent periods after shocks. Home and foreign (positive) shocks both depress the expected future interest rates. Thus, the interest payment to the foreign country in the future can be lower. When $\zeta_{sre1} > \zeta_{sre2}$, the home shock induces a relatively moderate decrease in interest payments (so consumption is relatively low) while the excess return on asset 1 is relatively high. So asset 1 is a good hedge against the future net portfolio return risk in terms of the smoothing consumption differential. The home country therefore chooses a long position on asset 1. Otherwise, if $\zeta_{sre1} < \zeta_{sre2}$, asset 1 would be shorted.

Adjustment term due to the demographic structure

$$\alpha\left[4\right]=\frac{1}{2r\phi}\left[\frac{1-\tau}{\tau}+\frac{1-\tau^*}{\tau^*}\right]>0$$

The fourth term emerges because we assumed that in each period, it is the decisions of only a fraction of the population that matters. Thus, this corresponds to a deduction of the consumption of yet-unborns from the per-capita aggregate consumptions in $\hat{c}_t^D$. In addition, the deduction is more responsive to the home shock than to the foreign shock, $\frac{(1-\tau)}{\tau} > \frac{(1-\tau^*)}{\tau^*}$. When, for instance, a positive shock takes place in the home country, because the deduction of new-borns' consumption is relatively high, the portfolio-relevant home consumption is relatively low while the excess return on asset 1 is relatively high. So asset 1 is, in a sense, a good hedge against this part of risk, which explains a positive sign of the above portfolio term.[31]

4 International diversification and external adjustment under global imbalances

With the above additional hedging terms, the implied portfolio is expected to be different from the full diversification of Lucas (1982). In particular, we wonder if it is biased toward the local or abroad asset. Since $z_1 = z_2$, we only need a condition concerning one of the two countries for the portfolio allocation to exhibit the asset home bias.[32] In the home country, this is $(z_1 + \alpha_1) / (z_1 + \alpha_1 + z_2 + \alpha_2^*) > 1/2$, i.e. the share of asset 1 in the home country's portfolio exceeds that in the world portfolio. In Appendix F, we show that, similar to α, the foreign gross holding of foreign asset $\alpha_2^* \equiv \alpha^*$ also comprises the above hedging terms. However, in α^*, first, except for the hedging of current net portfolio returns, all other hedging terms are the same. Second, $\alpha^*[2] = -w^* \frac{cov(\hat{r}_{1t},\, \hat{r}_{xt}^*)}{var(\hat{r}_{xt}^*)} > 0$ as opposed to $\alpha[2] = -w \frac{cov(\hat{r}_{2t},\, \hat{r}_{xt})}{var(\hat{r}_{xt})} < 0$. Therefore, whether the portfolio allocation is home-biased or not depends on the relative size of $\alpha[2]$ and $\alpha^*[2]$ that is controlled by the above covariance terms. An equity home bias emerges if and only if

$$cov(\hat{r}_{1t},\, \hat{r}_{xt}^*) < cov(\hat{r}_{2t},\, \hat{r}_{xt}) < 0$$

where $\hat{r}_{xt}^* = -\hat{r}_{xt} = \hat{r}_{2t} - \hat{r}_{1t}$. To understand, when this condition holds, the hedging of the current net portfolio return implies a relatively smaller short position of the home asset in the home portfolio, while it implies a relatively larger long position of the foreign asset in the foreign portfolio. All other hedging terms and asset supplies being equal, this means that both countries hold relatively more of their local asset in their country

[31] The sign of this portfolio term can also be understood in the following way: With relatively less risks (whose correlation with relative income is positive) to be hedged by a given amount of hedging vehicle, in order to stabilize the portfolio-relevant consumption differential, a smaller short position of the home asset is required.

[32] In such a case, if the local asset is preferred by one country, this must be also true for the other country.

portfolios. The asset home bias emerges due to the differing properties of the hedging of net external income between the two countries that are implied by their opposite status on international payment.[33]

Both net and gross country portfolios being determined, we combine the two countries' external budget constraints to yield

$$\hat{w}_{t+1} - \hat{w}_t = \frac{r-\tilde{n}}{\tilde{n}}\hat{w}_t + \underbrace{\frac{rw}{\tilde{n}}\hat{r}_{2t}}_{TT_t} + \underbrace{\frac{r\alpha}{\tilde{n}}\hat{r}_{xt}}_{VAL_t} + \underbrace{\frac{1}{2\tilde{n}}\left[\hat{y}_t - \hat{y}_t^* - (c\hat{c}_t - c^*\hat{c}_t^*)\right]}_{TB_t} \tag{13}$$

Eq. (13) shows that besides the traditional trade channel TB, an intertemporal terms-of-trade effect on net portfolios (TT) and a valuation effect on gross portfolios (VAL) are generated at the same time in the current model. Note that the two effects, TT and VAL, are both portfolio "valuation effects" and are captured empirically in the literature (Gourinchas and Rey, 2007). The existing theoretical models, however, fail to capture the two effects at the same time. The VAL effect is missing from the traditional single-bond literature because α is absent there. When they refer to the valuation effect, it is actually only the TT effect that exists.[34] On the other hand, the TT effect is missing from recent symmetric models of country portfolios because $w = 0$ there. When they refer to valuation effects, it is actually only the VAL effect that exists.[35]

Assuming a no-Ponzi-game condition and iterating Eq. (13), we obtain the intertemporal external constraint

$$\hat{w}_t = -\sum_{j=0}^{+\infty}\left[\frac{\tilde{n}}{r}\right]^{j+1}\left\{TT_{t+j} + VAL_{t+j} + TB_{t+j}\right\}.$$

This equation can be read in parallel with the similar equations in the literature, for example Eq. (9) of Gourinchas and Rey (2007) and Eq. (3) of Blanchard et al. (2005). Note that because the net and gross portfolio positions are endogenously determined in

[33]As a caveat, the equity home bias we observed in reality is not only that local assets outweigh overseas assets in a country's portfolio but also that most of local assets are invested in by domestic investors (French and Poterba, 1991). The difference between them can be better understood through a figure like Figure 1 below.

[34]See, e.g. Bhagwatti (1958) and textbook treatment of this issue like Chapter 1 of Obstfeld and Rogoff (1996).

[35]See, e.g. Devereux and Sutherland (2010), Tille and Wincoop (2010), Ghironi et al. (2015) among others.

this model, the terms of trade and valuation effects generated here are fully endogenous and micro-founded in contrast to these two other papers.

5 Model calibration and extension

5.1 Calibrating the baseline model

There are only four parameters in the baseline model, two βs, n and μ.[36] Taking one year as the frequency, we set the home discount factor β at 0.96 as is commonly used in the literature and β^* one percentage higher. This implies an autarky annual interest rate of 4% in the home country while it is 1% lower in the foreign country. The growth rate of population is chosen to be 0.01,[37] under which the related stability and dynamic efficiency conditions, i.e. $\tau, \tau^* < 1$ and $r > \tilde{n}$, hold. We set μ to be the medium estimate by Smets and Wouters (2007). Table 2 lists all parameter values and the resulting variable values in steady state.

Given the assumed parameterization, r is computed to be around 3.4%. The magnitudes of the NFA position and the asset supplies are very large. A one percent difference between βs results in a value of w at the level of around 12.5 times average GDP. The asset stock is around 30 times average GDP. Both are too large from an empirical point of view. This is because, like Lucas (1982), we assume that all incomes are capitalizable. We stick to this specification here to make it easy to compare the portfolio models with and without global imbalances that are both based on the Lucas's (1982) full-diversification benchmark. We will relax this assumption later.

International portfolios The optimal gross holding of home equity by the home country, α, is computed to be -20.773. We plot its components and implied international portfolio allocation in Figure 1. The left half of the figure shows the 4 components of α with 4 bars, i.e. $\alpha[1]$ to $\alpha[4]$ from the left to the right. To represent their signs, negative components are accumulated from the top line (whose height denotes the steady-state as-

[36]The choice of σ does not matter for computing αs in the model. It can be chosen to be any positive value. We choose it at 0.45, as estimated by Smets and Wouters (2007).

[37]Cavallo and Ghironi (2002) and Ghironi (2006) find that the average rate of quarterly population growth for the US between 1973:1 and 2000:3 has been 0.0025.

Description	Value
Home discount factor	$\beta = 0.96$
Foreign discount factor	$\beta^* = 0.97$
Population growth rate	$n = 0.01$
Shock persistence	$\mu = 0.95$
Home Euler equation parameter	$\tau = 0.983$
Foreign Euler equation parameter	$\tau^* = 0.993$
Home net foreign asset	$w = -12.47$
International interest rate	$r = 1.034$
Asset stock	$z_1,\ z_2 = 29.414$
Home consumption	$c = 0.70$
Foreign consumption	$c^* = 1.30$
Optimal portfolio holding	$\alpha = -20.773$
- Self-hedging	$\alpha\,[1] = -14.707$
- Hedging current return to w	$\alpha\,[2] = -6.221$
- Hedging future reurn to w	$\alpha\,[3] = 0.009$
- Demographic adjustment term	$\alpha\,[4] = 0.146$
$cov\,(\hat{r}_{2t},\ \hat{r}_{xt})$	-0.1634
$cov\,(\hat{r}_{1t},\ \hat{r}^*_{xt})$	-0.1642
External adjustment - Trade effect	0.625
- Intertemporal TT effect	-3.349
- Gross portfolio VAL effect	-8.607

Table 2: Simulation of the baseline model (y and y* are normalized at 1)

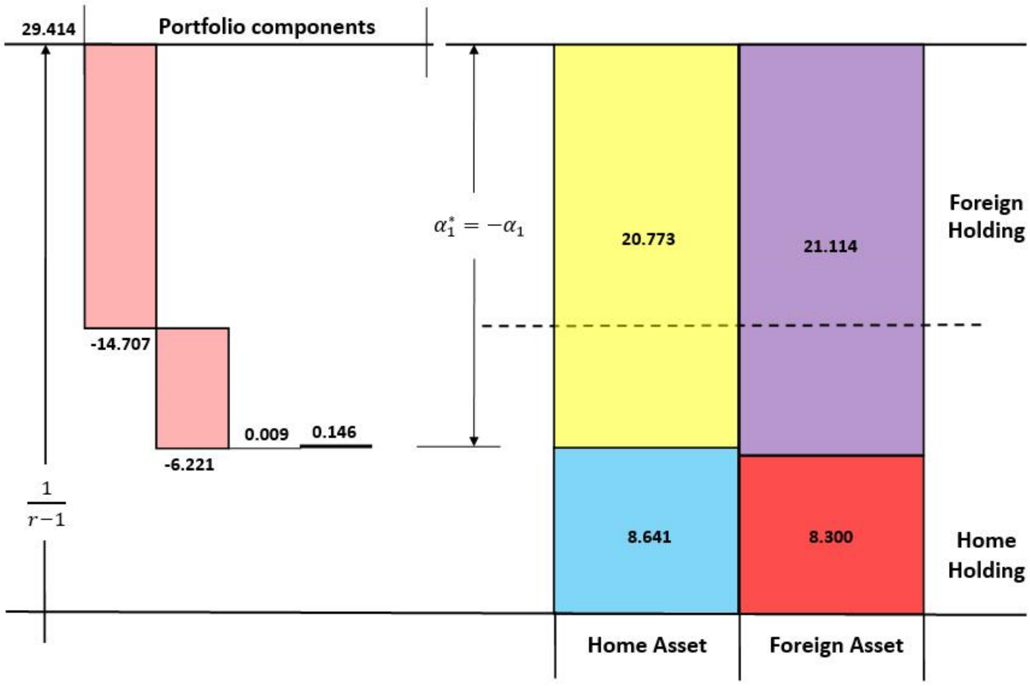

Figure 1: Steady-state international portfolios under global imbalances. Notes: In the right half, we break the Home and Foreign assets into four pieces representing net asset holdings: Foreign holding of home asset (20.77), Foreign holding of foreign asset (21.11), Home holding of foreign asset (8.30) and Home holding of home asset (8.64). In the left half, we break $\alpha = -20.77$ into the four hedging terms as in Section 3.

