

Home bias and portfolio dynamics in a multi-country model*

(Preliminary version)

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Abstract

We extend the algorithm proposed by Devereux and Sutherland (“Country portfolio dynamics, JEDC, 2010) for computing the optimal static and dynamic portfolio to a setting with multiple assets and multiple countries. We apply this technique to investigate the impact of the emerging economies, financially less developed, on the allocation of internationally traded assets in financially developed economies.

In a calibrated three-country economy, we discuss the impact of the trade structure and varying portfolio allocation strategies in financially less developed economies on the allocation of internationally traded assets in the rest of the world. Our results highlight that the inclusion of financially constrained emerging economies can help to replicate certain features of gross assets and liability positions in industrial economies, particularly in the United States. Furthermore, we show that our calibrated model is consistent with empirical evidence concerning home bias in equities and foreign equity turnover.

1 Introduction

Until recently standard open-economy models with incomplete financial markets have been unable to provide an appropriate framework to analyze the root causes of global

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gross asset positions. The difficulty in calculating the optimal portfolio with incomplete markets in standard DSGE models were so far of technical nature. Until recently, standard numerical methods could not be applied because portfolio choice is not well-defined in a certainty equivalence setting, as it would depend on higher order moments, like the variance and covariance of asset returns. An alternative, but more restrictive approach in the literature, going back to Lucas (1982), has been to assume complete markets and full risk-sharing between economies and then characterize the portfolio allocation in a decentralized equilibrium with a given set of assets; recent contributions are Engel and Matsumoto (2005) Heathcote and Perri (2005) and Kollmann (2006).

There is, however, a recent literature developing simple methods, applicable using standard solution techniques, to analyze portfolio allocation in dynamics general equilibrium models, on which we build in this paper. This growing literature includes key contributions by Devereux and Sutherland (2006, 2007), Evans and Hnatkovska (2006), and Van Wincoop and Tille (2007).

The contribution of our paper is thus twofold. First, we extend the Devereux and Sutherland (2007, 2010) methods for solving for optimal (steady-state and dynamic) portfolios in a setting with more than two agents/countries, allowing thereby for certain countries to follow diverse portfolio allocation strategies. Second, we analyze a calibrated three-country open-economy model in which one country, while fully integrated in goods market trading with the rest of the world, faces constraints in its savings decisions and portfolio allocation strategy. In the other two countries comprising the world economy, households will instead optimally trade in a given set of international assets, including bonds and equities. In this set up, we evaluate the sensitivity of international capital flows to the asset market structure and the stochastic environment. As for portfolio dynamics, our analysis contributes to the recent theoretical and empirical literature on the relation between home bias in equities, high turnover in foreign equities and trade flows (e.g. Tesar and Werner, 1995, Amadi and Bergin, 2008, Warnock, 2002, Hnatkovska, 2010, and, in particular Portes and Rey, 2005). We show that our benchmark calibration generates home bias in equities and high turnover in foreign equities, consistently with the empirical evidence. Nevertheless, we also show that for a given degree of openness to trade in goods, our three countries can display different degrees of volatility in financial trade, depending, in particular, on asset availability and the type of shocks that these economies experience.

Analyzing the impact of a less-financially developed economy on *global capital allocations* and their corresponding macroeconomic implications has been at the focus of recent policy and academic debates. For example, in a recent influential paper Caballero, Farhi and Gourinchas (2007) argue that institutional constraints in emerging Asia in its ability to generate financial assets from real investment might explain the recent decline in US long term real interest rates, and the growing share of US assets in the global portfolio. Mendoza, Quadrini and Rios-Rull (2008) show how this could occur in a general equilibrium model because of underdeveloped financial markets in emerging economies providing little insurance against idiosyncratic shocks at the micro level.

In light of these issues, this paper looks at the impact of emerging market portfolio decisions on global capital allocations. First, we show that the inclusion of a financially underdeveloped emerging economy into our calibrated three-country model is helpful in replicating some asymmetries in international portfolio allocations of mature and emerging economies. In particular, while the former set of countries holds a substantial fraction of their foreign assets in the form of equities (including FDI), the latter set of countries is more heavily invested in non-equity, debt securities, like sovereign bonds. Further, while debt represents the preponderant fraction of gross liabilities in advanced countries relative to equities, the opposite is true for emerging economies like China, in which 3/4 of foreign-held claims are in the form of equities and FDI. Note, however, the United States stands out even among G7 countries as over 1/2 of its gross assets consists of equity claims, to the point that its gross assets position in equities is more than 1.5 times as large as its gross equity liabilities. Our calibrated three-country model is able to reasonably account for these features

To put our results in some perspective, it is helpful to compare our results to those recently obtained by Heathcote and Perri (2008), Engel and Matsumoto (2005) and Couerdacier et al. (2007 and 2008). Allowing for preference heterogeneity and imperfect substitutability between domestic and foreign traded goods in a production economy with capital accumulation, Heathcote and Perri (2008) show that a standard two-country/ two-good RBC model can generate substantial home bias in equity holdings, because relative returns to domestic stocks move inversely with relative labor income in response to productivity shocks. In a similar vein, Engel and Matsumoto (2005) argue that sticky prices are an additional feature that is able to generate a negative correlation between labor income and profits of domestic firms, also tilting portfolio shares in favor of home equities.

In a paper that is related to ours, Coeurdacier, Kollmann and Martin (2007) show that in an endowment economy with multiple goods, substantial home bias in equities can be generated if assets traded in the model include not only equities but also real one-period bonds. In a second paper, Coeurdacier, Kollmann and Martin (2008) introduce shocks to investment demand and bond trading in the Heathcote and Perri (2008) model, with effectively complete asset markets, and are able to rationalize the observed pattern of international portfolios. In contrast to the former paper, our model assumes incomplete markets in a dynamic economy with nominal bonds, and, while also abstracting from the specification of the production function, provides an empirical calibration of the exogenous driving forces of our model. A closely related paper that also looks at the impact of emerging market economies on advanced economies is Devereux and Sutherland (2009). They focus is however on a two-country set up.

The remainder of the paper is organized as follows. In the following section, we describe the three-country open economy model that we utilize for our analysis. In Section 3, we discuss our multiple-agent extension of the Devereux-Sutherland (2007) algorithm for the steady state, while the Appendix discusses the extension to the dynamic portfolio problem. Sections 4, 5 and 6 present the model calibration results based on a two-country model and results based on the three-country model, respectively. Section 7 discusses the dynamic-portfolio results while Section 8 concludes.

2 The model economy

The world economy consists of three countries. All countries are completely specialized in one traded good, of which they receive an endowment each period. Agents in country 1 and 2 can freely trade domestic and foreign claims on a fraction of their endowment (equity) and borrow and lend in zero-net supply nominal bonds denominated in their respective currencies. In contrast, country 3 is subject to financial restrictions namely the lack of domestic bond market.

For the sake of simplicity, we describe below the equilibrium conditions that apply to unrestricted, symmetric countries 1 and 2, only for the former. Therefore, all (relative) prices will be expressed in terms of country 1 consumption basket. Obviously, in the case of asset prices and returns, appropriate arbitrage conditions will assure that the law of one price holds across all internationally traded securities.

2.1 Asset prices and returns

In country 1 and 2, four assets are traded internationally: two nominal one-period bonds and two equities. Following the standard approach in international finance since Lucas (1982), from country 1 perspective, domestic and foreign equities represent claims on (a fraction of) the endowments of goods 1 and 2, denoted by $D_{1,t}$ and $D_{2,t}$, respectively — specifically, shares in the fixed, positive amount of ‘trees’ yielding them, for simplicity normalized to 1.

The unitary real payoff of a share of the home equity purchased in period $t - 1$ at real price $Z_{1,t-1}^E$ is thus $P_{1,t}D_{1,t} + Z_{1,t}^E$, where Z_1^E is the real price of country 1 equity, and $P_{1,t}$ is the relative price of good 1 in terms of country 1’s CPI, $\mathcal{P}_{1,t}$. As a result the *realized*, ex-post gross rate of return on equities in country 1 is defined as:

$$r_{1,t+1}^E = \frac{P_{1,t}D_{1,t+1} + Z_{1,t+1}^E}{Z_{1,t}^E}. \quad (1)$$

Nominal bonds represent a claim on a unit of currency of country 1 or 2 the next period and are assumed to be in zero aggregate net supply. Assuming that the real price of a claim to country 1 currency is denoted by $Z_{1,t}^B$, then the real ex-post return on a nominal bond purchased at time t is therefore:

$$r_{1,t+1}^B = \frac{1}{Z_{1,t}^B \mathcal{P}_{1,t+1}}. \quad (2)$$

Similar conditions hold for assets issued in country 2, with their prices and returns being denoted with $Z_{2,t}^E$ and $Z_{2,t}^B$, and $r_{2,t+1}^E$ and $r_{2,t+1}^B$, respectively.

2.2 Households

Representative households in country 1 maximize expected lifetime utility by choosing purchases of the consumption good, C_t^1 given the following standard, CRRA utility

index:

$$E_t \left[\sum_{k=0}^{\infty} \beta^k \left(\frac{1}{1-\rho} (C_{t+k}^1)^{1-\rho} \right) \right],$$

where β is the discount factor, and ρ denotes risk aversion. Aggregate consumption C_t^1 is defined across all home and foreign goods, and its functional form is given by the following constant elasticity aggregator:

$$C_t^1 = \left[(\mu_1^1)^{\frac{1}{\theta}} (C_{1,t}^1)^{1-\frac{1}{\theta}} + (\mu_2^1)^{\frac{1}{\theta}} (C_{2,t}^1)^{1-\frac{1}{\theta}} + (\mu_3^1)^{\frac{1}{\theta}} (C_{3,t}^1)^{1-\frac{1}{\theta}} \right]^{\frac{\theta}{\theta-1}}$$

where $C_{i,t}^1$ with $i = 1, 2, 3$ stands for consumption goods originating in the corresponding country i . The parameter θ stands for the elasticity of substitution between goods of different origin, while μ_i^1 measures the importance of different goods in preferences of households, with $\sum_i \mu_i = 1$. The above aggregator could be easily generalized to the case of country and goods specific shares μ_i^j , and elasticities θ^j .

The corresponding demand for domestic and foreign goods, derived from expenditure minimization, can be written as follows:

$$\begin{aligned} C_{1,t}^1 &= \mu_1^1 P_{1,t}^{-\theta} C_t^1, \\ C_{2,t}^1 &= \mu_2^1 P_{2,t}^{-\theta} C_t^1, \\ C_{3,t}^1 &= \mu_3^1 P_{3,t}^{-\theta} C_t^1. \end{aligned}$$

Utility maximization is subject to following budget constraint in real terms:

$$C_t^1 + NFA_t^1 = r_{1,t}^B NFA_{t-1}^1 + \sum_{k=1}^{N-1} \alpha_{k,t-1}^1 r x_{k,t} + P_{1,t} (Y_{1,t} + D_{1,t}). \quad (3)$$

Each period the representative household has to decide how to split income between consumption and net foreign assets NFA_t . Its sources of income consist of the two stochastic endowments of good 1, $Y_{1,t}$ and $D_{1,t}$, and of the real returns on past savings,

$r_{1,t}^B NFA_{t-1}^1 + \sum_{k=1}^{N-1} \alpha_{k,t-1}^1 r x_{k,t}$, where $r x_{k,t}$ is real returns in excess of $r_{1,t}^B$ of all other assets, so that $N - 1 = 3$. The key distinction between the two endowments $Y_{1,t}$ and $D_{1,t}$ is that only claims to the latter could be traded on financial markets before uncertainty about it is resolved, as explained above, while the former could be traded only on spot goods markets after its amount is realized every period.

