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International Portfolios, Current Account Dynamics and Capital Accumulation

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Abstract

Despite the liberalization of capital flows among OECD countries, equity home bias remains sizable, but is now less severe than in earlier decades; as a result, fluctuations in returns on foreign assets have a substantial effect on countries' wealth. As documented in this paper, changes in net foreign asset positions (NFA) are highly volatile, serially uncorrelated and countercyclical. We show that a two-country RBC model with productive investment and unrestricted international trade in stocks and bonds can explain these facts. Capital accumulation and shocks to the efficiency of investment are key ingredients for the success of the model. In contrast to related models that abstract from capital, equity home bias is not sensitive to preference parameters. In the model, NFA changes are largely driven by capital gains/losses due to movements in equity prices. The model thus matches the high volatility and low serial correlation of NFA changes. We compare settings with complete and incomplete financial markets. Imperfect hedging is required to generate a realistic conventional current account measure that solely reflects aggregate net flows of assets between countries.

JEL classification: F2, F3, G1.

Keywords: international equity and bond portfolios; capital flows; current account; capital accumulation; news shocks; valuation effects.

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1 Introduction

Cross-country capital flows have increased greatly, since the liberalization of international capital markets two decades ago (Lane and Milesi-Feretti (2003)). Equity home bias remains sizable, but is now less severe than in earlier decades (French and Poterba (1991)). As a result, fluctuations in the value of domestic and foreign asset induce external capital gains/losses that have a substantial effect on countries' financial wealth (Rey and Gourinchas (2005), Tille (2005), Lane and Milesi-Ferretti (2006)). As documented below, changes in countries' net foreign asset position (NFA) are highly volatile, serially uncorrelated and countercyclical (negatively correlated with domestic GDP).

This paper shows that these facts can be explained using a simple two-country RBC model with capital accumulation and unrestricted international trade in equity shares and bonds. Capital accumulation is a key ingredient for the success of the model. A world with two imperfectly substitutable goods is considered; each country produces a distinct good using physical capital, however each country uses both domestic and foreign output for consumption and physical capital accumulation. In accordance with the data, we assume home bias in consumption and physical investment spending (i.e. spending is biased towards locally produced inputs). Each country has a representative firm that accumulates productive capital; the firm makes wage payments to the local household, and pays out a dividend (profits net of the cost of physical investment) to shareholders. There are two stocks: the Home (Foreign) stock is a claim to the dividend generated by the Home (Foreign) firm. In addition there are two long-lived bonds (consols) denominated in units of Home and Foreign output respectively. There are shocks to productivity (TFP) and to the efficiency of investment (Greenwood, Hercowitz and Krusell (1997, 2000)); the latter are assumed, as recent empirical research suggests that investment efficiency shocks are an important source of GDP fluctuations (Justiniano and Primiceri (2006), Justiniano et al. (2007)). An increase in investment efficiency in a given country raises demand for the country's output (due to a surge in productive investment); this improves the country's terms of trade; the shock has no immediate effect on the country's output, but it raises *future* capital and output; hence, the shock can be viewed as a 'news' shock about future output levels (Cochrane (1994), Beaudry and Portier (2006)).

With two stocks and two bonds, and two types of (Home and Foreign) shocks, markets are effectively complete (up to a first order approximation). We also explore model variants with additional shocks (preference shocks); in those model variants, markets are incomplete.

There has been a recent surge of research on general equilibrium models of international portfolio holdings; see Devereux and Sutherland (2006) and Coeurdacier, Kollmann and Martin (2007) [CKM] for references to that literature. That literature has mainly studied models of endowment economies– i.e. models without production or capital accumulation. In endowment economies, households trade in international financial markets solely for consumption smoothing and risk sharing purposes. In reality, one of the key functions of international capital markets is to finance physical investment (Obstfeld and Rogoff (1996)): productive investment is a key driver of fluctuations in net exports and the current account (Summers (1981)). Empirically, net exports are countercyclical. Models of endowment economies are inconsistent with this fact (when a country receives a higher endowment, it runs a trade balance surplus, in order to smooth its consumption and/or share risk with the rest of the world). By contrast, a model with productive investment can generate persistent, countercyclical movements in net exports and current accounts, due to the procyclical response of physical investment to (persistent) productivity shocks (Obstfeld and Rogoff (1996)).