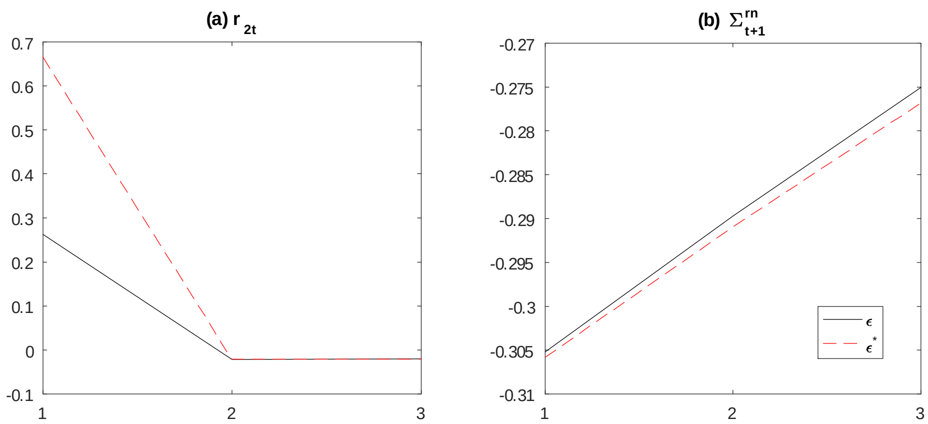

Figure 2: Response of $\hat{r}_{2t}$ and Σ^{rn}_{t+1} to positive home (solid line) shock ε and foreign (dashed line) shock ε^*. By panel (a), $\zeta_{r2e1} < \zeta_{r2e2}$. By panel (b), $\zeta_{se1} > \zeta_{se2}$.

set stock z) downwards while positive components are accumulated the other way around. The height of the bars corresponds to their sizes.

For the first and longest bar to the left, as explained, because home GDP always moves in the same direction as the home asset return, as a bad hedge against the risk, the home asset will be shorted by home households, i.e. $\alpha[1] = -14.707$. As proved, its size equals to $z/2$. The second bar represents hedging of the current net portfolio return, $\alpha[2]$. Because $Cov(\hat{r}_{2t}, \hat{r}_{xt}) < 0$, or from Panel ($a$) of Figure 2, the foreign asset's return increases more in response to the foreign shock than to the home shock $0 < \zeta_{r2e1} < \zeta_{r2e2}$, the home asset is a bad hedge against the underlying income. Home households further short the home asset $\alpha[2] = -6.221$. Similarly, we see from Panel (b) of Figure 2 that Σ_{t+1}^{rn} declines as the endowment increases in either country and it is more responsive to the shock in the foreign country $0 > \zeta_{sre1} > \zeta_{sre2}$. This leads to a positive $\alpha[3]$ (that equals to 0.009 here). Finally, the term due to the OLG structure is always positive and is given by $\alpha[4] = 0.146$ under this parameterization.

Let us compare the sizes of these components. Because self-hedging is linked to the risk associated with the relative GDP effect, the most important source of risk, the diversification term is the largest component. Under global imbalances, the hedging of the current net portfolio return is linked to the risk associated with the income difference between GNP and GDP, which should be secondary as compared to GDP. The hedging is thus less substantial. However, with a very large external net position here, the hedging of the net portfolio return is still considerable. Lastly, the hedging of future net portfolio return and the term due to the OLG structure are found to be very small.

The right half of the figure shows the implied international diversification pattern. There are two wide columns representing, from the left to the right, home and foreign equity supplies respectively. The starting axes for home and foreign holdings are the bottom and the top lines respectively. The values are divided by two solid lines so that there are four cells, i.e. upper left, bottom left, bottom right and upper right anti-clockwise, representing the foreign holding of the home asset of 20.773 (times of average GDP), the home holding of the home asset of 8.641, the home holding of the foreign asset of 8.300 and the foreign holding of the foreign asset of 21.114 respectively.

To compare the allocation to that of a symmetric model, we draw a dashed line in the middle of the two columns. It divides the two columns into four cells of the same area that corresponds to the Lucas's (1982) fully diversified allocation. The current model deviates from the symmetric case in two ways. First, the steady-state NFA at home is negative. The two solid lines move from the benchmark downwards to create an area that represents the home country NFA position, i.e. the area above the solid lines but below the dashed line. Second, the net portfolio allocations under global imbalances exhibit an asset home bias in the sense that the home holding of the home asset is larger than the home holding of the foreign asset even though the two assets are equally supplied in the world portfolio. The left solid line is higher than the right one. From the bottom of Table 2, we see that $cov\left(\hat{r}_{1t}, \hat{r}^*_{xt}\right) < cov\left(\hat{r}_{2t}, \hat{r}_{xt}\right) < 0$. As analysed, the asymmetry in the model biases the portfolio towards local assets through the hedging of net portfolio return that differs across countries. Changing the value of β^*, we find that, as the asymmetry between countries becomes larger, the two solid lines move downwards (i.e. the global NFA imbalance is exacerbated) and the gap between the two widens (i.e. the asset home bias deepens).

Risk-sharing and external adjustment Figure 3 plots the dynamics of the consumption differential, $\hat{c}^D$, and that of the components of net foreign assets, $\hat{w}$, after a home shock in the cases with (solid line) and without (dashed line) holdings of international portfolios. By 'without portfolio', we mean that the condition of $\alpha = 0$ is imposed. We show this hypothetical case and compare it to the case with portfolios in order to highlight the role of the presence of portfolio choices in giving rise to the VAL effect in a model.[38] Panels (a) to (h) depict responses of $\hat{c}^D$, home NFA, home and foreign consumption, the trade balance effect, the terms of trade effect, the valuation effect and the income shock.

In the case without portfolio holdings, most of the effect of an increase in home endowment on consumption will be on home consumption because the shock mainly affects consumption through the increased GDP (see the high dashed line in Panel (c) compared to the low dashed line in Panel (d)). The gap between home and foreign consumption is thus very large at around 0.73, as shown in Panel (a). However, if optimal portfolios are in place, the rise in the home endowment affects consumption not only through affecting

[38] In Appendix G, we instead compare $\hat{w}$'s dynamics to that with and without country asymmetry and global imbalances. In that experiment, we highlight, when country asymmetry and hence global imbalances are present, the role of the presence of non-zero net portfolio positions in giving rise to the TT effect.

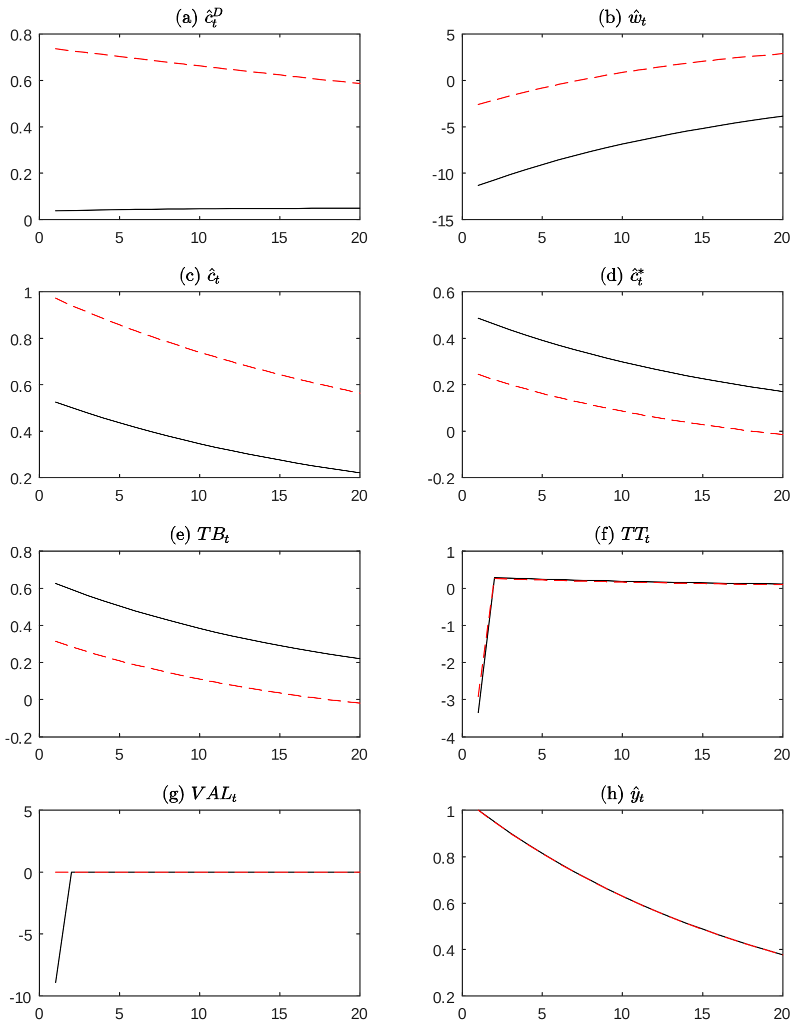

Figure 3: IRFs to home shock in a model with (solid line) and without (dashed line) gross portfolio choices

GDP, but also through affecting portfolio returns. The attendant negative TT and VAL effects imply a large wealth transfer from the home to the foreign country. Net external wealth, $\hat{w}$, is lower than in the case without portfolios (see Panel (b)).[39] Home consumption is depressed (to the low solid line in Panel (c) at the level of around 0.5) at the same time as foreign consumption is elevated (to the high solid line in Panel (d) also at the level of around 0.5). The consumption differential across countries is thus narrowed down substantially, indicating a significantly improved level of risk-sharing across countries.

To better see the roles of trade and valuation channels in affecting a country's external adjustment, we plot each component of $\hat{w}$ in the remaining panels of Figure 3. Panel (e) shows that the positive home shock raises the trade balance, which is due to the fact that when GDP increases, consumption increases but less than one for one. Without portfolio choices, this is represented by the dashed line in this panel. If countries hold optimal portfolios, the increase of home consumption will be lesser because there will be a negative VAL effect (shown below) which reduces wealth. The trade balance can therefore be higher (a higher solid line than dashed line in Panel (e)). For Panel (f), look at the dashed line first. Because $\hat{r}_2$ is immediately driven up after the shock, the TT effect is lower in the first period. In subsequent periods, $\hat{r}_{t+i}$ is negative but close to 0. So the interest payment on the negative position of NFA becomes positive, but is also close to 0. The inclusion of portfolio choices has no significant impact on the TT effect because the TT effect is mainly linked to the net instead of the gross portfolio position. Panel (g) shows that when $\hat{y}_t$ increases, a substantial rise in the excess return $\hat{r}_x$ combined with $\alpha < 0$ leads to a large negative VAL effect. Because expected future excess returns are 0 in this model, we do not observe any valuation effects in subsequent periods. The dashed line of Panel (g) lies at 0 because the presence of the VAL effect is linked to α. When $\alpha = 0$, the effect disappears.

The sizes of these effects are reported at the foot of Table 2. A one percent increase in $\hat{y}_t$ leads to a 0.63 percent increase in the trade balance. In the case without the country asymmetry and portfolio choices, this constitutes the entire adjustment in NFA

[39] Specifically, this is because of an additional VAL effect here. The TT effect appears in both with- and without-portfolio cases as long as the model features non-zero steady-state net portfolios. For comparison, as illustrated by the two Panel-(b)s of Figures 4 and 5 in Appendix G, $\hat{w}$ is lower in the asymmetric case due to an additional negative TT effect. The VAL effect appears in both the symmetric and the asymmetric case.

on impact, so $\hat{w}$ improves. However, with the presence of the country asymmetry, an external deficit implies a higher interest payment in the home country after the shock. So $\hat{w}$ decreases through the negative TT effect, which is -3.35%. Moreover, if portfolios are optimally chosen, then $\hat{w}$ decreases further as the VAL effect contributes another 8.61% adjustment downwards. Note that because both the net and the gross external positions are very large, these two effects are also very large, which totally offsets the effect of the initial TB effect and results in the substantial deterioration of the NFA position. We take this problem into account when extending the baseline model below.