Following Devereux and Sutherland (2009), we have written the budget constraint (3) in terms of NFA_t , the net foreign asset position of the country, defined as:

$$\begin{aligned} NFA_t &= B_{2t}^1 + s_{2t}^1 Z_{2,t}^E - s_{1t}^2 Z_{1,t}^E - B_{1t}^2, \\ &= B_{1t}^2 + B_{2t}^1 + s_{2t}^1 Z_{2,t}^E + (s_{1t}^1 - 1) Z_{1,t}^E, \end{aligned}$$

where B_{1t}^1 and B_{2t}^1 are country 1 real holdings of bonds denominated in currency 1 and 2; s_{1t}^1 and s_{2t}^1 are country 1 holdings of claims on $D_{1,t+1}$ and $D_{2,t+1}$. Correspondingly, B_{1t}^2 , B_{2t}^2 , s_{1t}^2 and s_{2t}^2 are holdings by residents of country 2. The second equality is

obtained by using the market clearing conditions for country 1 assets, requiring that bonds be in zero net supply and the equity shares sum up to 1, namely:

$$\begin{aligned} B_{1t}^1 + B_{1t}^2 &= 0 \\ s_{1,t}^2 + s_{1,t}^1 &= 1. \end{aligned}$$

Correspondingly, we denote real gross asset positions brought into period t from the end of the period $t - 1$ for country 1 as $\alpha_{k,t-1}^1$, defined as follows:

$$\alpha_{1,t-1}^1 = Z_{1,t-1}^E (s_{1,t-1}^1 - 1), \quad (4)$$

$$\alpha_{2,t-1}^1 = Z_{2,t-1}^E s_{2,t-1}^1, \quad (5)$$

$$\alpha_{3,t-1}^1 = B_{2,t-1}^1; \quad (6)$$

namely, they represent gross holdings of country 1 equities by the rest of the world, gross holdings of country 2 equities by country 1 residents, and gross holdings of currency 2 bonds by country 1 residents. Notice that, by construction, $B_{1t-1}^1 =$

$$NFA_{t-1} - \sum_{k=1}^{N-1} \alpha_{k,t-1}.$$

Finally, optimal savings and portfolio decisions can be characterized by the following standard first order conditions:

$$(C_t^1)^{1-\rho} = \beta E_t \left[(C_{t+1}^1)^{1-\rho} r_{1,t+1}^B \right], \quad (7)$$

$$E_t \left[(C_{t+1}^1)^{1-\rho} r x_{k,t+1} \right] = 0 \quad (8)$$

for $k = 1, \dots, N - 1$. Similar relations will hold for the representative household in country 2; in particular optimal savings and portfolio decisions will be characterized by the following first order conditions:

$$(C_t^2)^{1-\rho} = \beta E_t \left[(C_{t+1}^2)^{1-\rho} r_{1,t+1}^B \frac{Q_{2,t}^1}{Q_{2,t+1}^1} \right] \quad (9)$$

$$E_t \left[(C_{t+1}^2)^{1-\rho} r x_{k,t+1} \frac{Q_{2,t+1}^1}{Q_{2,t}^1} \right] = 0, \quad (10)$$

where $Q_{2,t}^1$ is the consumption-based real exchange rate between country 1 and country 2, expressed in such a way that a depreciation from the perspective of country 1 will imply an increase in its value.

Finally, in addition to resource constraints for each individual good demand to hold, the model's equilibrium description requires to the nominal price level in each country to be determined. As in Devereux and Sutherland (2009) we assume that the following quantity equation pins down the aggregate price level $\mathcal{P}_{i,t}$:

$$\frac{M_{i,t}}{\mathcal{P}_{i,t}} = \frac{P_{i,t}}{Q_{i,t}^1} (Y_{i,t} + D_{it}), \quad (11)$$

where obviously $Q_{1,t}^1 = 1$.

2.3 Exogenous processes

We consider the following real and nominal shocks. First, we assume that endowment components Y_{it} and D_{it} , $i = 1, 2, 3$, follow AR(1) processes with country specific parameters and innovations correlated across shocks and countries:

$$\log Y_{it} = \phi_{Yi} \log Y_{it-1} + \varepsilon_{Yi,t}, \quad (12)$$

$$\log D_{it} = \phi_{Di} \log D_{it-1} + \varepsilon_{Di,t}, \quad (13)$$

where ϕ_Y and ϕ_D are the persistence parameters, and $\varepsilon_{Y,t}$ and $\varepsilon_{D,t}$ are country specific iid innovations. Second, nominal shocks are introduced by assuming that in all countries the monetary authority follows an exogenous money supply rule:

$$\log M_{it} = \phi_{Mi} \log M_{it-1} + \varepsilon_{Mi,t},$$

where the term also $\varepsilon_{M,t}$ represents a country specific iid innovation. The variance-covariance matrix of all the shocks will be denoted by the $e \times e$ matrix Σ ; however, we will conduct some robustness checks in which we assume directly a process for the nominal price level.¹

3 Solving for steady-state portfolios

In this section we describe our solution procedure which extends the methods in Devereux and Sutherland (2006) to an economy with more than 2 agents, potentially solving different maximization problems. After briefly outlining the procedure for the 2-country case, we proceed to extend it to the 3-country case, where country 3 portfolio choice follows from utility-maximization or other criteria like portfolio return variance minimization.

3.1 The 2-country case

Under some general conditions, Devereux and Sutherland (2006) show that in the case of 2 countries/agents the (near-stochastic) steady-state optimal portfolio vector, $\bar{\alpha}$, will be implicitly defined by the following moment conditions obtained by taking a second order approximation of the (difference of the) portfolio first order conditions (8) for country 1 and its foreign counterpart, around a nonstochastic steady state:

$$E_{t-1} \left[\left(\widehat{C}_t^1 - \widehat{C}_t^2 - \frac{1}{\rho} \widehat{Q}_{2,t}^1 \right) \widehat{r}x_{k,t} \right] = 0, \quad (14)$$

¹In some experiments we also assumed that the nominal exchange rate between country 3 and 1 is fixed, so that money supply will have to be adjusted accordingly, but results are broadly similar to those with flexible exchange rates.

where $\widehat{x}$ denotes the log-deviation of variable x from its steady state value. Under the assumption of homoschedastic shocks, the above conditional moments, one for each excess return k , will be the same for any period.

As it is clear from (8) that up to first order of approximation excess returns are i.i.d. variables, the term $\sum_{k=1}^{N-1} \alpha_{k,t-1}^1 r x_{k,t}$ in the budget constraint depicting the wealth effect arising from realized excess returns on foreign assets and liabilities, can be replaced with the auxiliary, i.i.d. variable $\xi_t^{1,2}$, also up to first order. Therefore, a solution with standard methods for the log-linearized equilibrium around the non-stochastic steady state will yield policy rules for the vector of excess returns $\widehat{R}x_t$ (comprising all individual $\widehat{r}x_{k,t}$) and for the PPP adjusted, marginal utility differential $\Delta_t^{1,2} = \left(\widehat{C}_t^1 - \widehat{C}_t^2 - \frac{1}{\rho} \widehat{Q}_{2,t}^1 \right)$, which will be linear functions of innovations ε_t , also indirectly through $\xi_t^{1,2}$, namely:

$$\begin{aligned}\widehat{R}x_t &= R_1 \xi_t^{1,2} + R_2 \varepsilon_t \\ \Delta_{2,t}^1 &= d_1 \xi_t^{1,2} + d_2' \varepsilon_t,\end{aligned}$$

where R_1, R_2, d_1, d_2 are matrices of coefficients.² Since up to first order $\xi_t^{1,2} = \widetilde{\alpha}' \widehat{R}x_t$, where $\widetilde{\alpha} = \bar{\alpha} \beta^{-1}$ the auxiliary variable could be substituted out to obtain expressions in terms of fundamental innovations ε_t for $\Delta_t^{1,2}$ and $\widehat{R}x_t$. Therefore, the time-invarying portfolio moment conditions (14) will amount to the following matrix equation as a function of $\bar{\alpha}$:

$$0 = (I - R_1 \bar{\alpha}')^{-1} R_2 \Sigma \left[\beta^{-1} d_1 \bar{\alpha}' (I - R_1 \bar{\alpha}')^{-1} R_2 + d_2' \right]', \quad (15)$$

where Σ is the variance-covariance matrix of fundamental shocks. It is then easy to obtain an analytical solution for the vector $\bar{\alpha}$, representing the gross holdings of foreign assets and liabilities for country 1, excluding the reference asset — the latter's position will be derived from the assumed level of steady state net foreign assets:

$$\bar{\alpha}' = -\beta \frac{(d_2' \Sigma R_2') (R_2 \Sigma R_2')^{-1}}{(d_1 - (d_2' \Sigma R_2') (R_2 \Sigma R_2')^{-1} R_1)}; \quad (16)$$

this expression, though slightly different from that derived by Devereux and Sutherland (2006), could be shown to imply the same solution for $\bar{\alpha}$.³

²The real marginal utility differential Δ will also be a function of state variables, like foreign wealth distribution across countries.

³The moment conditions can be written also as:

$$\begin{aligned}R_2 \Sigma d_2 + R_2 \Sigma R_2' \left((I - R_1 \bar{\alpha}')^{-1} \right)' \bar{\alpha} d_1 &= 0 \\ \left((I - R_1 \bar{\alpha}') \right)'^{-1} \bar{\alpha} d_1 &= - (R_2 \Sigma R_2')^{-1} (R_2 \Sigma d_2);\end{aligned}$$

3.2 The 3-country case

In the case of more than two agents, to take into account the effects of asset returns on the wealth distribution across agents, we will have to first keep track of the asset holdings of $J - 1$ agents, and include the relevant moment conditions from their portfolio optimization problems. In our 3-country economy, in addition to country 1, it will be enough to characterize foreign asset holdings by country 3, replacing the term $\sum_{k=1}^{N-1} \alpha_{k,t-1}^3 r x_{k,t}$ in the corresponding budget constraint with the auxiliary, (up to

first order of approximation) i.i.d. variable $\xi_t^{1,3}$, and taking into account the effects of both $\xi_t^{1,2}$ and $\xi_t^{1,3}$ on country 2 wealth. By Walras's law, it must be the case that net foreign assets in country 2 will be equal to the negative of the sum of net foreign assets in country 1 and 3, NFA_t^1 and NFA_t^3 . Therefore, the negative of $(\xi_t^{1,2} + \xi_t^{1,3})$ will capture the effects of the steady state gross holdings on country 2 net wealth.

Secondly, with a first order approximation of the model in hand, we will solve for excess returns $\widehat{R}x_t$, $\Delta_t^{1,2}$, defined as above, and its counterpart $\Delta_t^{1,3}$ for country 3, which will depend on the specific portfolio problem solved by this country, as a function of fundamental innovations ε and of $\xi_t^{1,2}$ and $\xi_t^{1,3}$. Since as before

$$\begin{bmatrix} \xi_t^{1,2} \\ \xi_t^{1,3} \end{bmatrix} = \widetilde{\alpha}' \widehat{R}x_t,$$

the moments conditions from the specific portfolio optimization problem are a function of the optimal steady state portfolio, $\bar{\alpha} = \beta \widetilde{\alpha}$ — the latter will be now a matrix.