The model here predicts that a positive Home capital investment shock lowers Home dividend payments and net exports, and that it improves Home terms of trade (due to home bias in investment spending); the terms of trade response raises Home wage earnings (relative to Foreign wages). Hence, investment efficiency shocks induce negatively correlated movements in (relative) dividends and wage incomes. Thus holding local equity allows a household to hedge the fluctuations in her wage incomes. In equilibrium, a realistic degree of equity home bias emerges. The predicted equity home bias here is not sensitive to preference parameters–it only depends on the degree of home bias in consumption and investment, and on the labor share (fraction of GDP that accrues to workers).

This robust prediction of equity home bias sets the model here apart from most other general equilibrium models of portfolio choice: in those models, portfolio choices are highly sensitive to preference parameters. In terms of assuming productive investment, the closest paper to ours is Heathcote and Perri (2007) [HP]; in contrast to the paper here, HP assume only one source of shocks (TFP shocks), and they postulate that there is just trade in stocks (no bonds). We go further in modelling the dynamics of investment since the literature has shown that 'news' about the future is an important source of investment fluctuations. Moreover, the HP model only generates realistic equity portfolios for a very narrow range of preference parameters, namely when the coefficient of risk aversion and the substitution elasticity between domestic and foreign goods are close to unity. For risk aversion/substitution elasticities above unity, the HP model generates equity foreign bias, i.e. households *short* the local stock.[1] Also, these authors do not discuss the implications of capital accumulation for current account dynamics (see below).

We solve for time-varying (first-order accurate) equilibrium portfolio holdings using the method developed by Devereux and Sutherland (2006). In the model, fluctuations in a country's net foreign asset position (NFA) are largely driven by movements in equity and bond prices; NFA thus is predicted to have the time series properties of asset prices; the change (first difference) of a country's NFA is predicted to be highly volatile and to have low serial correlation. These predictions are consistent with new NFA measures evaluated at market prices that have recently been compiled by Lane and Milesi Ferretti (2006) and the IMF (International Investment Positions database).

In response to a positive TFP or investment productivity shock, a country is predicted to experience a reduction in its next exports, on impact; however, the present value of its current and future net exports falls; as the country's NFA equals the present value of its current and future net imports, the NFA drops, on impact. Thus, the change in NFA is predicted to be countercyclical, as is consistent with the data.

Models of endowment economies predict very limited trade in assets (Kollmann (2006)). The model here, with capital accumulation, generates sizable asset trades. In response to a positive domestic TFP and investment-efficiency shock, a country purchases local and foreign equity shares and it lowers its holding of local and foreign good bonds. In the baseline model with (effectively) complete asset markets, a 1% innovation to domestic TFP (relative to foreign TFP) induces a country to increase its share in the domestic and foreign firm by 1 percentage point. However, the complete markets model predicts that (up to a first order approximation), these asset transactions do not affect NFA: the value of stock purchases equals the value of bond sales. In other terms, NFA changes are *solely* due to asset price changes, under complete asset markets, and the conventional current account measure (value of net asset purchases) is zero. In order to generate a time-varying conventional current account, an incomplete markets structure

[1] Arespa Castello (2007) considers a set-up close to that of HP; in her model too, equity portfolios are highly sensitive to preference parameters.

is needed. We make markets incomplete by adding a source of shocks: random preference changes. The incomplete markets structure generates a conventional current account that undergoes persistent counter-cyclical fluctuations, and that is closely correlated with net exports, as is consistent with the data.

It can be mentioned that several recent empirical studies have shown that capital gains/losses greatly affect net foreign asset positions (NFA), and the change of NFA can differs significantly from the conventional measure of the current account. However, none of those previous papers has documented and analyzed quantitatively the cyclical behavior (volatility, serial correlation, correlation with output) of the change of NFA. For descriptions and analyses of the effect of asset price changes on net foreign asset positions, see, i.a. Kraay et al. (2005), Lane and Milesi-Ferretti (2001, 2005), Gourinchas and Rey (2005), Kim (2002), Tille (2003, 2004), Hau and Rey (2004), Devereux and Saito (2005), Ghironi, Lee and Rebucci (2005) and Backus et al. (2005). Cantor and Mark (1988) provided an early theoretical discussion of the role of equity price changes for current accounts, based on a one-good model with equities trade (their model predicts full portfolio diversification). Previous models of net exports and the (conventional) current account typically assume that international financial markets are restricted to bonds (e.g., Bergin (2004), Obstfeld and Rogoff (1996)).