5.2 Extending the baseline model

To confine our attention only to the impacts of global imbalances on financial integration, in the above baseline model, we consider a most parsimonious set of assumptions and deliberately exclude many realistic features for such a model empirically accounting for observed country portfolios. In particular, we maintain the assumption that all incomes are capitalizable. In reality, most incomes are non-diversifiable. The role of labour-income hedging in shaping portfolio allocations has also been emphasised by the literature.[40] Besides, in the baseline model, non-zero net portfolios emerge due to the differing patience. Yet the expanding literature on global imbalances finds many other complementary forces that have been driving the net capital flows to the North countries. In particular, Caballero et al. (2008, 2017) argue that the differing financial development of countries is an important reason behind the phenomena. In what follows, we extend the baseline model in these two aspects. Our questions are: is the hedging of returns on the net external position still important and will the magnitude of portfolio positions and diversification become more plausible when confronting data?

Consider the same demographic structure and utility function as in the baseline model. However, the budget constraint for vintage-v household at time t now reads

$$\alpha_{1t+1}^{v} + \alpha_{2t+1}^{v} = \alpha_{1t}^{v} r_{1t} + \alpha_{2t}^{v} r_{2t} + y_{lt} + y_{kt} - c_{t}^{v}.$$

While other notations are familiar, y_{lt} denotes a perishable endowment that the household receives. Besides this income, there are some "trees" in each country which serve as a

[40] See, e.g. Coeurdacier et al. (2010) and Heathcote and Perri (2013) among others.

storage of value and generate an income of y_{kt}. Equity assets represent claims on the yield of these trees whose return rates are

$$r_{1t} = \frac{y_{kt} + \tilde{n} z_{1t}}{z_{1t-1}},\ r_{2t} = \frac{y_{kt}^{*} + \tilde{n} z_{2t}}{z_{2t-1}}$$

where z_{1t-1} and z_{2t-1} are the equity prices at the end of time $t-1$.

We refer to y_{kt} and y_{lt} as the financial and non-financial incomes. Total income y_t is assumed to be given by the sum of y_{kt}, y_{lt} and a value loss that is proportional to the stock of trees, $d_t = n z_{1t}$.[41] We use a parameter δ to describe the share of these incomes in steady state, i.e. with $y = 1$, $y_k = \delta - \frac{n\delta}{(r-1)}$, $y_l = 1 - \delta$ and $d = \frac{n\delta}{(r-1)}$ respectively. Moreover, following Caballero at al. (2008), we assume $\delta > \delta^*$ in the two countries to capture their difference in financial development: the home (foreign) country supplies more (less) asset.

Total incomes follow the same process as in the baseline model. To capture the negative correlation between the financial and non-financial incomes in such an endowment economy, we follow Bretscher et al. (2016) in assuming additive distributive shocks, $\hat{e}_t = \mu_d \hat{e}_{t-1} + \varepsilon_{dt}$, $\hat{e}_t^* = \mu_d \hat{e}_{t-1}^* + \varepsilon_{dt}^*$, to the financial and non-financial incomes. For simplicity, we assume that $\mu_d = \mu$ and all $i.i.d.$ shocks have the same variance and zero covariance.

Appendix H shows that NFA global imbalances emerge here with the unbalanced financial developments. In particular, the autarky interest rate in steady state is relatively higher in the home country, $(1 + n\delta)/\beta > (1 + n\delta^*)/\beta$. The international interest rate lies in the exact middle of the two autarky interest rates, $r = \left(1 + n\bar{\delta}\right)/\beta$ with $\bar{\delta}$ denoting the average financial development, which channels net capital from the foreign country $w^* = \frac{\left(\bar{\delta} - \delta^*\right)}{\left(1-\bar{\delta}\right)(r-1)} > 0$ to the home country $w = \frac{\left(\bar{\delta} - \delta\right)}{\left(1-\bar{\delta}\right)(r-1)} < 0$. The optimal portfolio holding α is given by

$$\begin{aligned}
\alpha \quad = \quad & -\frac{cc^*}{(c+c^*)\, r} \frac{cov\left(\Delta y_{kt},\, \hat{r}_{xt}\right)}{var\left(\hat{r}_{xt}\right)} - \frac{cc^*}{(c+c^*)\, r} \frac{cov\left(\Delta y_{lt},\, \hat{r}_{xt}\right)}{var\left(\hat{r}_{xt}\right)} \\
& - w \frac{cov\left(\Sigma_{2t}^{rn},\, \hat{r}_{xt}\right)}{var\left(\hat{r}_{xt}\right)} + \frac{cc^*}{(c+c^*)\, r} \frac{1-\tau}{1-\beta} \frac{cov\left(\Delta c_t^n,\, \hat{r}_{xt}\right)}{var\left(\hat{r}_{xt}\right)}
\end{aligned}$$

where Δy_{kt} and Δy_{lt} are the relative financial and non-financial incomes[42] and $\Sigma_{2t}^{rn} = \hat{r}_{2t} + \frac{\tilde{n}}{r} \Sigma_{t+1}^{rn}$. Ignoring the last demographic adjustment term, the hedging of net external

[41] One can interpret d_t as the depreciation of these "trees" in the economy.

[42] Their definitions are similar to Δy_t of the baseline model and can be found in Appendix H.

	Home country	Foreign country
Gross holding of local asset	$\alpha = -0.660$	$\alpha^* = -0.484$
- Self-hedging	-1.783	-1.783
- Hedging non-financial income	1.259	1.259
- Hedging net external income	-0.096	0.080
- Demographic adjustment term	-0.040	-0.040

Table 3: The extended model: Portfolio holdings and their composition (y and y* are normalized at 1)

income now works with not only the self-hedging but also a hedging of non-financial income.

To calibrate the extended model, we continue to use the same value for n and μ as before and set β at 0.97 for both countries. For financial developments, we choose $\delta = 0.12$ following Caballero at al. (2008) who calibrate it to target an asset stock below 4 times average GDP based on the US data. Recently, Coeurdacier and Gourinchas (2016) estimate the US share of financial income at 0.13, a very close value. For the foreign country, Caballero at al. (2008) choose 0.08 for δ^* during the period of 1997 asian crisis, which may be too low for the normal time. We set δ^* at 0.11 to target an NFA to GDP ratio of less than 0.2 that is based on the US experience before the 2007 financial crisis.[43]

We first look at the portfolio composition of Table 3. α is equal to -0.66, in which the fundamental self-hedging is always negative and given by -1.783 here. Thanks to the distributive shocks, $cov\,(\Delta y_{lt},\, \hat{r}_{xt})$ is negative. The hedging of non-financial income therefore accounts for a long position of the local asset, i.e. 1.259 under our parameterization. This keeps most of the local asset within borders by offsetting the effect of the negative self-hedging, in the absence of country asymmetries, to the same degree. A symmetric asset home bias would emerge as emphasised by the aforementioned symmetric portfolio models. Moreover, the demographic adjustment term implied by population growth is given by -0.04 in the two countries.[44]

[43] From the recent figures, US's NFA to GDP ratio has reached more than 0.4, which allows the value of δ^* to be lower.

[44] Note that this hedging becomes negative as opposed to the baseline model. This is because the

	Data: 1987 $\sim$ 07 (2002 $\sim$ 07)		Model	
	US	China	Home	Foreign
Asset supply/GDP	3.24 (3.78)	2.63 (3.06)	3.74	3.42
NFA position/GDP	−0.11 (−0.19)	0.03 (0.15)	−0.18	0.18
(Gross) external asset/GDP	0.58 (0.90)	0.32 (0.53)	0.48	0.66
(Gross) external liability/GDP	0.69 (1.09)	0.29 (0.38)	0.66	0.48
Locally-held domestic asset share	0.79 (0.71)	0.89 (0.87)	0.82	0.86

Table 4: Portfolio allocation: Data vs The extended model

Our point is that, in the extended model, the heterogeneous financial developments of country open non-zero net external positions and, as such, once more, create the needs to hedge against the associated risks. Besides, as in the baseline model, the hedging has a opposite sign in the two countries. Should the country concerned be a creditor country, the hedging would be positive and reinforce the effect of the hedging of non-financial income in leading to a more home-biased portfolio. Otherwise, as is the case of the home country here, the hedging would be negative and reinforce the effect of the basic self-hedging in leading to a "more diversified" portfolio. Compare to a symmetric model, this implies that the preferences for the local asset in the two countries are bent to different degrees and the asset home bias exhibits a heterogeneity that corroborates data (Coeurdacier and Rey, 2013).

Table 4 compares the implied portfolio allocation to the US and China data over the following two periods: 1987 $\sim$ 2007 that is similar to that used by Heathcote and Perri (2013) and 2002 $\sim$ 2007 that starts from the year China joins the WTO. The asset supply to GDP ratio is measured by the capital stock to GDP ratio and is constructed in the same way as in Heathcote and Perri's (2013) Appendix C.[45] The portfolio position to GDP ratios are computed from Lane and Milesi-Ferretti's (2007) extended database.

The model predictions and the data are broadly consistent. Through this experiment,

non-financial income is now present. While the yet unborn generations' consumption that needs to be deducted always moves alongside the non-financial income, the latter moves with the local asset's excess return in an opposite way. This changes the sign of this hedging term.

[45] Unlike Heathcote and Perri (2013) who use a depreciation rate of 0.06 in a model of a production economy, we here use a depreciation rate of $n = 0.01$ which is consistent with our model, i.e. $d_t = nz_{1t}$ and $d_t^* = nz_{2t}$.

we emphasise that, even with a very simple structure, the model produces international portfolios of an empirically relevant magnitude for the countries with large unbalanced NFA positions. While here we only consider the extension to non-diversifiable incomes, we can further enrich this framework with other features such as production, heterogeneous goods, bond assets, etc.,[46] through which the data can be better matched.[47] We leave this to future research.

6 Conclusion

Accelerating financial globalization is inextricably intertwined with diverging NFA global imbalances, which requires a joint analysis. We studied their relationship by examining the interaction between the two most important optimizing tools in a global economy: current account smoothing of consumption over time and country portfolios across states. The hedging of net portfolio return is highlighted as the key link through which persistent

[46]For instance, Coeurdacier et al. (2010) and Heathcote and Perri's (2013) are symmetric models with production and capital accumulation. The former also considers hedging of real exchange rate. Both Coeurdacier et al. (2010) and Coeurdacier and Gourinchas (2016) consider additional bond assets. The model in this paper abstracts from these considerations but can easily be extended. In Appendix H, we present a model with an additional bond asset. In a companion paper, Zhang (2017), we extend the framework to a production economy with heterogeneous goods and a more rich structure of financial market.

[47]For portfolio allocation (Table 5), there **is** still some difference between the data and the model predictions, which calls for further extensions of the model. For instance, simulated asset supplies zs are higher than in the data, eg. $3.74 > 2.44$ in US. The size of zs in the model is determined by, aside from r (and hence β and n), the financial development δs while that of the data (or very likely that in practice) follows a capital accumulation relation of a production economy (Heathcote and Perri, 2013). To match this, δs need to be low, which would, however, reduce the relative importance of self-hedging to non-financial-income hedging. Gross positions become too small relative to the data, $0.66 < 1.09$ in the US. This type of trade-off problem in calibrating the model to the data is inherent to the simple endowment-economy set-up, which has nothing to do with our focus in this paper: the importance of modelling the effect of non-zero net portfolios on gross portfolio positions when facing the current world of global imbalances.

For decomposition of NFA dynamics, we present the results that are not shown in the main text: in response to a 1% increase in $\hat{y}_t$, $\hat{w}_t$ will increase by 0.025% on impact. The TB effect, the TT effect and the VAL effect contribute to 0.344%, −0.055% and −0.264% of the adjustments respectively. They reduce substantially in size as compared to the results of the baseline model.

unbalanced NFA positions affect gross portfolio choices. The model helps us understand the international portfolio diversification and the country's external adjustment in such a world.