Country 3 utility maximization In the case of utility based portfolio optimization by country 3, it is possible to obtain a closed form solution for $\bar{\alpha}$. The portfolio optimality conditions will be the counterpart of (14)

$$E_{t-1} \left[\left(\widehat{C}_t^1 - \widehat{C}_t^3 - \frac{1}{\rho} \widehat{Q}_{3,t}^1 \right) \widehat{r}x_{k,t} \right] = 0, \quad (17)$$

because of the following equality,

$$\left((I - R_1 \bar{\alpha}')^{-1} \right)' \bar{\alpha} = \bar{\alpha} \left((I - \bar{\alpha}' R_1)^{-1} \right)',$$

and noticing that $\bar{\alpha}' R_1$ is actually a scalar in this case, the above moment conditions simplifies to

$$\bar{\alpha} d_1 = - (R_2 \Sigma R_2')^{-1} (R_2 \Sigma d_2) (1 - R_1' \bar{\alpha}),$$

from which it is easy to derive the solution for $\bar{\alpha}$ provided by Devereux and Sutherland (2006):

$$\bar{\alpha} = (R_2 \Sigma d_2 R_1' - d_1 R_2 \Sigma R_2')^{-1} (R_2 \Sigma d_2).$$

implying that $\Delta_t^{1,3} = \left(\widehat{C}_t^1 - \widehat{C}_t^3 - \frac{1}{\rho} \widehat{Q}_{3,t}^1 \right)$. Up to first order, the relevant solutions for $\widehat{R}x_t$, $\Delta_t^{1,2}$, and $\Delta_t^{1,3}$ can be expressed as follows:

$$\begin{aligned}\widehat{R}x_t &= R_1 \begin{bmatrix} \xi_t^{1,2} \\ \xi_t^{1,3} \end{bmatrix} + R_2 \varepsilon_t \\ \Delta_t^{1,2} &= d'_1 \begin{bmatrix} \xi_t^{1,2} \\ \xi_t^{1,3} \end{bmatrix} + d'_2 \varepsilon_t + \dots, \\ \Delta_t^{1,3} &= \delta'_1 \begin{bmatrix} \xi_t^{1,2} \\ \xi_t^{1,3} \end{bmatrix} + \delta'_2 \varepsilon_t + \dots\end{aligned}$$

Substituting out $\xi_t^{1,2}$ and $\xi_t^{1,3}$:

$$\begin{aligned}\widehat{R}x_t &= \widetilde{R} \varepsilon_t \\ \Delta_t^{1,2} &= \widetilde{d} \varepsilon_t \\ \Delta_t^{1,3} &= \widetilde{\delta} \varepsilon_t,\end{aligned}$$

where:

$$\begin{aligned}\widetilde{R} &= (I - R_1 \widetilde{\alpha}')^{-1} R_2 \\ \widetilde{D} &= d'_1 \widetilde{\alpha}' (I - R_1 \widetilde{\alpha}')^{-1} R_2 + d'_2 \\ \widetilde{\delta} &= \delta'_1 \widetilde{\alpha}' (I - R_1 \widetilde{\alpha}')^{-1} R_2 + \delta'_2.\end{aligned}\tag{18}$$

The portfolio moment conditions for $\Delta_t^{1,2}$ (and likewise for $\Delta_t^{1,3}$) can thus be written as

$$\begin{aligned}0 &= \widetilde{D}' \Sigma \widetilde{R}' \\ 0 &= \left[d'_1 \widetilde{\alpha}' (I - R_1 \widetilde{\alpha}')^{-1} R_2 + d'_2 \right]' \Sigma R'_2 \left((I - R_1 \widetilde{\alpha}')^{-1} \right)',\end{aligned}\tag{19}$$

where as indicated above, $\widetilde{\alpha} = \beta^{-1} \overline{\alpha}$ is now a $(N-1) \times (J-1)$ matrix, where in the 3-country case $J-1 = 2$, and $N-1$ is the number of excess of returns, in our benchmark case with four internationally traded assets equal to 3. Rearranging the latter expression yields:

$$\begin{aligned}d'_1 \widetilde{\alpha}' &= -(d'_2 \Sigma R'_2) (R_2 \Sigma R'_2)^{-1} (I - R_1 \widetilde{\alpha}') \\ \left(d'_2 \Sigma R'_2 (R_2 \Sigma R'_2)^{-1} R_1 - d'_1 \right) \widetilde{\alpha}' &= (d'_2 \Sigma R'_2) (R_2 \Sigma R'_2)^{-1},\end{aligned}$$

or in more compact notation:

$$\underbrace{(d'_2 \mathcal{R} R_1 - d'_1)}_{1 \times (J-1)} \underbrace{\widetilde{\alpha}'}_{(J-1) \times (N-1)} = \underbrace{d'_2 \mathcal{R}}_{1 \times (N-1)},\tag{20}$$

where $\mathcal{R} = \Sigma R'_2 (R_2 \Sigma R'_2)^{-1}$. Stacking the above condition for $\Delta_t^{1,2}$, and its counterpart for $\Delta_t^{1,3}$ yields the following system:

$$\begin{bmatrix} (d'_2 \mathcal{R} R_1 - d'_1) \\ (\delta'_2 \mathcal{R} R_1 - \delta'_1) \end{bmatrix} \tilde{\alpha}' = \begin{bmatrix} d'_2 \\ \delta'_2 \end{bmatrix} \mathcal{R}, \quad (21)$$

which can be readily solved analytically for the steady state portfolio holdings if the right-hand side matrix matrix has a (generalized) inverse:⁴

$$\bar{\alpha}' = \beta \begin{bmatrix} (d'_2 \mathcal{R} R_1 - d'_1) \\ (\delta'_2 \mathcal{R} R_1 - \delta'_1) \end{bmatrix}^{-1} \begin{bmatrix} d'_2 \\ \delta'_2 \end{bmatrix} \mathcal{R}. \quad (22)$$

4 Calibration

We adopt the following symmetric parameterization, implying that all countries have equal size. Concerning preference parameters, we assume the following values: the risk aversion parameter $\rho = 2.0$; the elasticity of substitution parameter $\theta = 3$; and the time preference rate $\beta = 0.98$. Furthermore, in the baseline calibration we set the preference parameters μ_i^j so that in all three economies the exports-to-GDP ratio is 20%, divided equally between the two foreign countries — for instance, in the case of country 1 we set $\mu_1^1 = 0.8$, and $\mu_2^1 = \mu_3^1 = 0.1$; symmetric values are assumed for the other countries. As an implication, in the steady state, both the bilateral and overall trade is balanced, consistently with the assumption that NFA positions are all zero in the steady-state; subsequently we will look at a situation in which country 1 has a negative long-run international investment position vis-à-vis country 3, while keeping the preference parameters at their baseline values.

A crucial ingredient in the numerical exercises below is the stochastic properties of the exogenous processes, including the variance-covariance matrix of their innovations Σ . In our model, these processes contain two endowment shocks for each country i , denoted by $Y_{i,t}$ and $D_{i,t}$, and an exogenous process for money denoted by $M_{i,t}$ (or consumer prices $\mathcal{P}_{i,t}$ in some robustness exercise). While D_i represents the fraction of country endowments on which claims are tradable on financial markets, Y_i can be interpreted as financially non-tradable income. Therefore, we identify the empirical counterparts to the model's exogenous variables D_i and Y_i with the real dividends components of equity returns, and the real compensation of employees, respectively,

⁴Dedola and Lombardo (2008) formally solve for the general case of k excess returns, e shocks and n utility-maximizing agents, showing that the closed form solution for the optimal steady state portfolio matrix $\bar{\alpha}$ will be of the form:

$$\bar{\alpha}' = \beta \underbrace{\begin{bmatrix} (D_2^{1'} \mathcal{R} R_1 - D_1^{1'}) \\ \dots \\ (D_2^{i'} \mathcal{R} R_1 - D_1^{i'}) \\ \dots \\ (D_2^{n-1'} \mathcal{R} R_1 - D_1^{n-1'}) \end{bmatrix}}_{(n-1)x(n-1)} \underbrace{\begin{bmatrix} D_2^{1'} \\ \dots \\ D_2^{i'} \\ \dots \\ D_2^{n-1'} \end{bmatrix}}_{(n-1)xe} \underbrace{\mathcal{R}}_{exk}.$$

both deflated with domestic CPIs. The share of financially nontradable income in the steady-state Y^{SS} is set at 85 percent, so that D^{SS} equals 15 percent of total income – a similar proportion holds in the US data between dividend and nonfinancial personal income, although it could be a bit too high for emerging markets like China.⁵ Moreover, we use data on broad monetary aggregates for M_i and consumer price indices for $\mathcal{P}_{i,t}$. In a data appendix, we describe in details the data transformation and the data sources.

To obtain an estimate of the variance-covariance matrix of the exogenous shocks Σ and their autoregressive parameters, we estimated a VAR of 9 variables by OLS, for simplicity restricting the lag length to one and assuming a diagonal autoregressive matrix, as in the model. The sample consists of quarterly data from 1994:Q1 to 2007:Q4 for the USA, the euro area and China. The estimated parameters are reported in Table 1. Panel A presents the variance-covariance matrix, where the diagonal reports the relative variances of the shocks with respect to ε_{Y_1} , the innovation to financially non-tradable income in country 1 (the USA), while off-diagonal elements indicate the correlation between the shocks. As it is clear from the formulae derived in the previous section, this matrix is a crucial determinant of the optimal portfolio holdings. Note that all real shocks turn out to be substantially more volatile for country 3, reflecting the properties of Chinese data — and generally of emerging Asian economies, as discussed below. Real dividends shocks turns out to be more (than 5 times as) volatile in the euro area than in the US, but the opposite is true for financially non-tradable income, which is twice as volatile in the US as in the euro area.

Table1, Panel A: Estimated Shocks Covariance Matrix									
	ε_{Y_1}	ε_{Y_2}	ε_{Y_3}	ε_{M_1}	ε_{M_2}	ε_{M_3}	ε_{D_1}	ε_{D_2}	ε_{D_3}
ε_{Y_1}	1	0.16	-0.11	0.02	-0.07	0.08	0.26	0.17	-0.24
ε_{Y_2}	0.16	0.49	0.35	0.02	0.14	0.17	0.07	-0.03	-0.11
ε_{Y_3}	-0.11	0.35	37.31	0.06	0.09	0.37	-0.01	-0.03	0.16
ε_{M_1}	0.02	0.02	0.06	4.25	-0.01	0.16	0.30	0.02	0.04
ε_{M_2}	-0.07	0.14	0.09	-0.01	0.76	0.01	0.12	0.03	0.08
ε_{M_3}	0.08	0.17	0.37	0.16	0.01	3.22	0.25	0.05	-0.13
ε_{D_1}	0.26	0.07	-0.01	0.30	0.12	0.25	6.13	-0.09	-0.09
ε_{D_2}	0.17	-0.03	-0.03	0.02	0.03	0.05	-0.09	31.84	0.08
ε_{D_3}	-0.24	-0.11	0.16	0.04	0.08	-0.13	-0.09	0.08	269.89

The estimated persistence of shocks in all countries, reported in the Panel B of Table 1, turns out to be quite similar across the US and the euro area, although it

⁵Coeurdacier and Gourinchas (2009) come up with a higher estimate of the share of income on tradable financial claims for advanced countries, as they include in their measure not only dividends but all profits and a fraction of mixed income. Conversely, the identification of this income component with dividends on listed equities allows us to consistently estimate their stochastic process across advanced and emerging economies.

is relatively lower for Chinese data. Notice that the persistence of money shocks is irrelevant for portfolio decisions as they have only one period real effects in our model.

Table 1, Panel B: Estimated Shock Persistence

$$\begin{aligned}\rho_{Y_1} &= 0.96 \\ \rho_{Y_2} &= 0.94 \\ \rho_{Y_3} &= 0.78 \\ \rho_{M_1} &= 0.88 \\ \rho_{M_2} &= 0.99 \\ \rho_{M_3} &= 0.84 \\ \rho_{D1} &= 0.93 \\ \rho_{D_2} &= 0.95 \\ \rho_{D_3} &= 0.64\end{aligned}$$

As anticipated above, in some robustness experiments below we will use different shock calibrations. Specifically, we will look at the effects of assuming directly an exogenous process for nominal prices $\mathcal{P}_{i,t}$, and of calibrating country 3 shocks to data for an aggregate of emerging Asian economies, rather than only China. To save on space these alternative calibration are reported in a data appendix.