The paper is structured as follows. In section 2, we discuss the stylized facts about international portfolios and net foreign asset positions that motivate this research. Section 3 present our theoretical model. In section 4, we solve for the equilibrium under complete markets. Section 5 considers the case of incomplete markets. In section 6, we calibrate the model, present simulation results and compare these results with key empirical statistics. Section 7 concludes.

2 Empirical evidence: equity home bias; the dynamics of Net Foreign Asset positions

2.1 Home bias

Foreign equity holdings have grown during the past 30 years, but equity home bias remains sizable. Table 1 documents this for a sample of 18 OECD economies. Based on the Kraay et al. (2005) dataset (that reports capital stocks and external assets for 1966-1997), Col. 1 reports ratios of countries' foreign equity liabilities, FEL (defined as foreign direct investment (FDI) liabilities plus portfolio equity liabilities) to the physical capital stocks in the respective countries, in 1997. That ratio ranged between 5% (Germany, Italy) and 14% (Switzerland, UK), with a median value of 7%. The corresponding median ratio was 2% in 1973.

Cols. 2-5 report ratios of countries' FEL and foreign equity assets, FEA, to GDP, in 1997 and 2003, using FEL and FEA data taken from the IMF's IIP (International Investment Positions) database. (FEA: sum of FDI and portfolio equity assets.) The median FEL/GDP ratio was 0.32 [0.56] in 1997 [2003]. With two exceptions (Switzerland, Netherlands), the FEL/GDP and FEA/GDP ratios are below unity. The physical capital stock/GDP ratio is in the range of 3, in OECD economies. This suggests that, in almost all countries, foreign equity liabilities represent markedly less than one third of the domestic physical capital stock.

2.2 NFA dynamics, international business cycles

Table 2 shows descriptive statistics for changes in NFA and GDP for 17 OECD countries based on data from the IMF International Investment Positions (IIP) data; for most countries, the IIP sample begins in the 1980s, and ends in 2003. The IIP database valuates external assets and liabilities at market prices. All data are annual.

Conceptually, a country's current account balance is the change of its net foreign asset holdings (NFA), during a period (Obstfeld and Rogoff (1996, p.5)). The current account series published by statistical agencies do not conform to this notion: those series only measure the net flow of assets acquired by a country, and do *not* take into account external capital gains/losses (on assets acquired in the past).

This paper studies a current account measure that includes external capital gains/losses: the first difference of the IIP NFA series. Let $NFA_{t+1}, NB_{t+1}, FEA_{t+1}$ and FEL_{t+1} be a country's NFA, net foreign bond holdings, foreign equity assets and foreign equity liabilities, respectively, at the end of year t, with $NFA_{t+1} \equiv FEA_{t+1} - FEL_{t+1} + NB_{t+1}$. Table 2 describes the behavior of the change (first-difference) of annual NFA series: $\Delta NFA_{t+1} \equiv ECA_t + BCA_t$, where $ECA_t \equiv \Delta FEA_{t+1} - \Delta FEL_{t+1}$; $BCA_t \equiv \Delta NB_{t+1}$,with $\Delta x_{t+1} \equiv x_{t+1} - x_t$ for any variable x_t. ECA_t (the change in net foreign equity holdings) and BCA_t (change in net bond holdings) are the equity and bond components of the change in NFA, respectively. Table 2 also consider the conventional current account measure (taken from the

IMF's International Financial Statistics, IFS) that does not include external capital gains/losses, denoted CA. Our measure of output (Y_t) is real GDP. For each country in the sample, we construct a measure of "foreign" output that equals total output in 20 other OECD economies (see Appendix).

Output series are logged. Unless stated otherwise, all statistics are based on HP-filtered series (smoothing parameter: 400). See the Appendix for more detailed data definitions.