The model is fully optimizing and micro-founded in accounting for both net and gross portfolio positions. As a bridge between the literature on global imbalances and that on portfolio choices in international macroeconomics, it allows for meaningful extensions along these two dimensions. For the former, a different story of global imbalances than those adopted here can be explored. The hedging of net portfolio return, however, is expected to persist. For the latter, as mentioned, future work may involve the incorporation of production, additional hedging motives, hedging tools and realistic frictions into the analysis. While only steady-state portfolios are considered in this paper, the investigation of the dynamics of the gross portfolios, i.e. capital flows, can follow. It would also be very interesting to extend the model to study the related open economy policy issues under global imbalances.

REFERENCES

Angeletos, George-Marios & Vasia Panousi, 2011. Financial Integration, Entrepreneurial Risk and Global Dynamics. Journal of Economic Theory 146.3 (2011): 863-896.

Attanasio, Orazio & Kitao Sagiri & Giovanni L. Violante, 2006. Quantifying the Effects of the Demographic Transition in Developing Economies. B.E.J. Macroeconomics (Advances) 6 (1): Pages 1-44, April.

Banerjee, Abhijit & Meng, Xin & Porzio, Tommaso & Nancy Qian, 2014. Fertility Change and Household Savings in China: Evidence from a General Equilibrium Model and Micro Data, Yale University working paper.

Baxter, Marianne & Jermann, Urban J., 1997. The International Diversification Puzzle Is Worse Than You Think, American Economic Review, Vol. 87, No. 1 (Mar., 1997), pages 170-180.

Bernanke, Ben S., 2005. The Global Saving Glut and the U.S. Current Account Deficit, Speech 77, Board of Governors of the Federal Reserve System (U.S.)

Bhagwati, Jagdish., 1958, Immiserizing Growth: A Geometrical Note, The Review of Economic Studies, vol. 25, no. 3, 1958, pp. 201–205.

Blanchard, Olivier & Giavazzi, Francesco & Sa, Filipa, 2005. International Investors, the U.S. Current Account, and the Dollar, Brookings Papers on Economic Activity, Economic Studies Program, The Brookings Institution, vol. 36(1), pages 1-66.

Bodenstein, Martin, 2011. Closing Large Open Economy Models, Journal of International Economics, Elsevier, vol. 84(2), pages 160-177, July.

Bretscher, Lorenzo & Julliard, Christian & Rosa, Carlo, 2016. Human Capital and International Portfolio Diversification: A Reappraisal, Journal of International Economics, Elsevier, vol. 99, supplement 1, pages S78-96, March.

Buiter, Willem H, 1981. Time Preference and International Lending and Borrowing in an Overlapping-Generations Model, Journal of Political Economy, University of Chicago Press, vol. 89(4), pages 769-97, August.

Caballero, R. & Farhi E., & P.-O. Gourinchas, 2008. An Equilibrium Model of Global Imbalances and low Interest Rates, American Economic Review, 98(1), 358-93.

Caballero, R. & Farhi E., & P.-O. Gourinchas, 2017. The Safe Assets Shortage Conundrum, Journal of Economic Perspectives, (Summer): 29-46.

Cavallo, Michele & Ghironi, Fabio, 2002. Net Foreign Assets and the Exchange Rate: Redux Revived, Journal of Monetary Economics, 49, July 2002, Pages 1057-97.

Chamon, Marcos D. & Prasad, Eswar S., 2010. Why Are Saving Rates of Urban Households in China Rising? American Economic Journal: Macroeconomics, 2(1), 93-130.

Coeurdacier, Nicolas & P.-O. Gourinchas, 2016. When Bonds Matter: Home Bias in Goods and Assets, Journal of Monetary Economics, 82, 119-137.

Coeurdacier, Nicolas & Guibaud, Stéphane & Jin, Keyu, 2015, Credit Constraints and Growth in a Global Economy, American Economic Review, Vol. 105, No. 9 (Sep., 2015), pages 2838-81.

Coeurdacier, Nicolas & Robert Kollmann & Phillipe Martin, 2007. International Portfolios with Supply, Demand, and Redistributive Shocks. In National Bureau of Economic Research (NBER) International Seminar in Macroeconomics. Vol. 4, edited by Richard Clarica and Francesco Giavazzi, 231–81. Chicago: University of Chicago Press.

Coeurdacier, Nicolas & Robert Kollmann & Phillipe Martin, 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, 2012. Home Bias in Open Economy Financial Macroeconomics, Journal of Economic Literature, American Economic Association, vol. 51(1), pages 63-115, March.

Curtis, Chadwick C. & Lugauer, Steven & Mark, Nelson, 2015. Demographic Patterns and Household Saving in China, American Economic Journal: Macroeconomics, 7(2): 58-94.

Devereux, Michael. & Sutherland, Alan, 2009. A Portfolio Model of Capital Flows to Emerging Markets, Journal of Development Economics, 89, 181-193.

Devereux, Michael. & 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. & Sutherland, Alan, 2011. Country Portfolios in Open Economy Macro Models, Journal of the European Economic Association, 9, 337-369.

Engle, C. & J. Rogers, 2006. The U.S. Current Account Deficit and the Expected Share of World Output, Journal of Monetary Economics, Vol. 53, No. 5, pp. 1063–193.

Eugeni, Sara, 2015, An OLG Model of Global Imbalances, Journal of International Economics, Volume 95, Issue 1, January 2015, Pages 83-97.

Evans, Martin & Viktoria, Hnatkovska, 2012. A Method for Solving General Equilibrium Models with Incomplete Markets and Many Financial Assets, Journal of Economic Dynamics and Control, Vol. 36, Issue 12, 1909-30

Ferrero, Andrea & Mark Gertler & Lars E. O. Svensson, 2007. Current Account Dynamics and Monetary Policy, International Dimensions of Monetary Policy, University of Chicago Press, Edited by Jordi Galí and Mark J. Gertler: pp. 199-243.

French, Kenneth R., & James M. Poterba, 1991, Investor Diversification and International Equity Markets, American Economic Review, 81(2), 222-26.

Fogli, A. & Perri, F., 2015. Macroeconomic Volatility and External Imbalances, Journal of Monetary Economics, Volume 69, January 2015, Pages 1-15.

Ghironi, Fabio, 2006. Macroeconomic Interdependence under Incomplete Markets, Journal of International Economics, Volume 70, December 2006, Pages 428-450.

Ghironi, Fabio & Lee, Jaewoo & Rebucci, Alessandro, 2015. The Valuation Channel of External Adjustment, Journal of International Money and Finance 57 (October 2015): 86-114.

Gourinchas, Pierre-Olivier & Jeanne, Olivier, 2013. Capital Flows to Developing countries: The Allocation Puzzle, The Review of Economic Studies, Vol. 80, No. 4 (285) (October 2013), pp. 1484-1515.

Gourinchas, Pierre-Olivier & Rey, Hélène, 2007. International Financial Adjustment, Journal of Political Economy, University of Chicago Press, vol. 115(4), pages 665-703, 08.

Gourinchas, Pierre-Olivier & Rey, Hélène, 2013. External Adjustment, Global Imbalances and Valuation Effects, Handbook of International Economics, 585-640, Gopinath, Helpman and Rogoff eds.

Heathcote, Jonathan & Perri, Fabrizio, 2013, The International Diversification Puzzle Is Not as Bad as You Think, Journal of Political Economy, vol. 121, no. 6, 2013, pp. 1108–1159.

Henriksen, Espen R. 2005. A Demographic Explanation of U.S. and Japanese Current Account Behavior. Manuscript, Univ. Oslo.

Jin, Keyu, 2012. Industrial Structure and Capital Flows, American Economic Review, 102(5), 2111-2146.

Kollmann, Robert, 2006. International Portfolio Equilibrium and the Current Account, CEPR Discussion Papers 5512, C.E.P.R. Discussion Papers.

Lane, Philip R. & Milesi-Ferretti, Gian Maria, 2007, The External Wealth of Nations Mark II: Revised and Extended Estimates of Foreign Assets and Liabilities, 1970–2004, Journal of

International Economics, 73, November, 223-250.

Lewis, Karen K., 1999, Trying to Explain Home Bias in Equities and Consumption, Journal of Economic Literature, 37(2), 571-608.

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.

Mendoza, E. & V. Quandrini & V. Rios Rull, 2009. Financial Integration, Financial Deepness, and Global Imbalances, Journal of Political Economy, 117(3), 371-416.

Mukherjee, R., 2015. Institutions, corporate governance and capital flows. Journal of International Economics96 (2), 338–359.

Obstfeld, Maurico, 2004. External Adjustment, Review of World Economics (Weltwirtschaftliches Archiv), Springer, vol. 140(4), pages 541-568, December.

Obstfeld, Maurice & Rogoff, Kenneth S., 1996. Foundations of International Macroeconomics, MIT Press Books, The MIT Press, edition 1, volume 1, number 0262150476, December.

Rabitsch, Katrin & Serhiy, Stepanshuk & Viktor, Tsyrennikov, 2015. International Portfolios: A Comparison of Solution Methods, Journal of International Economics, Vol. 97, 404-422

Schmitt-Grohe, S., Uribe, M., 2003. Closing Small Open Economy Models. Journal of International Economics, 61, 163–185

Sercu, Piet & Rosanne Vanpee, 2007, Home bias in International Equity Portfolios: A Review, Catholic University Leuven Department of Accountancy, Finance and Insurance Working Paper 0710.

Smets, Frank & Wouters, Rafael, 2007. Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach, American Economic Review, Vol. 97, No. 3, June, 586-606.

Song, M. & Storesletten K. & Zilibotti F., 2011. Growing like China. American Economic Review, Vol. 101(1), 196-233.

Stepanchuk, Serhiy & Viktor, Tsyrennikov, 2015. Portfolio and Welfare Consequences of Debt Market Dominance, Journal of Monetary Economics, Vol. 74, pages 89-101

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

Wei, Shang-Jin, & Xiaobo Zhang, 2011, The Competitive Saving Motive: Evidence from Rising Sex Ratios and Savings Rates in China, Journal of Political Economy, 199(3): 511-64.

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

Zhang, Ning, 2017. Asset home bias in debtor and creditor countries, Working Paper, University of Glasgow.

Technical Appendix (Not For Publication)

A The models with and without global imbalances

In this Appendix, we present the model equations for the asymmetric model and a comparison symmetric model both in their log-linearised form. Models are on the level of per-capita variables. By the demographic structure, per-capita variables are obtained from the following aggregation relation: taking consumption as an example,

$$c_t = \frac{c_t^0 + nc_t^1 + n\tilde{n}c_t^2 + \cdots + n\tilde{n}^{t-1}c_t^t}{\tilde{n}^t}$$

where c_t is per-capita consumption, c_t^vs are individual consumptions.

Note that in the paper, an individual variable with a hat denotes its log-deviation from its perfect-foresight optimal path while a per-capita variable with a hat denotes the log-deviations from its steady state. So $\hat{c}_t^v = \log\left(\frac{c_t^v}{\bar{c}_t^v}\right)$, $\hat{c}_t = \log\left(\frac{c_t}{c}\right)$ and $\hat{r}_t = \log\left(\frac{r_t}{r}\right)$. The only exception is for $\hat{w}$. In conventional symmetric models, steady-state w is zero. So $\hat{w}$ is usually defined as deviation of w_t relative to steady-state GDP, i.e. $\log w_t - \log y$. We follow this so as to make the comparison between the results in our paper and those in a symmetric model more convenient.