5 Country portfolios in a two country setting

In this section, we first analyze the optimal steady-state portfolio in a two-country version of our model with no restrictions on financial trading by domestic households, before turning to the main objective of the paper, to investigate how exposing these economies to a third-country with distorted savings and different degrees of financial restrictions affects their portfolio choices. Moreover, to provide an empirical counterpart to our numerical results in this section and the next, we first report some evidence concerning the composition of country portfolios in selected advanced and emerging economies. The results for our two-country economy with incomplete markets and trade in nominal bonds are of independent interest, as they complement analyses in the recent literature on country portfolios conducted under complete markets and trade in real bonds, often in static setting (see e.g. Coeurdacier and Gourinchas (2009) and Coeurdacier, Kollmann and Martin (2007)). Because of flexible prices, in our economy monetary shocks have real effects only on impact, when inflation surprises affect the value of nominal bonds (see Akimoto and Engel, 2009 for an analysis of the sticky price case with complete markets).

5.1 Empirical evidence on country portfolios

We start by documenting the well-known large amount of domestic equities in country portfolio holdings, and the correspondingly under-representation of foreign equities,

usually referred to in the literature as ‘equity home bias’. Table 2 presents in the first column the share of domestic holdings of domestic equities in the G7 countries, China and other Asian emerging economies for the year 2007; in the G7 this measure ranges from 90 percent in the US to 65.3 percent in the UK, while it is around 80 percent in emerging markets. The last column of Table 2 reports data in 2007 on a widely used index of equity home bias, computed as $1 - (\text{Share of Foreign Equities in Country } i \text{ Equity Holdings}) / (\text{Share of Foreign Equities in the World Market Portfolio})$.⁶ This index is equal to zero if the share of foreign equities in country i ’s portfolio is equal to the share of foreign equities in the world market portfolio, while it is equal to 1 in the opposite polar case of full equity home bias. The values of this index in the last column of Table 2 confirm the little openness to foreign equities of all countries, with particularly China and the other Asian emerging economies posting values very close to 1, full equity home bias. In our model these measures would correspond to s_j^i , $j = i$, and, given the assumed symmetry among countries, $1 - \frac{n}{n-1} \sum_{j \neq i} s_j^i$, respectively, where $n = 2$ or 3 depending on the assumptions about the tradability of country 3 equities.

Table 2: Domestic and Foreign Equity Holdings in Selected Countries		
	Financial Domestic Share	Equity Home Bias
	(in percent)	(in percent)
United States	90.0	75.6
Japan	85.0	89.1
Germany	68.9	61.5
France	70.4	72.3
UK	65.3	66.8
Italy	77.2	57.2
China	85.9	92.1
Emerging Asia (ex-China) ^a	77.2	96.5

^aDefined as the simple average of the following countries: Korea, Hongkong, India, Indonesia, Malaysia, Singapore and Thailand.

Next in Table 3 we analyze the composition of foreign gross assets and liabilities for the same set of countries, also in the year 2007.⁷ The first column of the table displays the share of gross foreign assets held in the form of equities over the total of foreign portfolio assets, including securities held as official reserves. Developed economies, with the exception of Japan in which foreign reserves are also quite large, are characterized by a relatively high share of equities, ranging from 0.73 in the U.S.

⁶See, e.g., Fidora, Fratzscher, Thimann (2007) and Coeurdacier and Gourinchas (2009) for details.

⁷The data is from the IMF’s CPIS database and the updated and extended version of the External Wealth of Nations Mark II database developed by Lane and Milesi-Ferretti (2007); for the US economy we also draw from the following 2007 US Treasuries’ documents: the "Report on US holdings of foreign debt securities", as well as the "Report on Foreign holdings of US debt securities".

to 0.28 in France, with respect to emerging economies like China, in which this share is as low as 0.02.

Conversely, column 2 shows the opposite for the share of equities in gross portfolio liabilities, as for advanced economies the latter mostly comprise non-equity claims held abroad, whereas China presents a much higher fraction of domestic equity claims held abroad, equal to 0.96. However, the US stands out even among advanced countries as its portfolio assets comprise over 2/3 of foreign equity claims. This is clear from column 3 and 4, respectively reporting the ratio of the absolute value of the equity gross positions in portfolio assets and liabilities, and in overall gross assets and liabilities, but now including FDI among equities.⁸ This ratio, very similar across the two measures, is much larger in advanced economies than in China, in line with the findings in column 1 and 2, and it exceeds 1.5 in the U.S., while it is below 1 in other major currency blocks like Japan and the euro area.⁹

Table 3, Panel A: Composition of Portfolio Assets and Liabilities in Selected Countries

	Share of Equities		Equities- Assets/Liabilities Ratio	
	Assets	Liabilities	Portfolio Investment	Including FDI
	(1)	(2)	(3)	(4)
United States	0.73	0.31	1.62	1.53
Japan	0.17	0.64	0.46	0.81
Germany	0.37	0.26	1.17	1.21
France	0.28	0.35	0.86	1.26
Italy	0.46	0.21	1.57	1.50
Euro area	0.41	0.49	0.64	0.89
UK	0.44	0.43	0.92	1.15
China	0.02	0.96	0.06	0.12

The above findings for China are in line with data for other Asian emerging economies, as shown by Panel B of Table 3. These countries (also in striking similarity to Japan) tend to have a share of equities in foreign securities generally much lower than the US and the euro area, on average below 0.2, and a much higher share of equity claims held abroad, often well in excess of 2/3. Even countries like Singapore and Taiwan, although holding substantial amounts of foreign equities similarly to advanced economies, differ from the latter in the composition of their liabilities, also primarily in domestic equity claims.

⁸If we recompute the shares in columns 1 and 2 with the same convention, using total assets and liabilities but including FDI among equity claims, we obtain very similar numbers for most countries. Specifically, in the case of the US, euro area and China the shares in columns 1 and 2 would be: 0.56 and 0.32; 0.41 and 0.42; 0.06 and 0.76, respectively.

⁹The euro area as whole results less open than member countries like Italy or France, as cross-holdings among the latter are netted out.

Table 3, Panel B: Composition of Portfolio Assets and Liabilities in EME Asia				
	Share of Equities		Equities- Assets/Liabilities Ratio	
	Assets	Liabilities	Portfolio Investment	Including FDI
	(1)	(2)	(3)	(4)
Singapore	0.51	0.89	1.62	1.09
Korea	0.23	0.70	0.30	0.40
Malaysia	0.11	0.66	0.18	0.39
Indonesia	0.03	0.73	0.01	0.13
Thailand	0.03	0.89	0.06	0.08
Taiwan	0.35	0.97	0.97	1.44
Philippines	0.05	0.53	0.07	0.15
<i>Average</i>	0.19	0.77	0.46	0.52

Taking stock of the evidence presented so far, the following features of country portfolios, which will be the main focus of our numerical analysis in the rest of the paper, stand out. First, both developed and developing countries are characterized by substantial home bias in equity holdings, in terms of concentration of holdings of domestic equities and values of the home bias index. Second, while the former set of countries holds a substantial fraction of their foreign assets in the form of equities, the latter set of countries is more heavily invested in non-equity, debt securities, such as bonds. Third, while debt securities represent the preponderant fraction of gross liabilities in advanced countries relative to equities, the opposite is true for emerging economies such as China, in which almost 100% of foreign-held assets are in the form of domestic equity claims. However, the US, while displaying a degree of home bias not dissimilar to that of European countries, stands out even among the G7 as over 1/2 of its foreign assets consists of equities, to the point that its gross asset position in equities is more than 1.5 times as large as its gross equity liabilities.

6 Steady-state portfolios in a three-country model

In this section we turn to investigating the effects on international portfolios in a model with unfettered trade in goods with a third country — country 3 — but different degrees of financial integration. Our goal is twofold. On the one hand, from a positive perspective, we want to check whether extending this way the analysis we can improve the ability of the model to replicate features of country portfolios we have highlighted above. On the other hand, from a counterfactual perspective, we think it interesting to explore the impact of differing asset market structures in emerging economies, in light of the increasing degree of financial development and integration that these economies are bound to experience.

Let us start, however, by examining the impact of the introduction of third country in the model. It is instructive to consider first the case of financial trade limited to bonds only. This case is the extension to three countries of the model used in Devereux-Sutherland (2006). These authors show that the optimal bond portfolio in

the two-country endowment model with bonds only amounts to:¹⁰

$$B_2^1 = -\frac{1}{2} \frac{1}{(1 - \beta\phi_Y)} \left(\frac{\sigma_{1,Y}^2 + \sigma_{2,Y}^2}{\sigma_{1,Y}^2 + \sigma_{2,Y}^2 + \sigma_{1,M}^2 + \sigma_{2,M}^2} \right). \quad (23)$$

This result shows that “global” monetary policy is important in determining bond-portfolio positions. In particular, the larger the volatility of money supply in either country, the smaller the long-run gross-portfolio holdings. By introducing a third country we break this symmetry. With more than two countries it is not true anymore that all bond-portfolio positions contract as any of the monetary policy stances become more volatile. For example, it is possible to show that, in the limit of an infinitely volatile money supply in country 3, the portfolio position of country 3 reduces to

$$\lim_{\sigma_{M3}^2 \rightarrow \infty} B_1^3 = \frac{\sigma_{Y1}^2 - \sigma_{Y2}^2}{3(1 - \phi_Y \beta)(\sigma_{M1}^2 + \sigma_{M2}^2 + \sigma_{Y1}^2 + \sigma_{Y2}^2)} \quad (24)$$

for country 3’s holding of country 1’s bonds and $B_3^3 = 0$. Moreover the position of country 1 reduces to¹¹

$$\lim_{\sigma_{M3}^2 \rightarrow \infty} B_1^1 = -\frac{2\sigma_{Y1}^2 + \sigma_{Y2}^2}{3(1 - \phi_Y \beta)(\sigma_{M1}^2 + \sigma_{M2}^2 + \sigma_{Y1}^2 + \sigma_{Y2}^2)} \quad (25)$$

and $B_3^1 = 0$.

Therefore the symmetry imposed by the two-country set-up can hide important factors driving observed portfolio positions, like large idiosyncratic volatility of monetary policy that tilts the (short or long) bond holdings in favor of foreign currencies.¹² In this regard, introducing a third country further differentiates our work from Devreux and Sutherland (2009) who, in a two-country model, find that “[in] particular, more volatility arising from price shocks will reduce the size of optimal portfolios, and reduce risk-sharing across countries” (page 182).

We first start to examine the impact of a third country by controlling for any changes in the covariance matrix and shock persistence, and comparing it to the results of a two-country model. In column 1 of Table 3, we reproduce the results for the two-country case by setting the assuming no correlation and identical values for the persistence and variances of the exogenous processes. As shown, the international

portfolio is subject to a large degree of home bias ($s_1^1=1.05$ and $s_2^2=1.05$). This is mainly financed by a large short position in domestic bonds. The results reflect the desire by risk-averse households to insure against consumption fluctuations by choosing assets that provide a good hedge against shocks to their wealth. It is well-known that when all wealth is financially tradable, comprising only income on equity claims

¹⁰all shocks are assumed to have the same autocorrelation coefficient ϕ_Y .

¹¹Country 2 is symmetric to country 1 and, hence, holds the same portfolio composition, *mutatis mutandis*.

¹²In the two-country model with bonds and equities, even in the limit case of infinitely volatile money supply agents would still trade in bonds denominated in the other currency. In this regard, the number of assets and the number of countries play a similar and complementary role.

D_i , households would like to diversify the associated country-specific risk by holding a substantial fraction of their wealth in foreign equities (e.g. as in Lucas (1982)).¹³ However, the introduction of a financially nontradable component Y_i , imperfectly correlated with dividends, generates a well-known motive to shift portfolio allocations in favor of domestic equities (see e.g. Heathcote and Peri, 2008). Specifically, in our setting with specialization in imperfectly substitutable goods and bias in favor of domestically produced goods in preferences, this mechanism works in the following way. Consider for instance a negative shock to Y_1 , which in our model leads to an appreciation of the real exchange rate in country 1; for a given level of D_1 and D_2 , this domestic appreciation makes domestic equities more valuable compared to foreign equities and thus a better hedge against fluctuations in non-financial endowment, thus tilting the domestic demand in favor of domestic equities.