A.1 The baseline portfolio model of global imbalances

Based on the assumptions described in Section 2, the asymmetric portfolio model of this paper consists of the following 11 equations

$$\hat{r}_{1t} = \left(1 - \frac{1}{r}\right)\hat{y}_t + \frac{1}{r}\hat{z}_{1t} - \hat{z}_{1t-1} \tag{A.1}$$

$$\hat{r}_{2t} = \left(1 - \frac{1}{r}\right)\hat{y}_t^* + \frac{1}{r}\hat{z}_{2t} - \hat{z}_{2t-1} \tag{A.2}$$

$$\tilde{n}\hat{w}_{t+1} = r\hat{w}_t + rw\hat{r}_{2t} + r\alpha\hat{r}_{xt} + \hat{y}_t - c\hat{c}_t \tag{A.3}$$

$$E_t\hat{c}_{t+1} = \tau\hat{c}_t + (1-\tau)\,E_t\hat{c}_{t+1}^n + \tau E_t\hat{r}_{1t+1} \tag{A.4}$$

$$E_t\hat{c}_{t+1} = \tau\hat{c}_t + (1-\tau)\,E_t\hat{c}_{t+1}^n + \tau E_t\hat{r}_{2t+1} \tag{A.5}$$

$$E_t\hat{c}_{t+1}^* = \tau^*\hat{c}_t^* + (1-\tau^*)\,E_t\hat{c}_{t+1}^{n*} + \tau^* E_t\hat{r}_{2t+1} \tag{A.6}$$

$$c\hat{c}_t + c^*\hat{c}_t^* = \hat{y}_t + \hat{y}_t^* \tag{A.7}$$

$$\hat{y}_t = \mu\hat{y}_{t-1} + \varepsilon_t \tag{A.8}$$

$$\hat{y}_t^* = \mu\hat{y}_{t-1}^* + \varepsilon_t^* \tag{A.9}$$

$$\hat{c}_t^n = \frac{r-1}{r-\mu}\hat{y}_t \tag{A.10}$$

$$\hat{c}_t^{n*} = \frac{r-1}{r-\mu}\hat{y}_t^* \tag{A.11}$$

Approximations are conducted around the per-capita steady state that we discussed in Section 2 of the paper.

Equations $(A.1)$ and $(A.2)$ come from Eqs.(4) which define the rates of return for the two equity assets.

$$r_{1t} = \frac{y_t + z_{1t}}{z_{1t-1}}, \; r_{2t} = \frac{y_t^* + z_{2t}}{z_{2t-1}}$$

Eq.$(A.3)$ comes from the per-capita intertemporal budget constraint for the home country. Note that, as explained in Section 2, denoting net wealth of household $w_{t+1}^v = \alpha_{1t+1}^v + \alpha_{2t+1}^v$, budget constraint Eq.(2) can be re-written as $w_{t+1}^v = w_t^v r_{2t} + \alpha_{1t}^v r_{xt} + y_t^v - c_t^v$. Aggregating this budget constraint and making use of the assumption that newly born generations do not own financial wealth, we obtain the per-capita budget constraint of the following form[48]

$$\tilde{n}w_{t+1} = w_t r_{2t} + \alpha_{1t} r_{xt} + y_t - c_t$$

Log-linearising this constraint yields Eq.$(A.3)$.

Eqs.$(A.4-6)$ are aggregated per-capita Euler equations. There should have been four such equations in total yet one of them is redundant. The derivation of them can be found below in Appendix B.

Eq.$(A.7)$ comes from the resource constraint for the whole world $c_t + c_t^* = y_t + y_t^*$.

Eqs.$(A.8-9)$ are Eqs.(5).

Eqs.$(A.10-11)$ describe new-born's consumption $\hat{c}_t^n$ and $\hat{c}_t^{n*}$ which are from Eq.(7) and its foreign counterpart. In the home country,

$$c_t^n = (1-\beta)\sum_{i=0}^{\infty}\frac{1}{r^i}y_{t+i}$$

[48] See Weil's (1989) original paper or Eq.(67) Section 3.7.3 of Obstfeld and Rogoff's (1996) textbook.

From this equation, steady-state c_t^n is

$$c^n = \frac{r(1-\beta)}{r-1}$$

Log-linearising c_t^n and c_t^{n*} around their steady-states gives Eqs.$(A.10-11)$.

Note that α in the national budget constraint, Eq.$(A.3)$, represents the steady-state country portfolio to be determined in the model. (As discussed in Section 2 of main text, it denotes home gross holding of home equity, the other three gross portfolio holdings link to α through asset market clearing condition, Table 1.) α is determined by the optimal condition Eq.(10) which is derived in Appendix C.

A.2 The standard portfolio model without global imbalances

To compare the current model to a standard symmetric portfolio model, we present here another model where there is no country asymmetry and OLG structure. The model is based on Devereux and Sutherland (2011) free of non-financial incomes. We log-linearise the model around its steady state of $c = y$, $c^* = y^*$, $w = 0$ and $r = \frac{1}{\beta}$. The corresponding model reads

$$\hat{r}_{1t} = \left(1 - \frac{1}{r}\right)\hat{y}_t + \frac{1}{r}\hat{z}_{1t} - \hat{z}_{1t-1} \tag{A.1'}$$

$$\hat{r}_{2t} = \left(1 - \frac{1}{r}\right)\hat{y}_t^* + \frac{1}{r}\hat{z}_{2t} - \hat{z}_{2t-1} \tag{A.2'}$$

$$\hat{w}_{t+1} = r\hat{w}_t + r\alpha\hat{r}_{xt} + \hat{y}_t - \hat{c}_t \tag{A.3'}$$

$$E_t\hat{c}_{t+1} = \hat{c}_t + E_t\hat{r}_{1t+1} \tag{A.4'}$$

$$E_t\hat{c}_{t+1} = \hat{c}_t + E_t\hat{r}_{2t+1} \tag{A.5'}$$

$$E_t\hat{c}_{t+1}^* = \hat{c}_t^* + E_t\hat{r}_{2t+1} \tag{A.6'}$$

$$\hat{c}_t + \hat{c}_t^* = \hat{y}_t + \hat{y}_t^* \tag{A.7'}$$

$$\hat{y}_t = \mu\hat{y}_{t-1} + \varepsilon_t \tag{A.8'}$$

$$\hat{y}_t^* = \mu\hat{y}_{t-1}^* + \varepsilon_t^* \tag{A.9'}$$

As in the asymmetric model, Eqs.$(A.1' - 2')$ define the rates of return on the two assets while Eq.$(A.3')$ is the home budget constraint. Eq.$(A.4' - 6')$ are Euler equations. Eq.$(A.7')$ is the resource constraint and Eqs.$(A.8' - 9')$ are shocks to endowments. Note that abstracting from OLG structure, the model is of representative agent form. There is no difference between the individual and per-capita variables.

Optimal choice of α is, as shown in Devereux and Sutherland (2011), determined by the condition

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

In Section 3, we explained why $\hat{c}_t^D \equiv \left[\frac{1}{\tau}\left(\hat{c}_t - (1-\tau)\,\hat{c}_t^n\right) - \frac{1}{\tau^*}\left(\hat{c}_t^* - (1-\tau^*)\,\hat{c}_t^{n*}\right)\right]$ in Eq.(10) differs from $(\hat{c}_t - \hat{c}_t^*)$.

The major difference between the two models is compared below.

A.3 Comparison between the two models

The log-linearised per-capita Euler equations are (Appendix B)

$$E_t\hat{c}_{t+1} = \tau\hat{c}_t + (1-\tau)\,E_t\hat{c}_{t+1}^n + \tau E_t\hat{r}_{jt+1}$$

for $j = 1,\ 2$. In the foreign counterparts, $\tau^* = \frac{r\beta^*}{\tilde{n}} > \tau$. By these equations, to the first order accuracy, asset returns are expected to move the same way, i.e. $E_t\hat{r}_{1t+1} = E_t\hat{r}_{2t+1} \equiv E_t\hat{r}_{t+1}$ and $E_t\hat{r}_{xt+1} = 0$. Additionally, note that the counterparts of the above equations in a standard symmetric model are familiar $E_t\hat{c}_{t+1} = \hat{c}_t + E_t\hat{r}_{jt+1}$ for $j = 1,\ 2$. The difference between a standard symmetric model and our model lies in the presence of differing patience and the OLG structure, therefore, in terms of log-linearised Euler equations, it is not surprising to find: (1) A new term of $\hat{c}^n$ emerges reflecting the fact of population growth. τ determines the relative importance of consumption of different population groups. The higher the growth rate n, the more important is the new-born's consumption relative to the old's, which is captured by the first two terms of the right-hand-side (RHS) of the above equations. While n is the same across countries, the new-born's consumption in the home country is relatively more important ($(1-\tau) > (1-\tau^*)$) than that in the foreign country due to the fact that $\beta < \beta^*$. (2) As the coefficient of $E_t\hat{r}_{t+1}$, τ and τ^* gain another interpretation, i.e. the consumption tilting factors. The magnitude of tilting factors is reduced here ($\tau, \tau^* < 1$) compared to a standard symmetric model because each period only the existing population (which accounts for only a fraction of aggregate consumption now) tilts consumption in response to $E_t\hat{r}_{t+1}$, which is captured by the third term of the RHS of the above equations. Because $\tau < \tau^*$, the tilting effect is more responsive in the foreign than in the home country.

The budget constraint of the home country and world resource constraint read

$$\tilde{n}\hat{w}_{t+1} = r\hat{w}_t + rw\hat{r}_{2t} + r\alpha\hat{r}_{xt} + \hat{y}_t - c\hat{c}_t$$

$$c\hat{c}_t + c^*\hat{c}_t = \hat{y}_t + \hat{y}_t^*$$

The main differences between the constraints of a standard symmetric and the current model are: (1) With the existence of population growth, we have $\tilde{n}$ in the budget constraint. (2) Because $w \neq 0$, variation in its return emerges as the term $rw\hat{r}_{2t}$. This term is absent from a symmetric model. (3) Unbalanced consumption ratios appear, $c < 1$ and $c^* > 1$, as opposed to the symmetric case of $c = c^* = 1$.

B Log-linearised per-capita Euler equations

To find the per-capita Euler equations corresponding to Eqs.(3), we approximate the individual equations first and then aggregate them. As explained, because there is no steady state around which we approximate individual consumptions, the approximation is conducted around the levels along their perfect foresight optimal path $\bar{c}_{t+1}^v = r\beta\bar{c}_t^v$. The individual Euler equations after approximation are

$$\hat{c}_t^v = E_t\hat{c}_{t+1}^v - E_t\hat{r}_{jt+1} \tag{B.1}$$

for $j = 1,\ 2$ in the home country.

To aggregate the above individual conditions, we substitute them into the approximated aggregation relation, which yield the per-capita Euler equations as appeared in the paper and Eqs.$(A.4-5)$

$$E_t\hat{c}_{t+1} = \tau\hat{c}_t + (1-\tau)\,E_t\hat{c}_{t+1}^n + \tau E_t\hat{r}_{jt+1} \tag{B.2}$$

for $j = 1,\ 2$.

For instance, for $j = 2$, Eq.$(B.1)$ is

$$E_t\hat{c}_{t+1}^v = \hat{c}_t^v + E_t\hat{r}_{2t+1} \tag{B.3}$$

Approximated aggregation relation at time $t+1$ is

$$E_t\hat{c}_{t+1} = \frac{1}{\tilde{n}^{t+1}c}E_t\left[\begin{array}{c} \bar{c}_{t+1}^0\hat{c}_{t+1}^0 + n\bar{c}_{t+1}^1\hat{c}_{t+1}^1 + ...+ \\ n\tilde{n}^{t-1}\bar{c}_{t+1}^t\hat{c}_{t+1}^t + n\tilde{n}^t\bar{c}_{t+1}^{t+1}\hat{c}_{t+1}^{t+1} \end{array}\right]$$

where $\bar{c}_{t+1}^{v}$ are the individual consumption level along the optimal path that based on Eqs.(3), i.e. $\bar{c}_{t+1}^{v}=r\beta\bar{c}_{t}^{v}$ for $v<t+1$. For $v=t+1$, $\bar{c}_{t+1}^{t+1}$ is simply the steady-state consumption of new-borns, i.e. steady-state c_{t+1}^{n} that defined in Eq.(7). Substituting $\bar{c}_{t+1}^{v}=r\beta\bar{c}_{t}^{v}$, $\bar{c}_{t+1}^{t+1}=c^{n}$ and Eq.(A.3) into the above approximated aggregation relation yields

$$E_t\hat{c}_{t+1}=\frac{r\beta}{\tilde{n}^{t+1}c}\left[\begin{array}{c}\bar{c}_t^0\left(\hat{c}_t^0+E_t\hat{r}_{2t+1}\right)+n\bar{c}_t^1\left(\hat{c}_t^1+E_t\hat{r}_{2t+1}\right)\\ +...+n\tilde{n}^{t-1}\bar{c}_t^t\left(\hat{c}_t^t+E_t\hat{r}_{2t+1}\right)\end{array}\right]+\frac{nc^n}{\tilde{n}c}\hat{c}_{t+1}^n$$

Note that, $\frac{nc^n}{\tilde{n}c}=(1-\tau)$. We rearrange the above equation to obtain

$$E_t\hat{c}_{t+1}=\tau\hat{c}_t+(1-\tau)\,E_t\hat{c}_{t+1}^n+\tau E_t\hat{r}_{2t+1}$$

C Optimality condition for α

Households' decisions on portfolio choices are made individually. We consider individual portfolio conditions first. α^v is determined by Eqs.(3). Combining the two yields

$$E_{t-1}\left[\left(c_t^v\right)^{-1}r_{1t}\right]=E_{t-1}\left[\left(c_t^v\right)^{-1}r_{2t}\right]$$

for $v=1,\,2,\,...,\,(t-1)$.

Following Devereux and Sutherland (2011) and Tille and Wincoop (2010), to pin down zero-order component of the portfolio, the above condition should be approximated to at least second-order accuracy, which is

$$E_{t-1}\left[\hat{c}_t^v\hat{r}_{xt}\right]=E_{t-1}[\hat{r}_{xt}+\frac{1}{2}\hat{r}_{xt}^{(2)}]+O\left(\varepsilon^{(3)}\right)$$

for $v=1,\ 2,\ ...,\ (t-1)$, where $\hat{r}_{xt}^{(2)}=\hat{r}_{1t}^2-\hat{r}_{2t}^2$ denotes the second-order terms of $\hat{r}_{xt}$. For the foreign country, a similar condition is obtained to be

$$E_{t-1}\left[\hat{c}_t^{v*}\hat{r}_{xt}\right]=E_{t-1}[\hat{r}_{xt}+\frac{1}{2}\hat{r}_{xt}^{(2)}]+O\left(\varepsilon^{(3)}\right)$$

for $v=1,\ 2,\ ...,\ (t-1)$. These are two conditions for individual portfolio $\bar{\alpha}^v$ (along the perfect foresight optimal path).

What matters for our analysis is the per-capita aggregate portfolio, α, instead of individual $\bar{\alpha}^v$s, which implies we need corresponding per capita aggregate conditions. This can be achieved by, similar to the aggregation when we obtain the log-linearised per-capita Euler equation as is shown in Appendix B, substituting the above two individual conditions into the log-linearised aggregation relation, that multiplied by $\hat{r}_{xt}$, which leads to

$$E_{t-1}\left[\hat{c}_t\hat{r}_{xt}\right] = \tau E_{t-1}[\hat{r}_{xt} + \frac{1}{2}\hat{r}_{xt}^{(2)}] + (1-\tau)\,E_{t-1}\left[\hat{c}_t^n\hat{r}_{xt}\right] + O\left(\varepsilon^{(3)}\right)$$

$$E_{t-1}\left[\hat{c}_t^*\hat{r}_{xt}\right] = \tau^* E_{t-1}[\hat{r}_{xt} + \frac{1}{2}\hat{r}_{xt}^{(2)}] + (1-\tau^*)\,E_{t-1}\left[\hat{c}_t^{n*}\hat{r}_{xt}\right] + O\left(\varepsilon^{(3)}\right)$$

Given individual portfolio conditions being always satisfied, the above per-capita aggregate condition should be also always satisfied. Combining the above two equations gives us the optimal portfolio condition Eq.(10).

D Consumption differential $\hat{c}_t^D$

In response to a shock, fluctuations in current consumptions, $\hat{c}_t$ and $\hat{c}_t^*$, are made up of two effects from the point of view of consumption smoothing. The first is the effect due to the change in lifetime resource or consumption that can be viewed as a wealth effect. The second is the effect due to the change in the optimal ratio of current consumption to overall consumption that can be viewed as a composition effect. We decompose these two effects in what follows.

Wealth effect of consumption We iterate the home country's budget constraint to obtain

$$\underbrace{\Sigma_t^c}_{\text{Consumption wealth effect}} = \underbrace{\frac{rw}{c}\left[\hat{r}_{2t} + \frac{\tilde{n}}{r}\Sigma_{t+1}^{rn}\right]}_{\text{Net portfolio return}} + \underbrace{\frac{r\alpha}{c}\hat{r}_{xt}}_{\text{Gross portfolio return}} + \underbrace{\frac{r}{c\,(r-\mu\tilde{n})}\hat{y}_t}_{\text{Total endowment}}$$

with $\Sigma_t^c \equiv \Sigma_{i=0}^{\infty}\left(\frac{\tilde{n}}{r}\right)^i\hat{c}_{t+i}$ and $\Sigma_{t+1}^{rn} \equiv \Sigma_{i=0}^{\infty}\left(\frac{\tilde{n}}{r}\right)^i\hat{r}_{t+1+i}$.

This formula describes the movement in the discounted sum of future consumptions after shocks. After a shock, the total resource that a country can enjoy changes through three channels. First, the endowments for not only the current generation but also those to be born in the future will change accordingly. Second, the return to net portfolio w will change. Third, the return to the gross portfolio α changes. Notice that imposing $\tilde{n}=1$, $w=0$, $c=1$ in the above formula gives us the corresponding wealth effect in a standard symmetric model. Comparing the result to that in a symmetric case, we find that the net portfolio return emerges as a new channel as a result of the presence of global imbalances,

$w \neq 0$. Moreover, in the current model, all of these three channels work in an asymmetric way across countries due to the unequal consumption steady states $c \neq c^*$.

Composition effect of consumption To determine how much of the above total resource increment is allocated to the current period for consuming, we use a discount factor of $\tilde{n}/r$ to aggregate Euler equations over $s = t, t+1, ...$, to obtain

$$\hat{c}_t = \underbrace{(1-\beta)\,\Sigma_t^c}_{\text{Average wealth effect}} - \underbrace{\frac{(1-\tau)\,\tilde{n}}{(r-\mu\tilde{n})}\hat{c}_{t+1}^n}_{\text{New-born's consumption deduction}} - \underbrace{\beta\Sigma_{t+1}^{rn}}_{\text{Interest rate tilting effect}}$$

Again, the analogues of this equations in a standard symmetric model follow once we impose $n = 0$, $\beta^* = \beta$, $\tau = \tau^* = 1$ on the above formula and redefine Σ_t^c, r, Σ_{t+1}^{rn} accordingly.

This formula describes the movements of the current consumption after shocks. As should be familiar, due to the existence of the interest rate tilting effect, i.e. a higher expected future interest rate tending to reduce the current consumption, the movements in consumption are not flat (even in a symmetric model). Thus the effect on $\hat{c}_t$ after shocks will be generally given by an average wealth effect adjusted by an interest rate tilting effect, $-\beta\Sigma_{t+1}^{rn}$. In our model, we see that the tilting effects of the two countries differ in their strengths. It is weaker in the home country. In addition, because we assumed the entry of a new generation each period, we have to deduct the (average) consumption that is due to yet-to-be-born generations from the (average) wealth effect, $-\frac{(1-\tau)\tilde{n}}{(r-\mu\tilde{n})}\hat{c}_{t+1}^n$. This effect is also asymmetric across countries. Specifically, it is stronger in the home country because $(1-\tau) > (1-\tau^*)$.

Combining the above two effects from both countries and taking difference, we obtain the $\hat{c}_t^D$ as in the main text.

E Proof of $\alpha[1] = -z/2$

Note that $-\frac{1}{2(r-1)}\frac{(r-\mu)}{(r-\mu\tilde{n})} + \frac{1}{2r\phi}\frac{\mu\tilde{n}}{r-\mu\tilde{n}}\left[\frac{1-\tau}{\tau} + \frac{1-\tau^*}{\tau^*}\right] = -\frac{z}{2} = -\frac{1}{2(r-1)}$ is equivalent to

$$\frac{rn\phi}{(r-1)\,\tilde{n}} = \left[\frac{1-\tau}{\tau} + \frac{1-\tau^*}{\tau^*}\right] \tag{E.1}$$

where $\phi = \left[\frac{(1-\beta)}{c\tau} + \frac{(1-\beta^*)}{c^*\tau^*}\right]$, $\tau = \frac{r\beta}{\tilde{n}}$ and $\tau^* = \frac{r\beta^*}{\tilde{n}}$.

Substituting Eq.(8) into $c = 1 + (r - \tilde{n})\,w$, we obtain the steady-state consumption in the home country. c^* follows similarly.

$$c = \frac{rn\,(1-\beta)}{(\tilde{n} - r\beta)\,(r-1)}, \quad c^* = \frac{rn\,(1-\beta^*)}{(\tilde{n} - r\beta^*)\,(r-1)}$$

We substituting c and c^* into ϕ, the left-hand-side of Eq.$(E.1)$ can be simplified to be $\left[\frac{\tilde{n}-r\beta}{r\beta} + \frac{\tilde{n}-r\beta^*}{r\beta^*}\right]$ which is the right-hand-side of the equation.

F Derivation of α^*

Denoting the foreign (gross) holding of foreign asset $\alpha^* = \alpha_2^*$, from the relation $(-\alpha) - (-\alpha^*) = w^*$,[49] we know

$$\alpha^* = w^* + \alpha$$

where α, from the main text of the paper, consists of $\alpha\,[1]$ to $\alpha\,[4]$. Note that $w^* + \alpha\,[2]$ equals to

$$\begin{aligned} w^* - w\frac{cov\,(\hat{r}_{2t},\ \hat{r}_{xt})}{var\,(\hat{r}_{xt})} &= w^* - w\frac{cov\,(\hat{r}_{2t} - \hat{r}_{1t} + \hat{r}_{1t},\ \hat{r}_{xt})}{var\,(\hat{r}_{xt})} \\ &= w^* - w^* - w\frac{cov\,(\hat{r}_{1t},\ \hat{r}_{xt})}{var\,(\hat{r}_{xt})} \\ &= -w^*\frac{cov\,(\hat{r}_{1t},\ \hat{r}^*_{xt})}{var\,(\hat{r}^*_{xt})} \end{aligned}$$

where $\hat{r}^*_{xt} \equiv -\hat{r}_{xt} = \hat{r}_{2t} - \hat{r}_{1t}$. Therefore, denoting the above expression as $\alpha^*\,[2]$, we can write α^* as

$$\alpha^* = \underbrace{-\frac{cov\,(\Delta y^*_t,\ \hat{r}^*_{xt})}{var\,(\hat{r}^*_{xt})}}_{\alpha^*[1]=\alpha[1]} \underbrace{-w^*\frac{cov\,(\hat{r}_{1t},\ \hat{r}^*_{xt})}{var\,(\hat{r}^*_{xt})}}_{\alpha^*[2]>0} \underbrace{-\frac{\tilde{n}w^*}{r}\frac{cov\,\left(\Sigma^{rn}_{t+1},\ \hat{r}^*_{xt}\right)}{var\,(\hat{r}^*_{xt})}}_{\alpha^*[3]=\alpha[3]} + \underbrace{\frac{cov\,(\Delta c^{n*}_t,\ \hat{r}^*_{xt})}{var\,(\hat{r}^*_{xt})}}_{\alpha^*[4]=\alpha[4]}$$

where $\Delta y^*_t \equiv -\Delta y_t$ and $\Delta c^{n*}_t \equiv \Delta c^n_t$ are relative income and new-born's consumption from the perspective of the foreign country.

[49] For the foreign country, the difference between its gross external asset $(-\alpha)$ and gross external liability $(-\alpha^*)$ gives its NFA, i.e. w^*.

G Model dynamics

We present the results of first-order dynamics of the model in this Appendix. This helps in understanding the composition of portfolio holdings since the latter depends on the stochastic properties of income and the hedging properties of the relevant assets.