In column 2, we extend the model by introducing country 3, which is allowed to trade equities internationally, but is unable to issue bonds. The latter reflects the lack of functioning domestic bonds market in emerging market economies. In order to control for the effects of a change in the covariance matrix, we continue to assume that shocks are uncorrelated and have the same variance. The results indicate that the introduction of country 3, increases the home bias in equities in country 1 and 2 ($s_1^1=1.10$ and $s_2^2=1.10$). At the same time, country 3 is subject to a relatively large degree of home bias as $s_3^3 = 0.9463$, but below the one documented in country 1 and 2. The latter reflect the lack of domestic bonds in country 3. As discussed in Coeurdacier and Gourinchas (2009), there is a negative relationship between the degree of home bias and the country's bond position in its own currency. The reason is that an increase in domestic equity holdings increases its implicit domestic currency exposure. Investors optimally undo this exposure by shorting the domestic currency bond. As country 3 is lacking a functioning bond market, it is unable shortening the domestic bond, which results in a lower home bias in equity. This establishes our first set of result: the introduction of an emerging economy with no local bond market into the international financial system, increase the home bias in advanced economies. The lack of domestic bonds market results in lower home bias in emerging economies than in advanced economies.¹⁴

In the next step, we add the calibrated shocks to the two-country model. The results are shown in column (3). There are several features of the calibrated two-country model that stand in contrast to the stylized facts documented above. First, home bias in equities in country 1 are below those documented for the US. Second, the share of equities in assets in country 1 (documented in a third row from below) are too low compared to the data. Adding a third country changes this picture significantly (column 4). As we have discussed above, the introduction of a third country with no trade in domestic bonds, increases the home bias in advanced economies. This is effect, particularly in country 1, is not driven by the calibration of the covariance

¹³Because of equality of the two countries, including preferences, in Lucas' model countries hold a perfectly diversified, 50-50, portfolio of foreign and domestic equities.

¹⁴Notice, however, that our results depend on the behavior of monetary policy in the model. Here we assume that monetary policy follows a simple rule associated quantity equation. See Deveraux and Sutherland (2008).

matrix, but by the endogenous propagation mechanism of the model. The home bias in country 1 is increased close to its empirical counterpart of $s_1^1 = 0.69$. At the same time, the third-country model is also able to reproduce an additional stylized fact in the model, namely the large share of equities in assets, but the relatively low share of equities in liabilities in the data for country 1. Both ratios change into the right direction compared to the two-country setting.

Table 7: Steady State Portfolios

	(1)	(2)	(3)	(4)
s_1^1	1.05	1.10	0.57	0.69
s_2^2	1.05	1.10	0.74	0.64
s_3^1		0.03		0.40
B_1^1	-2.00	-2.45	-0.33	-0.72
B_2^1	2.00	1.24	1.59	-1.04
s_1^3		-0.13		-0.13
s_2^3		-0.13		0.22
s_3^3		0.95		0.53
B_1^3		1.20		0.55
B_2^3		1.20		2.30
Equities in Assets			0.55	1.00
Equities in Liabilities			0.91	0.54

Taking stock of our results, we have found that extending the calibrated model to a third country, financially underdeveloped, goes a long way in bringing about several realistic features of advanced and emerging country portfolios, both qualitatively and quantitatively. While equity home bias in both (‘advanced’) countries 1 and 2 significantly increases relative to the two-country version of the model, these countries hold a substantial fraction of their foreign assets in the form of equities. We have argued that this result is mainly driven by one particular feature of the model, namely the lack of domestic bond markets in country 3, the emerging economy.

7 Portfolio dynamics

Devereux and Sutherland (2010) have shown how to derive the first-order-accurate optimal law of motion for the portfolio shares in a two-country two-assets model. One of the contributions of our paper is to extend their technique to portfolio problems with more than two countries and more than two assets.¹⁵ We discuss the details of

¹⁵Coeurdacier et al. (2010) study the optimal portfolio dynamics in a two-country model with two bonds and two equities. As there are only four shocks in their model (TFP and investment specific shocks) there is perfect spanning and asset markets are (effectively) complete. In our model there is no perfect spanning as we have more shocks than assets.

the solution technique in the Appendix.

In this section, we apply the extended DS technique to study the implications of our model for international transaction flows in equities (turnover). Tesar and Werner (1995) show that turnover in domestic holding of foreign equities is higher than the turnover in domestic holding of domestic equities. These authors define turnover in foreign equities as the ratio of total transactions (purchases as sales) to total holding of these equities. Due to data availability, the domestic turnover is simply the sum of all transactions (purchases and sales) in the domestic stock market divided by the market capitalization. They argue that their evidence casts doubts on explanations of the home bias in equities based on transaction costs (see also Lewis, 1999).¹⁶ Hnatkovska (2010) develops a solution technique for portfolio dynamics alternative to DS and uses her technique to calculate the home bias and turnover in equities in a two-country, two-sector DSGE model. She finds that “Both home bias and international capital flows are driven by variations in international relative prices which arise from productivity changes.” Portes and Rey (2005) provide evidence that bilateral trade flows and bilateral equity flows are positively linked.¹⁷ They also find some evidence that bilateral equity flows and equity holding are positively correlated.¹⁸

In light of this literature, we cast our analysis in terms of the link between trade in goods (openness), home bias in equities and equity-transaction flows.

Figure 1 shows turnover and home bias in equity for different values of the home bias in consumption.¹⁹ Since trade elasticity is also an important determinant of home bias in equities, we report the results for three possible values of θ , i.e. 1.5, 3 and ∞ . The first two values correspond to values considered in the open economy literature. The perfect substitutability case, instead, is a polar case of particular theoretical importance, as, in this case, the relative prices are constant so that there is no terms-of-trade risk.²⁰

Consistently with our results discussed in previous sections, home bias in consumption (trade flows) has implications for home bias in equities, with the relationship between the two forms of home bias being non monotonic. These results are robust to different values of the trade elasticity.

As for turnover, Figure 1 shows three important results. First, foreign turnover is not always larger than domestic turnover for all countries and for all degrees of

¹⁶Warnock (2002) shows that by using updated observations foreign-equity turnover is smaller than that reported in Tesar and Werner (1995), although it is still about twice as large as domestic turnover for US and Canada. Rowland (1999) points out that these measures are very sensitive to the relative denominators used in calculating the turnovers. So while the turnover in foreign equities is higher, the total number of transactions might be much lower. Amadi and Bergin (2008) report high turnover rates in foreign equity holding and find that they are compatible with fixed costs of entering the foreign market, as opposed to per-unit trading costs.

¹⁷They estimate an elasticity of about 0.36 which increases to 0.48 when the sample is restricted to European countries.

¹⁸Indeed they find that the elasticity of flows of foreign equities with respect to domestic holding of foreign equities is one for the US. Acknowledging the limits of their “US-centered” sample they argue that their evidence is “a first step towards gathering a set of stylized facts that unified theories of trading and asset holdings will have to match.

¹⁹In our three country model, home bias in consumption is obtained for values of $\mu > \frac{1}{3}$.

²⁰Perfect substitutability is approximated by setting $\theta = 1000$.

home bias in consumption. In particular the trade elasticity plays an important role. Second, foreign turnover is not systematically increasing in the degree of home-bias in consumption across countries. Third, there is no systematic relationship between domestic and foreign turnover across countries for varying degrees of home bias in consumption.

Under our benchmark parametrization ($\mu = 0.8$ and $\theta = 3$) turnover in foreign equities is larger than turnover in domestic equities for all countries. Therefore, and similarly to Hnatkovska (2010), we show that it is possible to generate empirically plausible degrees of home bias in equities and high foreign equity turnover in a relatively simple model and without trading costs. Nevertheless, our analysis also shows that factors determining home bias in equities (i.e. trade flows) not necessarily bring about higher turnover in foreign assets.

This implies, for example, that for country 2 and 3 and relatively small trade elasticities our model can produce results that are qualitatively in line with Portes and Rey (2005) while the pattern displayed for country 1 is inconsistent with the available empirical evidence.

Our simple analysis suggests that there could be heterogeneity across countries concerning the trade-holding-flows relationship. In our model this heterogeneity derives from different asset structures as well as from differences in the stochastic shocks affecting the economies. Further empirical research in this direction could shed light on the cross-sectional variation in the trade-holding-flows relationship.

8 Concluding remarks

This paper investigated the effects of the emergence of financially constrained ("emerging") economies on the long run portfolio allocation of financially liberalized ("mature") economies. To do so, we depart from the usual small open economy assumption and adopt a multi-country model. We extend the Devereux and Sutherland (2006) algorithm, solving for optimized portfolios in a macroeconomic model with more than two agents, possibly with different objective functions. While we were able to obtain closed form solutions in the case of utility optimization by all countries representative agents, unfortunately closed form solutions are not generally available in other cases, and the model has to be solved numerically. In this setting, we have conducted several experiments, assuming that country 3, though fully integrated in goods market trading with the rest of the world — the financially integrated country 1 and 2, one country — is subject to varying degrees of international financial restrictions.

First, however, we have shown that our calibrated two-country DSGE model, though simple, is consistent with the degree of domestic equity homes bias observed in the data. Furthermore, we have also shown that under incomplete markets, the time series properties of the shock processes, like their persistence and covariance structure, as well as preference parameters like the elasticity of substitution, matter for the equilibrium long-run portfolio, in contrast to the complete markets invariance results obtained in the literature.

Second, we have shown that, even the trade pattern with a financially autarkic third country is an important determinant of gross asset positions in the rest of the world. Under our benchmark symmetric calibration, the emergence of trade with country 3 reduces the role of domestic and foreign assets in providing hedging against consumption fluctuations in mature economies, resulting in a decline of gross assets positions and an increase in equity home bias. The latter result is amplified by the degree of openness.

Third, assuming inefficiencies in savings decisions in country 3, we have explored the consequences of different foreign reserves allocation strategies by this country. Interestingly, we have shown that there are substantial differences in the international assets allocation depending on the objective of reserves allocation pursued by country 3. In particular, adoption of an objective of return variance minimization increases the degree of home bias in unconstrained economies (country 1 and 2), compared to mechanical investment of reserves in country 1 bonds. Moreover, we have shown that in this case the denomination of the real return on the reserves portfolio in country 3 has only limited effects on asset allocations internationally. Interestingly, pursuing a benevolent reserve allocation strategy, based on domestic households utility maximization, will lead to very different results, as in this case country 3 holds very large gross positions in foreign equities, reflecting the large hedging demand caused by the relative high domestic shock volatility. In turn, a substantial reshuffling of equity holdings in the rest of the world will ensue.

These results are interesting, as they highlight the relevance of a change in portfolio allocation strategy in systematically important financially underdeveloped economies on international capital markets. As a result, policy changes in reserves allocation strategies may have substantial effects on international holdings of foreign assets not only in emerging economies, but also in financially developed industrial economies.

As for portfolio dynamics, our analysis contributes to the recent theoretical and empirical literature on the relation between home bias in equities, high turnover in foreign equities and trade flows (e.g. Tesar and Werner, 1995, Amadi and Bergin, 2008, Warnock, 2002, Hnatkovska, 2010, and, in particular Portes and Rey, 2005). We show that our benchmark calibration generates home bias in equities and high turnover in foreign equities, consistently with the empirical evidence. Nevertheless, we also show that for a given degree of openness to trade in goods, our three countries can display different degrees of volatility in financial trade, depending, in particular, on asset availability and the type of shocks that these economies experience.

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Appendix

A Computing portfolio dynamics

We are now in the position to solve for the portfolio dynamics. We first present the case of two agents and one asset to re-cast the Devereux and Sutherland (2010) result into our notation. The multiple-agent multiple-asset case will be a straightforward extension.