To better see how the presence of global imbalances matter, we first report the results for a symmetric case. Figure 4 plots the case of $\beta = \beta^* = 0.97$. It displays the responses after a 1 percentage upward deviation of the home (solid line) or/and foreign (dashed line) endowments from the steady state (Panel (j)). Panels (a) to (h) are respectively the response of $\hat{c}_t^D$, home NFA (relative to y), home and foreign consumptions, asset returns, and asset prices. [50]

Let us look at the solid lines first. In response to a positive shock to the home endowment, consumption in both country rise as shown in Panels (c) and (d). With the shock decaying, consumption decreases gradually towards the steady state. With current consumption being higher than future consumption, expected future interest rates are driven down according to the Euler equations. That is $\hat{r}_1$ and $\hat{r}_2$ are equal and both below 0 from the second period onwards as seen in Panels (e) and (f). The sum of the discounted expected future interest rates, Σ^{rn}, is thus also negative which pushes up asset prices $\hat{z}_1$ and $\hat{z}_2$. Given that the shock hits the home country, higher expected future dividend drives up the price of the home asset $\hat{z}_1$ further, i.e. $\hat{z}_1 > \hat{z}_2$, as shown in Panels (g) and (h). As there are capital gains, the higher price of the foreign equity implies a higher current rate of return to the foreign equity which explains the first period increase in $\hat{r}_{2t}$ in Panel (f). By the same token, $\hat{r}_{1t}$ will be also higher due to a higher $\hat{z}_1$. On top of this, a higher current dividend payment means $\hat{r}_{1t}$ increase even further, i.e. $\hat{r}_{1t} > \hat{r}_{2t}$ or $\hat{r}_{xt} > 0$. With gross external positions across countries in the model, the rise in $\hat{r}_{xt}$ implies a wealth transfer from the home country to the foreign country, i.e. a negative VAL effect. This effect is so big that it exceeds that of the initial trade surplus. So the net foreign asset position of the home country, $\hat{w}_t$, declines, as shown in Panel (b).

The dashed lines describe the model responses after a positive foreign shock. It is ob-

[50] Panel (i) shows responses of new-born's consumption in the two countries. We use this to represent the case of a symmetric model even though in the literature, these models feature representative agents. Except for inclusion of new-born's consumption, the dynamics of the model is similar to a standard model without overlapping generations.

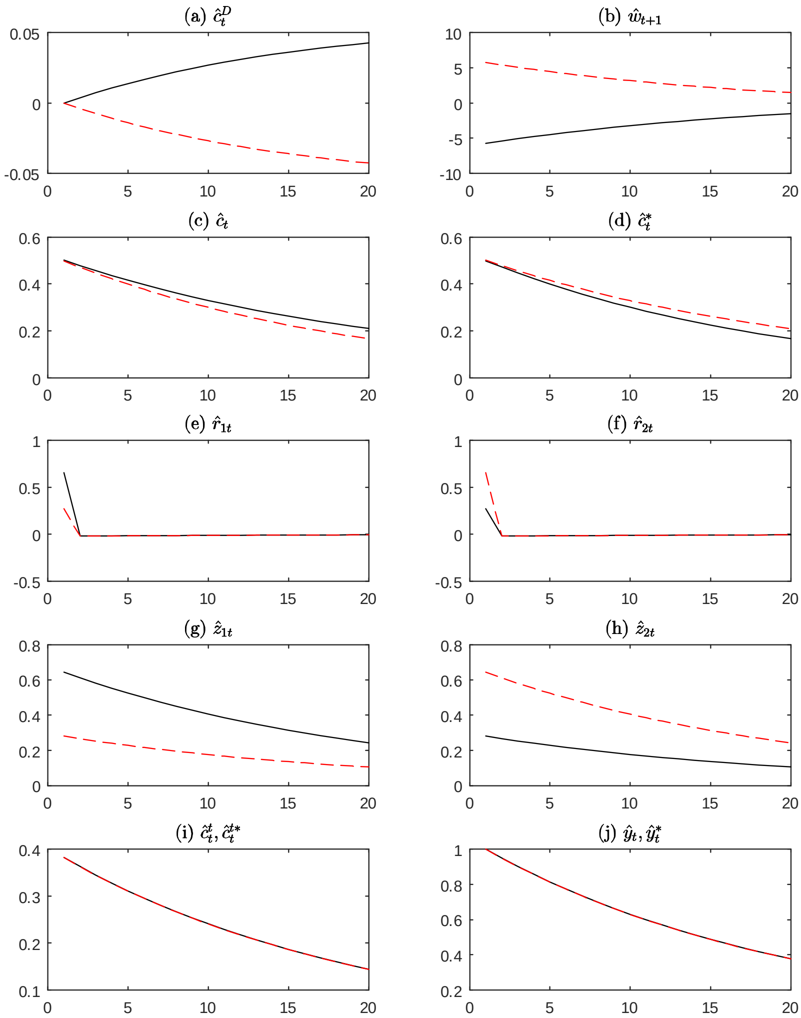

Figure 4: IRFs of the model to home (solid line) and foreign (dashed line) shocks: Symmetric case

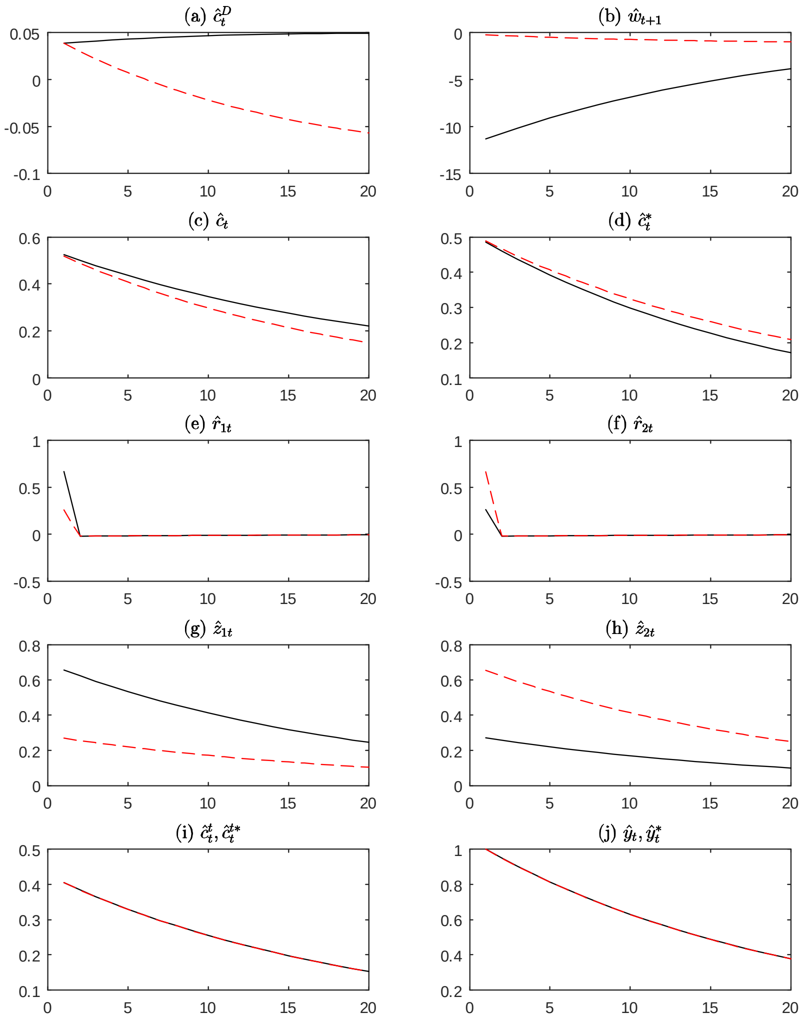

Figure 5: IRFs of the model to home (solid line) and foreign (dashed line) shocks: Asymmetric case

vious that the dynamics are symmetric to above dynamics in the sense that the responses of home (foreign) variables now is just the responses of foreign (home) variables, which is easy to understand because the home country in this case steps into the foreign country's previous shoes.

Now let us turn to the asymmetric case where $\beta < \beta^*$. Figure 5 depicts the corresponding dynamics. The panels represent responses of variables in the same sequence as in Figure 4. We find that, except for $\hat{w}_t$, the responses of variables do not change very much given that the asymmetry is small. They are qualitatively the same but with quantitative differences. The symmetry between the responses to the two shocks (i.e. the solid and dashed lines) that exists in Figure 4 therefore breaks down.

With preservation of the qualitative properties of the variable responses, importantly, we find that as previously, a positive domestic shock still raises the rate of return of the domestic asset more than that of overseas asset. This in turn implies $0 < \zeta_{r2e1} < \zeta_{r2e2}$. In addition, the sum of discounted expected future interest rates on impact is depressed and is more responsive to the foreign shock, i.e. $0 > \zeta_{sre1} > \zeta_{sre2}$. These observations are very important in understanding the hedging property of country portfolio to international interest payment. As analysed in Section 3, these relations imply $\alpha\,[2] < 0$ and $\alpha\,[3] > 0$.

As for $\hat{w}_t$, positive shocks again involve TB and VAL effects. But in the asymmetric case because $w < 0$, no matter where the shock come from, the attendant rise in $\hat{r}_2$ will burden the home country's interest payment to the foreign country. A negative TT effect therefore emerges, which tends to worsen the net external balance. So both the solid and dashed lines of $\hat{w}_t$ are now (Figure 5) lower than in the symmetric case (Figure 4).

H Model extension

In this Appendix, we extend the baseline model in the following aspects: 1. Additional hedging motive: labour income. 2. Alternative country asymmetry: financial development that follows Caballero at al., (2008, 2017). 3. Additional hedging tool: international bond. There are only equities in the baseline model. We introduce one international bond in the extension (in a symmetric way). This is motivated by Coeurdacier et al. (2010) and Coeurdacier and Gourinchas (2016) who emphasise the importance of including bond assets in the analysis. The purpose is to show that the framework is applicable to this extension and how this might alter the optimal portfolios. Note that only the first two of these ingredients are present in the extended model of Section 5 of the paper. In order to recover that model specification, one can choose to mute the bond assets by simply setting the bond asset holdings in this appendix to zero.

H.1 An extended model

The demographic structure and utility function are the same. The budget constraint for vintage v household at time t becomes

$$\alpha_{1t+1}^{v}+\alpha_{2t+1}^{v}+\alpha_{bt+1}^{v}=\alpha_{1t}^{v}r_{1t}+\alpha_{2t}^{v}r_{2t}+\alpha_{bt}^{v}r_{bt}+y_{lt}+y_{kt}-c_{t}^{v}$$

While other notations are familiar, α_{bt+1}^{v} denotes the household's holding of an international bond that defined below at the end of time t and r_{bt} denotes gross rate of return on the bond from time $t-1$ to t. y_{lt} denotes a perishable endowment income that the household receives.

Besides the endowment income, there are some "trees" in each country which serve as a storage of value and generate an income of y_{kt}. Equity assets represent claims on the income of these trees. Their return rate

$$r_{1t}=\frac{y_{kt}+\tilde{n}z_{1t}}{z_{1t-1}},\ r_{2t}=\frac{y_{kt}^{*}+\tilde{n}z_{2t}}{z_{2t-1}}$$

where z_{1t-1} and z_{2t-1} are the equity prices at the end of $t-1$.

In addition, an international bond (of an internationally net supply of zero) is available with the payoff defined by

$$r_{bt}=\frac{1}{z_{bt-1}}$$

where z_{bt-1} is the bond price at the end of $t-1$.

We refer to y_{kt} and y_{lt} as financial and non-financial income. Total income y_t is assumed to be given by the sum of financial income, non-financial income and a value loss that is proportional to the value of trees $d_t=nz_{1t}$, i.e. $y_t=y_{kt}+y_{lt}+d_t$. We use a parameter δ to describe the share of these income in steady state, i.e. after normalizing $y=1$, we have $y_k=\delta-\frac{n\delta}{(r-1)}$, $y_l=1-\delta$ and $d=\frac{n\delta}{(r-1)}$ respectively. Moreover, following Caballero at al. (2008), we assume $\delta>\delta^{*}$ in the two countries to capture their difference: the home (foreign) country is more (less) financially developed.