A.1 The two-agents one-asset case

Devereux and Sutherland (2010) show that in order to obtain a second-order accurate solution for the portfolio dynamics, one has to take a third order approximation of the consumption Euler equation of each agent.²¹ In particular, with reference to their equation (26) we have

$$E_t \left[-\rho (C_{t+1} - C_{t+1}^*) r_{x,t+1} + \frac{\rho^2}{2} (C_{t+1}^2 - C_{t+1}^{*,2}) r_{x,t+1} - \frac{\rho}{2} (C_{t+1} - C_{t+1}^*) (r_{1,t+1}^2 - r_{2,t+1}^2) \right] = 0 \quad (26)$$

In order to evaluate this expression we need the solution for consumption and the return on the assets at most to the second order of accuracy.

As shown in Lombardo and Sutherland (2007) the second order solution for the consumption differential between the two agents can be written as

$$(C - C^*) = \underbrace{D_1 \xi + D_2 \varepsilon + D_3 z}_{\text{First order part}} + \underbrace{D_0 + D_4 \text{vec}(\varepsilon \varepsilon') + z' \hat{D}_5 \varepsilon + D_6 \text{vec}(zz')}_{\text{Second order part}} \quad (27)$$

and

$$r_x = \underbrace{R_1 \xi + R_2 \varepsilon}_{\text{first order part}} + \underbrace{E[r_x] - R_4 \vec{\Sigma} + R_4 \text{vec}(\varepsilon \varepsilon') + z' \hat{R}_5 \varepsilon}_{\text{Second order part}} \quad (28)$$

where all the variables have the same timing, $\vec{\Sigma} = E[\text{vec}(\varepsilon \varepsilon')]$, and where $z' = [x_t, s_{t+1}]$; x_t being the $e \times 1$ vector of shocks and s_t the $l \times 1$ vector of endogenous state variables.²²

²¹This subsection does not add anything to Devereux and Sutherland (2010) except reproducing their calculations using matrix notation in place of tensor notation.

²²See the Subsection A.6 for a second-order state-space representation of the solution. The matrices in equations (27) and (28) correspond to transformations of the rows of the P matrices given in the Subsection A.6. Notice that, up to second order, $R_0 = E[r_x] - R_3 z - R_4 \vec{\Sigma} - R_6 \text{vec}(zz')$ and that, since up to first order r_x is *i.i.d.*, $R_3 z = 0$. Notice also that it is possible to re-write terms like $R_5 \text{vec}(\varepsilon \varepsilon')$ as $z' \hat{R}_5 \varepsilon$. The arrows denote vectorization.

Devereux and Sutherland (2010), show that the portfolio dynamics can be described as a linear transformation of the state variables, i.e.

$$\alpha_{t-1} = \gamma' z_t \quad (29)$$

where γ in this case is a $(l + e) \times 1$ vector of coefficients to be determined.

The second order approximation of the budget constraint of each agent (equation (3)) generates a term in the cross product of the portfolio and the excess returns: $\alpha_{t-1} r_{x,t}$. Following Devereux and Sutherland (2010), we can express this product as an i.i.d. variable

$$\xi_{t+1} \equiv \alpha_t r_{x,t+1} = \gamma z_{t+1} r_{x,t+1} \quad (30)$$

Since this relation involves only first order variables, we can use the first order part of equation (28) in the latter expression to get (dropping time subscripts)

$$\xi = \gamma' z R_2 \varepsilon = R_2 \varepsilon z' \gamma \quad (31)$$

Replace this into (27) and (28)

$$\begin{aligned} (C - C^*) &= D_0 + D_1 z' \gamma R_2 \varepsilon + D_2 \varepsilon + D_3 z \\ &\quad + D_4 \vec{\varepsilon} \vec{\varepsilon} + z' \hat{D}_5 \varepsilon + D_6 \vec{z} \vec{z} \end{aligned} \quad (32)$$

and

$$\begin{aligned} r_x &= E[r_x] - R_4 \vec{\Sigma} + R_1 z' \gamma R_2 \varepsilon + R_2 \varepsilon \\ &\quad + R_4 \vec{\varepsilon} \vec{\varepsilon} + z' \hat{R}_5^i \varepsilon. \end{aligned} \quad (33)$$

As this expression involves first order terms in C and $r_{1,2}$ we need the first order solution to these variables, i.e.

$$\begin{aligned} C &= C_2^H \varepsilon + C_3^H z & C^* &= C_2^F \varepsilon + C_3^F z \\ r_1 &= R_2^H \varepsilon + R_3^H z & r_2 &= R_2^F \varepsilon + R_3^F z \end{aligned}$$

where by the *i.i.d.* nature of r_x must be that $R_3^F = R_3^H$.

Taking cross-products of these equations we have, e.g.

$$C^2 = (C_2^H \otimes C_2^H) \vec{\varepsilon} \vec{\varepsilon} + (C_3^H \otimes C_3^H) \vec{z} \vec{z} + [(C_2^H \otimes C_3^H) + (C_3^H \otimes C_2^H) P_v] \vec{\varepsilon} \vec{z} \quad (34)$$

where P_v is a vector-permutation matrix. For convenience we re-write these cross products as

$$\begin{aligned} C^2 &= C_{2 \otimes 2}^H \vec{\varepsilon} \vec{\varepsilon} + C_{3 \otimes 3}^H \vec{z} \vec{z} + C_{2 \otimes 3}^H \vec{\varepsilon} \vec{z} & C^{*,2} &= C_{2 \otimes 2}^F \vec{\varepsilon} \vec{\varepsilon} + C_{3 \otimes 3}^F \vec{z} \vec{z} + C_{2 \otimes 3}^F \vec{\varepsilon} \vec{z} \\ r_1^2 &= R_{2 \otimes 2}^H \vec{\varepsilon} \vec{\varepsilon} + R_{3 \otimes 3}^H \vec{z} \vec{z} + R_{2 \otimes 3}^H \vec{\varepsilon} \vec{z} & r_2^2 &= R_{2 \otimes 2}^F \vec{\varepsilon} \vec{\varepsilon} + R_{3 \otimes 3}^F \vec{z} \vec{z} + R_{2 \otimes 3}^F \vec{\varepsilon} \vec{z} \end{aligned}$$

and

$$C^2 - C^{*,2} = C_{2\otimes 2}^{H-F} \vec{\varepsilon} \vec{\varepsilon} + C_{3\otimes 3}^{H-F} \vec{z} \vec{z} + C_{2\otimes 3}^{H-F} \vec{\varepsilon} \vec{z}$$

and

$$r_1^2 - r_2^{*,2} = R_{2\otimes 2}^{H-F} \vec{\varepsilon} \vec{\varepsilon} + R_{2\otimes 3}^{H-F} \vec{\varepsilon} \vec{z}$$

where we have defined e.g. $C_{2\otimes 2}^{H-F} \equiv (C_{2\otimes 2}^H - C_{2\otimes 2}^F)$.

Consider one addendum of equation (26) at a time (and abstract from the ρ coefficient for the time being), i.e.

$$D_0 r_x + D_1 z' \gamma R_2 \varepsilon r_x + D_2 \varepsilon r_x + D_3 z r_x + D_4 \vec{\varepsilon} \vec{\varepsilon} r_x + z' \hat{D}_5 \varepsilon r_x + D_6 \vec{z} \vec{z} r_x \quad (35)$$

$$(C_{2\otimes 2}^{H-F} \vec{\varepsilon} \vec{\varepsilon} + C_{3\otimes 3}^{H-F} \vec{z} \vec{z} + C_{2\otimes 3}^{H-F} \vec{\varepsilon} \vec{z}) \times \varepsilon' R_2' \quad (36)$$

$$(D_2 \varepsilon + D_3 z) \times (R_{2\otimes 2}^{H-F} \vec{\varepsilon} \vec{\varepsilon} + R_{2\otimes 3}^{H-F} \vec{\varepsilon} \vec{z})' \quad (37)$$

Let's start with equation (35). Recall that to first order $r_x = R_2 \varepsilon$, while, to a first order $C - C^* = C_2^{H-F} \varepsilon + C_3^{H-F} z$

Notice that since $D_2 \varepsilon \varepsilon' R_2' = 0$, and assuming that third moments of the shocks are zero, the (conditional on time t) expected value of equation (35) reduces to (omitting the expectation operator)

$$\begin{aligned} & \left[R_2 \varepsilon \varepsilon' R_2' D_1 z' \gamma + z' \hat{D}_5 \varepsilon \varepsilon' R_2' \right] + \left(z' \hat{R}_5 \varepsilon \varepsilon' D_2' \right) + \\ & + D_2 \varepsilon E[r_x] + \left(E[r_x] - \left(\vec{\Sigma} \right)' R_4' + (\vec{\varepsilon} \vec{\varepsilon})' R_4' \right) (D_3 z) \end{aligned}$$

Notice that

$$\left(E[r_x] - \left(\vec{\Sigma} \right)' R_4' + (\vec{\varepsilon} \vec{\varepsilon})' R_4' \right) (D_3 z) = (E[r_x]) (D_3 z)$$

Furthermore notice that the sum of the second order expansion of the Euler equations we can derive an expression for $E[r_x]$. So for, say the home country, have

$$C^{-\rho} \beta \left(\hat{r}_1 - \hat{r}_2 + \frac{1}{2} \hat{r}_1^2 - \frac{1}{2} \hat{r}_2^2 \right) - \rho \beta C^{-\rho} \left(\hat{C} \right) (\hat{r}_1 - \hat{r}_2) = 0.$$

Adding this to the foreign counterpart yields,

$$E[r_x] = \frac{\rho}{2} E \left[(C_2^H + C_2^F) \varepsilon \varepsilon' R_2' + (C_3^H + C_3^F) z \varepsilon' R_2' \right] - \frac{1}{2} (R_{2\otimes 2}^{H-F} \vec{\varepsilon} \vec{\varepsilon} + R_{2\otimes 3}^{H-F} \vec{\varepsilon} \vec{z})$$

implying that

$$(E[r_x]) (D_3 z) = \rho (C_2^H) [D_3 z \Sigma R_2'] - \frac{1}{2} R_{2\otimes 2}^{H-F} \vec{\varepsilon} \vec{\varepsilon} D_3 z$$

and that

$$D_2 \varepsilon E[r_x] = \rho(C_3^H + C_3^F) z R_2 \varepsilon \varepsilon' D_2' - \frac{1}{2} D_2 \varepsilon (R_{2 \otimes 3}^{H-F} \vec{\varepsilon} \vec{z}) = -\frac{1}{2} D_2 \varepsilon (R_{2 \otimes 3}^{H-F} \vec{\varepsilon} \vec{z}) = 0$$

where we have used the fact that

$$D_2 \varepsilon (R_{2 \otimes 3}^{H-F} \vec{\varepsilon} \vec{z}) = D_2 \varepsilon (R_2^H \varepsilon \varepsilon' R_2^H - R_2^F \varepsilon \varepsilon' R_2^F) = D_2 \varepsilon R_2^H \varepsilon \varepsilon' R_2' = 0$$

and that $D_3 z$ is a scalar and that $(C_2^H + C_2^F) \Sigma R_2' = 2C_2^H \Sigma R_2' + D_2 \Sigma R_2'$.

The first addendum of equation (26) gives²³

$$E_t \left[R_2 \varepsilon \varepsilon' R_2' D_1 z' \gamma + z' \hat{D}_5 \varepsilon \varepsilon' R_2' \right] + \\ \left(z' \hat{R}_5 \varepsilon \varepsilon' D_2' \right) + \rho(C_2^H) [D_3 z \Sigma R_2'] - \frac{1}{2} R_{2 \otimes 2}^{H-F} \vec{\varepsilon} \vec{\varepsilon} D_3 z$$

As for the second addendum one can show that it reduces to

$$\begin{aligned} R_2 \varepsilon \varepsilon' (z' \otimes I)' (C_{2 \otimes 3}^{H-F})' &= 2R_2 \varepsilon [(C_2^H \varepsilon z' C_3^{H'}) - (C_2^F \varepsilon z' C_3^{F'})] \\ &= 2C_2^H D_3 z \Sigma R_2' \end{aligned} \quad (38)$$

And for the third have

$$(R_{2 \otimes 2}^{H-F} \vec{\varepsilon} \vec{\varepsilon}) (D_3 z) + D_2 \varepsilon \varepsilon' (z' \otimes I)' (R_{2 \otimes 3}^{H-F})'$$

where

$$\begin{aligned} D_2 \varepsilon \varepsilon' (z' \otimes I)' (R_{2 \otimes 3}^{H-F})' &= 2 D_2 \varepsilon [R_2^H \varepsilon z' R_3^{H'} - R_2^F \varepsilon z' R_3^{F'}] \\ &= 2D_2 \varepsilon \varepsilon' R_2^{H'} z' R_3^{H'} - D_2 \varepsilon \varepsilon' R_2^H z' R_3^{F'} \\ &= 2D_2 \varepsilon \varepsilon' R_2^{H'} z' [R_3'] = 0 \end{aligned}$$

and

$$(R_{2 \otimes 2}^{H-F} \vec{\varepsilon} \vec{\varepsilon}) (D_3 z) = [R_2^H \varepsilon \varepsilon' R_2^{H'} - R_2^F \varepsilon \varepsilon' R_2^{F'}] (D_3 z)$$

Taking all terms together yields

$$\begin{aligned} &-E_t \left[R_2 \varepsilon \varepsilon' R_2' D_1 z' \gamma + z' \hat{D}_5 \varepsilon \varepsilon' R_2' \right] + \\ &- \left(z' \hat{R}_5 \varepsilon \varepsilon' D_2' \right) - \rho(C_2^H) [D_3 z \Sigma R_2'] + \frac{1}{2} R_{2 \otimes 2}^{H-F} \vec{\varepsilon} \vec{\varepsilon} D_3 z + \\ &\quad \rho[C_2^H D_3 z \Sigma R_2'] + \\ &\quad -\frac{1}{2} [(R_{2 \otimes 2}^{H-F}) \vec{\varepsilon} \vec{\varepsilon} (D_3 z)] \end{aligned}$$

Simplifying gives

$$E_t z' \left\{ \left[\gamma R_2 \Sigma R_2' D_1 + \hat{D}_5 \Sigma R_2' \right] + \left(\hat{R}_5 \Sigma D_2' \right) \right\} = 0$$

²³Notice that $D_2 \varepsilon \varepsilon' R_2' = 0$ implies that $D_2 \varepsilon \varepsilon' R_2^{H'} = D_2 \varepsilon \varepsilon' R_2^{F'}$ and that $C_2^H \varepsilon \varepsilon' R_2' = C_2^F \varepsilon \varepsilon' R_2'$.

This must be valid for all possible z i.e.

$$\left\{ \left[\gamma R_2 \Sigma R'_2 D_1 + \hat{D}_5 \Sigma R'_2 \right] + \left(\hat{R}_5 \Sigma D'_2 \right) \right\} = 0$$

or

$$\gamma = - \frac{\hat{D}_5 \Sigma R'_2 + \hat{R}_5 \Sigma D'_2}{R_2 \Sigma R'_2 D_1}$$

which is the formula derived in Devereux and Sutherland (2010).

A.2 Two-agents multiple-assets case

In order to extend the result of Devereux and Sutherland (2010) to the multiple-asset case we notice that α_t and $r_{x,t}$ are now $k - 1$ vectors.

Now we have $k - 1$ different Euler equations, one for asset

$$\begin{aligned} (C - C^*) &= D_0 + D_1 \xi + D_2 \varepsilon + D_3 z \\ &\quad + D_4 \text{vec}(\varepsilon \varepsilon') + z' \hat{D}_5 \varepsilon + D_6 \text{vec}(zz') \end{aligned} \quad (39)$$

and, for the i -th asset

$$\begin{aligned} r_{x,i} &= E[r_x] - R_4^i \vec{\Sigma} + R_1^i \xi + R_2^i \varepsilon \\ &\quad + R_4^i \text{vec}(\varepsilon \varepsilon') + z' \hat{R}_5^i \varepsilon + R_6^i \text{vec}(zz') \end{aligned} \quad (40)$$

The first order solution to the vector of excess returns can be written as

$$r_x = \underbrace{R_2}_{(k-1) \times e} \varepsilon \quad (41)$$

where $R'_2 = \begin{bmatrix} R_2^{1'} & \dots & R_2^{(k-1)'} \end{bmatrix}$. Then the cross-product of assets and their excess return can still be written as

$$\xi_{1 \times 1} = z' \gamma R_2 \varepsilon \quad (42)$$

where γ is a $l \times (k - 1)$ matrix of coefficients.

Then, by analogy with the results shown earlier we have

$$E_t z' \left\{ \left[\gamma R_2 \varepsilon \varepsilon' R_2^{i'} D_1 + \hat{D}_5 \varepsilon \varepsilon' R_2^{i'} \right] + \left(\hat{R}_5^i \varepsilon \varepsilon' D'_2 \right) \right\} = 0$$

Notice that have $k - 1$ of these equations. Notice also that R_5^i is $l \times (k - 1)$, R_2^i is $1 \times (k - 1)$ and D'_2 is $(k - 1) \times 1$. Therefore, $\left(\hat{R}_5^i \varepsilon \varepsilon' D'_2 \right)$ is a $l \times 1$ vector.

or using the fact that

$$\left(\hat{R}_5^i \varepsilon \varepsilon' D'_2 \right) = \text{vec} \left(I \hat{R}_5^i \varepsilon \varepsilon' D'_2 \right) = (D_2 \varepsilon \varepsilon' \otimes I_{l \times l}) \text{vec} \left(\hat{R}_5^i \right) \quad (43)$$

$$\underbrace{E_t z' \left\{ \left[\gamma R_2 \varepsilon \varepsilon' R_2^{i'} D_1 + \hat{D}_5 \varepsilon \varepsilon' R_2^{i'} \right] + (D_2 \varepsilon \varepsilon' \otimes I_{l \times l}) \text{vec} \left(\hat{R}_5^i \right) \right\}}_{l \times 1} = 0_{s \times 1}$$

This must be valid for all possible z i.e.

$$\underbrace{\left\{ \left[\gamma R_2 \Sigma R_2^{i'} D_1 + \hat{D}_5 \Sigma R_2^{i'} \right] + (D_2 \Sigma \otimes I_{l \times l}) \text{vec} \left(\hat{R}_5^i \right) \right\}}_{l \times 1} = 0_{s \times 1}$$

$$\vdots$$

$$\underbrace{\left\{ \left[\gamma R_2 \Sigma R_2^{k-1'} D_1 + \hat{D}_5 \Sigma R_2^{k-1'} \right] + (D_2 \Sigma \otimes I_{l \times l}) \text{vec} \left(\hat{R}_5^{k-1} \right) \right\}}_{l \times 1} = 0_{s \times 1}$$

stack column wise all the $k - 1$ conditions and get

$$\underbrace{\left\{ \left[\gamma R_2 \Sigma R_2' D_1 + \hat{D}_5 \Sigma R_2' \right] + (D_2 \Sigma \otimes I_{l \times l}) R_{5,l \cdot e \times (k-1)}' \right\}}_{l \times k-1} = 0_{s \times k} \quad (44)$$

or

$$\gamma = - \left[\hat{D}_5 \Sigma R_2' + (D_2 \Sigma \otimes I_{l \times l}) R_{5,l \cdot e \times (k-1)}' \right] (R_2 \Sigma R_2' D_1)^{-1}$$

A.3 The multiple-agents multiple-assets case

Notice that now we have $n - 1$ i.i.d. terms

$$\xi_{1 \times 1}^j = \alpha_j' r_x : j = 1 \dots n - 1$$

where α_j and r_x are $(k - 1) \times 1$.

Furthermore, now we have $k - 1$ different equations for the assets excess return and $n - 1$ for the consumption differentials.

Our solution strategy is to find the optimal portfolio condition agent-by-agent and then stack them together to solve the simultaneous portfolio problem. The counterpart of the optimal portfolio condition as found in the previous section (equation (44)) is the following for agent i

$$E_t \left[\underbrace{D_1^{i,1} \gamma_1 R_2 \varepsilon \varepsilon' R_2 + \dots + D_1^{i,n-1} \gamma_{n-1} R_2 \varepsilon \varepsilon' R_2 + \hat{D}_5^i \varepsilon \varepsilon' R_2' + (D_2^i \Sigma \otimes I_{l \times l}) R_5^i}_{l \times (k-1)} \right] = 0$$

where $D_1^{i,j}$ is a scalar, γ_j is a $l \times (k - 1)$ matrix ($j = 1 \dots (n - 1)$).

More compactly we can write

$$\mathcal{D}_1^i \begin{bmatrix} \gamma_1 \\ \vdots \\ \gamma_2 \end{bmatrix} = - \left[\mathcal{D}_5^i \Sigma R_2' + \mathcal{D}_2^i R_{5,l \cdot e \times (k-1)}' \right] (R_2 \Sigma R_2')^{-1}$$

where $\mathcal{D}_1^i \equiv [D_1^{i,1} I_{l \times l} \dots D_1^{i,n-1} I_{l \times l}]$, $\mathcal{D}_2^i \equiv (D_2^i \Sigma \otimes I_{l \times l})$ and $\mathcal{D}_5^i = \hat{D}_5^i$.

We can stack these equations (for agent $i = 1 \dots (n - 1)$) row by row to get

$$\mathcal{D}_1 \begin{bmatrix} \gamma_1 \\ \vdots \\ \gamma_2 \end{bmatrix} = - [\mathcal{D}_5 \Sigma R'_2 + \mathcal{D}_2 R'_{5,l \cdot e \times (k-1)}] (R_2 \Sigma R'_2)^{-1}$$

where $\mathcal{D}_1$ is $(n-1) \cdot l \times (n-1) \cdot l$. Then have

$$\begin{bmatrix} \gamma_1 \\ \vdots \\ \gamma_2 \end{bmatrix} = -\mathcal{D}_1^{-1} [\mathcal{D}_5 \Sigma R'_2 + \mathcal{D}_2 R'_{5,l \cdot e \times (k-1)}] (R_2 \Sigma R'_2)^{-1} \quad (45)$$

A.4 Cross product notation

Notice that the solution equation of each variable has a term of the form (e.g. for equation 1)

$$z' A_1 \varepsilon = \varepsilon' A'_1 z$$

This can be written as

$$(z' \otimes \varepsilon') \text{vec}(A'_1) = \text{vec}(A'_1)' (z \otimes \varepsilon)$$

Therefore, stacking each equation on top of the other would have

$$\underbrace{\begin{bmatrix} \text{vec}(A'_1)' \\ \vdots \\ \text{vec}(A'_n)' \end{bmatrix}}_A (z \otimes \varepsilon) = A \text{vec}(\varepsilon z').$$

A.5 Other Kronecker rules

$$\varepsilon \otimes r'_x = \varepsilon r'_x$$

$$\text{vec}(\varepsilon z') \varepsilon' = (z \otimes I_{m \times m}) \varepsilon \varepsilon'$$

and also

$$\varepsilon \text{vec}(\varepsilon z')' = \varepsilon \varepsilon' (z \otimes I_{m \times m})'$$