As in the baseline model, total incomes follow the process

$$\hat{y}_t = \mu \hat{y}_{t-1} + \varepsilon_{yt},\ \hat{y}_t^* = \mu \hat{y}_{t-1}^* + \varepsilon_{yt}^*$$

In addition, we follow Bretscher et al. (2016) to assume additive distributive shocks to the financial and non-financial income, i.e. $y_{lt} = (1-\delta)\, y_t + e_t$ and $y_{kt} + d_t = \delta y_t - e_t$ in the home country and

$$\hat{e}_t = \mu \hat{e}_{t-1} + \varepsilon_{dt},\ \hat{e}_t^* = \mu \hat{e}_{t-1}^* + \varepsilon_{dt}^*$$

H.2 Steady-state net portfolio: Global imbalances

From the household's optimization problem, an additional Euler equation is

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

The individual consumption function can be obtained as

$$c_t^v = (1-\beta) \left[r \left(\alpha_{1t}^v + \alpha_{2t}^v + \alpha_{bt}^v + z_{1t-1} \right) + E_t \sum_{i=0}^{\infty} \frac{1}{r^i} y_{lt+i} \right],\ v < t$$

$$c_t^n \equiv c_t^t = (1-\beta)\, E_t \sum_{i=0}^{\infty} \frac{1}{r^i} y_{lt+i}$$

where r is the steady-state interest rate that determined below.

As in the baseline model, the budget constraint can be aggregated to be

$$\tilde{n} g_{t+1} = g_t r_{2t} + \left(\alpha_{1t} + z_{1t-1} \right) r_{xt} + \alpha_{bt} r_{xt}^b + y_{lt} - c_t$$

if we define $g_{t+1} = \alpha_{1t+1} + \alpha_{2t+1} + \alpha_{bt+1} + z_{1t}$ as the per-capita gross wealth of household at the end of time t, $r_{xt} = r_{1t} - r_{2t}$ and $r_{xt}^b = r_{bt} - r_{2t}$ as the excess return of home equity and bond over foreign equity.

Consumption function can be aggregated to be

$$c_t = (1-\beta) \left[r g_t + E_t \sum_{i=0}^{\infty} \frac{1}{r^i} y_{lt+i} \right]$$

Combining these two relations, we obtain the law of motion of g_t

$$g_{t+1} = \frac{r\beta}{\tilde{n}} g_t + \frac{r\beta - 1}{\tilde{n}\,(r-1)} y_{lt}$$

Under the stability condition $\tau = \frac{r\beta}{\tilde{n}} < 1$, the steady-state asset demand is found to be

$$g = \frac{r\beta - 1}{(\tilde{n} - r\beta)(r-1)} y_l = \frac{(r\beta - 1)(1-\delta)}{(\tilde{n} - r\beta)(r-1)}$$

Similarly, in the foreign country $g^* = \frac{(r\beta-1)(1-\delta^*)}{(\tilde{n}-r\beta)(r-1)}$. Asset demand positively depends on the amount of perishable non-financial income in a country. With relatively lower $1-\delta$, the home country features relatively lower g.

By the asset pricing relation, the equity supplies in the two countries are

$$z_1 = \frac{y_k}{r - \tilde{n}} = \frac{\delta}{(r-1)},\; z_2 = \frac{y_k^*}{r-\tilde{n}} = \frac{\delta^*}{(r-1)}$$

Asset supply positively depends on the amount of financial income in a country. With relatively higher δ, the home country features relatively higher z.

Net foreign assets, w and w^*, can thus be obtained from the subtraction of asset supply from asset demand in the two countries

$$w = g - z_1 = \frac{r\beta - 1 - n\delta}{(\tilde{n} - r\beta)(r-1)},\; w^* = g^* - z_2 = \frac{r\beta - 1 - n\delta^*}{(\tilde{n} - r\beta)(r-1)}$$

In autarky, interest rate, for instance in the home country, is determined by $w = 0$, i.e. $r^a = \frac{1+n\delta}{\beta}$. Interest rate in a country depends positively on its level of financial development (and population growth rate and negatively on household patience).

In an open economy, steady-state interest rate is determined by $w = w^*$, which yields

$$r = \frac{1+n\bar{\delta}}{\beta}$$

where $\bar{\delta} = (\delta + \delta^*)/2$. As in the baseline model, r lies in between two autarky interest rates.

NFA global imbalances emerge

$$w = \frac{\left(\bar{\delta} - \delta\right)}{\left(1-\bar{\delta}\right)(r-1)} < 0,\; w^* = \frac{\left(\bar{\delta} - \delta^*\right)}{\left(1-\bar{\delta}\right)(r-1)} > 0$$

Consumptions in the two countries are

$$c = 1 - \frac{n\delta}{r-1} + (r - \tilde{n})\, w,\; c^* = 1 - \frac{n\delta^*}{r-1} + (r-\tilde{n})\, w^*$$

$$c^n = \frac{r(1-\beta)}{(r-1)}(1-\delta),\; c^{n*} = \frac{r(1-\beta)}{(r-1)}(1-\delta^*)$$

H.3 Steady-state gross portfolio

As in the baseline model, the optimal condition of portfolio can be obtained as

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

where portfolio relevant consumption differential

$$\hat{c}_t^D = \hat{c}_t - \hat{c}_t^* - (1-\tau)\left(\hat{c}_t^n - \hat{c}_t^{n*}\right)$$

Budget constraints in the two countries

$$\tilde{n}w_{t+1} = \alpha_{1t}r_{1t} + \alpha_{2t}r_{2t} + \alpha_{bt}r_{bt} + y_{kt} + y_{lt} - c_t$$

$$\tilde{n}w_{t+1}^* = \alpha_{1t}^*r_{1t} + \alpha_{2t}^*r_{2t} + \alpha_{bt}^*r_{bt} + y_{kt}^* + y_{lt}^* - c_t^*$$

can be first-order approximated and aggregated to obtain

$$\Sigma_t^c = \frac{rw}{c}\left[\hat{r}_{2t} + \frac{\tilde{n}}{r}\Sigma_{t+1}^{rn}\right] + \frac{y_k}{c}\Sigma_t^k + \frac{y_l}{c}\Sigma_t^l + \frac{\alpha_1 r}{c}\hat{r}_{xt} + \frac{\alpha_b r}{c}\hat{r}_{xt}^b$$

$$\Sigma_t^{c*} = -\frac{rw}{c^*}\left[\hat{r}_{2t} + \frac{\tilde{n}}{r}\Sigma_{t+1}^{rn}\right] + \frac{y_k^*}{c^*}\Sigma_t^{k*} + \frac{y_l^*}{c^*}\Sigma_t^{l*} - \frac{\alpha_1 r}{c^*}\hat{r}_{xt} - \frac{\alpha_b r}{c^*}\hat{r}_{xt}^b$$

where $\Sigma_t^c = \Sigma_{i=0}^{\infty}\left(\frac{\tilde{n}}{r}\right)^i \hat{c}_{t+i}$, $\Sigma_{t+1}^{rn} = \Sigma_{i=0}^{\infty}\left(\frac{\tilde{n}}{r}\right)^i \hat{r}_{t+1+i}$, $\Sigma_t^k = \Sigma_{i=0}^{\infty}\left(\frac{\tilde{n}}{r}\right)^i \hat{y}_{kt+i}$, $\Sigma_t^l = \Sigma_{i=0}^{\infty}\left(\frac{\tilde{n}}{r}\right)^i \hat{y}_{lt+i}$, $\hat{r}_{xt} = \hat{r}_{1t} - \hat{r}_{2t}$, $\hat{r}_{xt}^b = \hat{r}_{bt} - \hat{r}_{2t}$. In the foreign country, the related definitions are similar.

Making use of the Euler equations in the two countries, we have

$$\hat{c}_t = (1-\beta)\,\Sigma_t^c - \frac{(1-\tau)\,\tilde{n}}{r}\Sigma_{t+1}^{cn} - \beta\Sigma_{t+1}^{rn}$$

$$\hat{c}_t^* = (1-\beta)\,\Sigma_t^{c*} - \frac{(1-\tau)\,\tilde{n}}{r}\Sigma_{t+1}^{cn*} - \beta\Sigma_{t+1}^{rn}$$

where $\tau = r\beta/\tilde{n}$ as defined before.

Using the above relations, we obtain the consumption differential in the extended model

$$\hat{c}_t^D = (1-\beta)\left[\left(\frac{1}{c} + \frac{1}{c^*}\right)\left(\tilde{\alpha}\hat{r}_{xt} + \tilde{\alpha}_b\hat{r}_{xt}^b\right) + \Delta y_{kt} + \Delta y_{lt} + \left(\frac{1}{c} + \frac{1}{c^*}\right)rw\Sigma_{2t}^{rn}\right] - (1-\tau)\,\Delta c_t^n$$

where

$$\tilde{\alpha} = \alpha_1 r$$

$$\tilde{\alpha}_b = \alpha_b r$$

$$\Delta y_{kt} = \frac{y_k}{c}\Sigma_t^k - \frac{y_k^*}{c^*}\Sigma_t^{k*}$$

$$\Delta y_{lt} = \frac{y_l}{c}\Sigma_t^l - \frac{y_l^*}{c^*}\Sigma_t^{l*} - \frac{(1-\tau)\,\tilde{n}}{(1-\beta)\,r}\left(\Sigma_{t+1}^{cn} - \Sigma_{t+1}^{cn*}\right)$$

$$\Sigma_{2t}^{rn} = \hat{r}_{2t} + \frac{\tilde{n}}{r}\Sigma_{t+1}^{rn}$$

$$\Delta c_t^n = \left(\hat{c}_t^n - \hat{c}_t^{n*}\right)$$

The optimal portfolio holdings can therefore be expressed as

$$\begin{aligned}\tilde{\alpha} \;&=\; -\frac{cc^*}{c+c^*}\frac{cov_{\hat{r}_{xt}^b}\left(\Delta y_{kt},\,\hat{r}_{xt}\right)}{var_{\hat{r}_{xt}^b}\left(\hat{r}_{xt}\right)} - \frac{cc^*}{c+c^*}\frac{cov_{\hat{r}_{xt}^b}\left(\Delta y_{lt},\,\hat{r}_{xt}\right)}{var_{\hat{r}_{xt}^b}\left(\hat{r}_{xt}\right)} \\ &\quad -rw\frac{cov_{\hat{r}_{xt}^b}\left(\Sigma_{2t}^{rn},\,\hat{r}_{xt}\right)}{var_{\hat{r}_{xt}^b}\left(\hat{r}_{xt}\right)} + \frac{cc^*}{c+c^*}\frac{1-\tau}{1-\beta}\frac{cov_{\hat{r}_{xt}^b}\left(\Delta c_t^n,\,\hat{r}_{xt}\right)}{var_{\hat{r}_{xt}^b}\left(\hat{r}_{xt}\right)}\end{aligned}$$

$$\begin{aligned}\tilde{\alpha}_b \;&=\; -\frac{cc^*}{c+c^*}\frac{cov_{\hat{r}_{xt}}\left(\Delta y_{kt},\,\hat{r}_{xt}^b\right)}{var_{\hat{r}_{xt}}\left(\hat{r}_{xt}^b\right)} - \frac{cc^*}{c+c^*}\frac{cov_{\hat{r}_{xt}}\left(\Delta y_{lt},\,\hat{r}_{xt}^b\right)}{var_{\hat{r}_{xt}}\left(\hat{r}_{xt}^b\right)} \\ &\quad -rw\frac{cov_{\hat{r}_{xt}}\left(\Sigma_{2t}^{rn},\,\hat{r}_{xt}^b\right)}{var_{\hat{r}_{xt}}\left(\hat{r}_{xt}^b\right)} + \frac{cc^*}{c+c^*}\frac{1-\tau}{1-\beta}\frac{cov_{\hat{r}_{xt}}\left(\Delta c_t^n,\,\hat{r}_{xt}^b\right)}{var_{\hat{r}_{xt}}\left(\hat{r}_{xt}^b\right)}\end{aligned}$$

where $cov_c\,(a,\,b)$ denotes covariance of a and b conditional on c, $var_d\,(e)$ denotes variance of e conditional on d. With the presence of the wealth division, labour hedging (the second term in the above expressions) emerges in addition to the self-hedging, international-net-portfolio-return hedging and adjustment term that due to the demographic assumption in the optimal portfolio holdings.