A.6 Shift of endogenous state variables

The solution we are interested in is a function of the cross products of the state vector $z'_t = [x_{t-1}, s_t]$, such that $E_t z_{t+1} = z_{t+1}$. Some solution algorithms would deliver a

solution in terms of the state vector $\hat{z}'_t = [x_t, s_t]$. For example, as shown in Lombardo and Sutherland (2007) have

$$s_t = F_1 x_{t-1} + F_2 s_{t-1} + F_3 V_{t-1} + F_4 \Sigma \quad (46)$$

$$c_t = P_1 x_t + P_2 s_t + P_3 V_t + P_4 \Sigma \quad (47)$$

$$V_t = \tilde{\Phi} V_{t-1} + \tilde{\Gamma} \tilde{\varepsilon}_t + \tilde{\Psi} \tilde{\xi}_t \quad (48)$$

$$x_t = N x_{t-1} + \varepsilon_t \quad (49)$$

$$s_t^f = F_1 x_{t-1} + F_2 s_{t-1}^f \quad (50)$$

where $V_t = (\hat{z}_t \otimes \hat{z}_t)$ and $\tilde{\xi}_t = (\hat{z}_{t-1} \otimes \varepsilon_t)$, or

$$\hat{z}_t \equiv \begin{bmatrix} x_t \\ s_t \end{bmatrix} = \begin{bmatrix} N & 0 \\ F_1 & F_2 \end{bmatrix} \begin{bmatrix} x_{t-1} \\ s_{t-1} \end{bmatrix} + \begin{bmatrix} 0 \\ F_3 \end{bmatrix} V_{t-1} + \begin{bmatrix} 0 \\ F_4 \end{bmatrix} \Sigma + \begin{bmatrix} I \\ 0 \end{bmatrix} \varepsilon_t \quad (51)$$

$$c_t = \begin{bmatrix} P_1 P_2 \end{bmatrix} \hat{z}_t + P_3 (\hat{z}_t \otimes \hat{z}_t) + P_4 \Sigma \quad (52)$$

$$(\hat{z}_t \otimes \hat{z}_t) = \tilde{\Phi} (\hat{z}_{t-1} \otimes \hat{z}_{t-1}) + \tilde{\Gamma} \tilde{\varepsilon}_t + \tilde{\Psi} (\hat{z}_{t-1} \otimes \varepsilon_t) \quad (53)$$

$$s_t^f = F_1 x_{t-1} + F_2 s_{t-1}^f \quad (54)$$

Say that we want to express c_t in terms of z_t . Then we should recognize that

$$\hat{z}_t = \underbrace{\begin{bmatrix} N & 0 \\ 0 & I \end{bmatrix}}_{U_1} z_t + \underbrace{\begin{bmatrix} I \\ 0 \end{bmatrix}}_{U_2} \varepsilon_t \quad (55)$$

Then replacing this in equation (52) we have

$$c_t = \begin{bmatrix} P_1 P_2 \end{bmatrix} U_1 z_t + \begin{bmatrix} P_1 P_2 \end{bmatrix} U_2 \varepsilon \quad (56)$$

$$+ P_3 ((U_1 z_t + U_2 \varepsilon) \otimes (U_1 z_t + U_2 \varepsilon)) + P_4 \Sigma \quad (57)$$

Then, noting that for given matrices A , B , C and D we have

$$(A + B) \otimes (C + D) = (A \otimes C) + (A \otimes D) + (B \otimes C) + (B \otimes D)$$

we can rewrite

$$\begin{aligned} c_t &= \begin{bmatrix} P_1 P_2 \end{bmatrix} U_1 z_t + \begin{bmatrix} P_1 P_2 \end{bmatrix} U_2 \varepsilon + P_4 \Sigma \\ &+ P_3 ((U_1 z_t \otimes U_1 z_t) + (U_1 z_t \otimes U_2 \varepsilon)) \\ &+ P_3 ((U_2 \varepsilon \otimes U_1 z_t) + (U_2 \varepsilon \otimes U_2 \varepsilon)) \end{aligned} \quad (58)$$

or

$$\begin{aligned} c_t &= \begin{bmatrix} P_1 P_2 \end{bmatrix} U_1 z_t + \begin{bmatrix} P_1 P_2 \end{bmatrix} U_2 \varepsilon + P_4 \Sigma \\ &+ P_3 (U_1 \otimes U_1) (z_t \otimes z_t) + P_3 [(U_1 \otimes U_2) + (U_2 \otimes U_1) P_v] (z_t \otimes \varepsilon) \\ &+ P_3 (U_2 \otimes U_2) (\varepsilon_t \otimes \varepsilon_t) \end{aligned} \quad (59)$$

where P_v is a vector permutation matrix such that $P_v (z_t \otimes \varepsilon_t) = (\varepsilon_t \otimes z_t) = \text{vec}(z_t \varepsilon_t')$.

With reference to the portfolio solutions given in the text, notice that $D_5 = P_3(i_C, :)[(U_1 \otimes U_2) + (U_2 \otimes U_1)P_v]$ where i_C indicates here the row corresponding to the consumption differential. Similarly $R_5 = P_3(i_r, :)[(U_1 \otimes U_2) + (U_2 \otimes U_1)P_v]$ where i_r indexes the row corresponding to the excess return.

If the state-space solution was given in terms of $P_3vech(\hat{z}_t\hat{z}_t')$, then can use the matrix L^h such that $L^hvech(\cdot) = vec(\cdot)$, to have $P_3vech(\hat{z}_t\hat{z}_t') = P_3L^hvec(\hat{z}_t\hat{z}_t')$.

Finally notice that the solution for the dynamics of the portfolio is given by

$$\alpha_t = \gamma' z_{t+1}$$

$$z_{t+1} = \begin{bmatrix} I & 0 \\ F1 & F2 \end{bmatrix} \hat{z}_t + \begin{bmatrix} 0 \\ F1 \end{bmatrix} \varepsilon_t \quad (60)$$

B Deriving the wealth accumulation equation

It is useful to show how to derive the above wealth accumulation equation of country 1 in terms of the net foreign asset position NFA_t from the more standard period by period budget constraint. The latter would be as follows:

$$\begin{aligned} Z_{1,t}^E s_{1,t}^1 + Z_{2,t}^E s_{2,t}^1 + B_{1t}^1 + B_{2t}^1 &= \left(Z_{1,t}^E + \frac{P_{1,t}}{P_t} D_{1,t} \right) s_{1,t-1}^1 + (Z_{2,t}^E + D_{2,t}) s_{2,t-1}^1 \\ &\quad + r_{1,t}^B B_{1t-1}^1 + r_{2,t}^B B_{2t-1}^1 + \frac{P_{1,t}}{P_t} Y_{1,t} - C_t, \end{aligned}$$

or, by using the above definition of equity return (1):

$$\begin{aligned} Z_{1,t}^E s_{1,t}^1 + Z_{2,t}^E s_{2,t}^1 + B_{1t}^1 + B_{2t}^1 &= r_{1,t}^E (Z_{1,t-1}^E s_{1,t-1}^1) + r_{2,t}^E (Z_{2,t-1}^E s_{2,t-1}^1) \\ &\quad + r_{1,t}^B B_{1t-1}^1 + r_{2,t}^B B_{2t-1}^1 + \frac{P_{1,t}}{P_t} Y_{1,t} - C_t. \end{aligned}$$

It is then easy to rewrite the last expression in terms of NFA_t by adding and subtracting $\frac{P_{1,t}}{P_t} D_{1,t}$ from its right-hand side, and subtracting from both sides $Z_{1,t}^E$, since:

$$r_{1,t}^E (Z_{1,t-1}^E s_{1,t-1}^1) - Z_{1,t}^E = Z_{1,t-1}^E \frac{\left(Z_{1,t}^E + \frac{P_{1,t}}{P_t} D_{1,t} \right)}{Z_{1,t-1}^E} (s_{1,t-1}^1 - 1) + \frac{P_{1,t}}{P_t} D_{1,t}.$$

Now adding and subtracting $r_{1,t}^B NFA_{t-1}$ we get:

$$\begin{aligned} NFA_t &= (r_{1,t}^E - r_{1,t}^B) \alpha_{1,t-1} + (r_{2,t}^E - r_{1,t}^B) \alpha_{2,t-1} + (r_{2,t}^B - r_{1,t}^B) B_{2,t-1} \\ &\quad + r_{1,t}^B NFA_{t-1} + \frac{P_{1,t}}{P_t} (Y_t + D_t) - C_t \end{aligned}$$

C Data Appendix

In the calibration exercise, we approximate the model specific definition of non-financial and financial income, as well as money by using quarterly data on dividends, net compensation of employees, monetary aggregates over the period 1994:Q1 to 2007:Q4. The beginning of the sample period is determined by the availability of data for China (dividends). For the US and euro area, the measure of non-financial income is approximated by net compensation of employees. The data for the United States is from Global Financial Data, while the one for the euro area is from the Area Wide Model (see Fagan et al., 2001). The best approximation of non-financial income

using Chinese data is earnings of employees from the National Bureau of Statistics available from the CEIC database. Due to the lack of the data of real dividend income from the national accounts for all countries (except United States), we approximate dividend income by multiplying dividend yields by stock market capitalization. The data is obtained from Datastream. We deflate all variables, except money by the corresponding GDP Deflator available from Global Financial Data for the US and China, and the AWM database for the euro area. For estimating the stochastic properties of the money shock, we use for China and the United States M2 data from the IFS, while for the euro area, we use M3 data from the AWM database²⁴. Data on emerging Asia is the US Dollar GDP weighted aggregate of the corresponding variables as defined above.

Using the data, we estimate an AR(1) process using a constant, and a linear trend for each of the variables and calculate the variance-covariance matrix of the corresponding residuals. The latter is used in the model solution for the determination of the corresponding gross asset positions.

D Calibration with Exogenous CPI

Table A: Estimated Shocks Covariance Matrix

	ε_{Y_1}	ε_{Y_2}	ε_{Y_3}	ε_{P_1}	ε_{P_2}	ε_{P_3}	ε_{D_1}	ε_{D_2}	ε_{D_3}
ε_{Y_1}	1	0.16	-0.11	-0.17	-0.22	0.10	0.26	0.17	-0.24
ε_{Y_2}	0.16	0.49	0.35	-0.38	-0.80	-0.31	0.07	-0.03	-0.11
ε_{Y_3}	-0.11	0.35	37.31	-0.06	-0.26	0.11	-0.01	-0.03	0.16
ε_{P_1}	0.02	0.02	0.06	0.37	0.63	0.23	0.30	0.02	0.04
ε_{P_2}	-0.07	0.14	0.09	0.63	0.26	0.32	0.12	0.03	0.08
ε_{P_3}	0.08	0.17	0.37	0.24	0.32	1.57	0.25	0.05	-0.13
ε_{D_1}	0.26	0.07	-0.01	-0.24	-0.10	0.14	6.13	-0.09	-0.09
ε_{D_2}	0.17	-0.03	-0.03	0.25	0.13	-0.09	-0.09	31.84	0.08
ε_{D_3}	-0.24	-0.11	0.16	0.21	0.04	0.05	-0.09	0.08	269.89

²⁴Note that for China, no M3 data is available, while for the US the collection of M3 data has been discontinued.

E Calibration with Emerging Asia Aggregates

Table B: Estimated Shocks Covariance Matrix

	ε_{Y_1}	ε_{Y_2}	ε_{Y_3}	ε_{M_1}	ε_{M_2}	ε_{M_3}	ε_{D_1}	ε_{D_2}	ε_{D_3}
ε_{Y_1}	1	0.05	0.03	-0.06	0.05	0.11	0.22	0.03	-0.02
ε_{Y_2}	0.05	0.35	0.41	-0.05	0.17	0.20	0.10	0.01	-0.43
ε_{Y_3}	0.03	0.41	4.14	0.04	-0.10	0.37	-0.08	0.12	-0.19
ε_{M_1}	-0.06	-0.05	0.04	4.64	-0.03	0.16	0.37	-0.11	0.08
ε_{M_2}	0.05	0.17	-0.10	-0.03	0.84	-0.06	0.21	0.12	0.28
ε_{M_3}	0.11	0.20	0.37	0.16	-0.06	1.16	-0.08	0.29	-0.27
ε_{D_1}	0.22	0.10	-0.08	0.37	0.21	-0.08	5.48	-0.16	-0.11
ε_{D_2}	0.03	0.06	0.12	-0.11	0.12	0.29	-0.16	30.85	0.34
ε_{D_3}	-0.02	-0.43	-0.19	0.08	0.28	-0.27	0.11	0.34	94.21

Figure 1: Turnover and home bias in equities as a function of home bias in consumption (dashed line = domestic turnover; solid line = foreign turnover; circled line = home bias)