For all countries in the sample, ΔNFA_{t+1} is more volatile than output. For most countries, the autocorrelation of ΔNFA_{t+1} (and of its components) does not significantly differ from zero; the median (and mean) autocorrelation of ΔNFA_{t+1} is -0.08. In 14 of the 17 countries, ΔNFA_{t+1} is negatively correlated with domestic GDP; the median (mean) correlation with GDP is -0.12 (-0.14). By contrast, correlations of ΔNFA_{t+1} with foreign GDP show no clear pattern.

For almost all countries, the (conventional) current account CA_t is markedly less volatile than ΔNFA_{t+1} and highly persistent (median standard deviations of ΔNFA_{t+1} and CA_t : 6.94%, 2.46%). CA_t too is typically negatively correlated with domestic GDP_t.[2]

3 The model

There are two symmetric countries, Home (H) and Foreign (F), each with a representative household. Each country i produces one good using labor and capital with perfectly competitive markets. There is trade in goods and in financial assets (stocks and bonds).

3.1 Preferences

Country i is inhabited by a representative household who lives in periods t=0,1,2,.... The household has the following life-time utility function:

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{C_{i,t}^{1-\sigma}}{1-\sigma} \tag{1}$$

where $C_{i,t}$ is i's aggregate consumption in period t. Like much of the macroeconomics and finance literature, we take the coefficient of relative risk aversion to be greater than unity: $\sigma > 1$. $C_{i,t}$, for

[2] See Kollmann (1996b) for a more detailed discussion of these facts. Faruquee and Lee (2007) confirm some of the key findings here, for a sample of 100 countries: in that larger sample too, ΔNFA is markedly more volatile and less persistent than CA.

$i = H, F$ is a composite good given by:

$$C_{H,t} = \left[a^{1/\phi}\left(c_{H,t}^{H}\right)^{(\phi-1)/\phi} + (1-a)^{1/\phi}\left(c_{F,t}^{H}\right)^{(\phi-1)/\phi}\right]^{\phi/(\phi-1)} \tag{2}$$

$$C_{F,t} = \left[a^{1/\phi}\left(c_{F,t}^{F}\right)^{(\phi-1)/\phi} + (1-a)^{1/\phi}\left(c_{H,t}^{F}\right)^{(\phi-1)/\phi}\right]^{\phi/(\phi-1)} \tag{3}$$

where $c_{j,t}^{i}$ is country $i\prime s$ consumption of the good produced by country j at date t. $\phi > 0$ is the elasticity of substitution between the two goods. In a symmetric steady state, a is the share of consumption spending devoted to the local good. We assume a preference bias for local goods, $\frac{1}{2} < a < 1$.

The welfare based consumer price indices that correspond to these preferences are:

$$P_{H,t} = \left[a\left(p_{H,t}\right)^{1-\phi} + (1-a)\left(p_{F,t}\right)^{1-\phi}\right]^{1/(1-\phi)} \tag{4}$$

$$P_{F,t} = \left[(1-a)\left(p_{H,t}\right)^{1-\phi} + a\left(p_{F,t}\right)^{1-\phi}\right]^{1/(1-\phi)}, \tag{5}$$

where $p_{H,t}$ and $p_{F,t}$ are the prices of goods H and F, respectively.

3.2 Technologies

In period t, country i produces $y_{i,t}$ units of good i according to the production function

$$y_{i,t} = \theta_{i,t}(l_{i,t})^{1-\varkappa}(k_{i,t})^{\varkappa}, \tag{6}$$

with $0 < \kappa < 1$. $l_{i,t}$ is labor supply in country i; we assume that labor suply is inelastic: $l_{i,t} = 1$. $k_{i,t}$ is the country's stock of capital Total factor productivity $\theta_{i,t} > 0$ is an exogenous random variable.

Capital is derived from physical investment in previous periods:

$$k_{i,t+1} = (1-\delta)k_{i,t} + \chi_{i,t}I_{i,t} \tag{7}$$

where $0 < \delta < 1$ is the depreciation rate of capital. $I_{i,t}$ is gross investment in country i at fate t. $\chi_{i,t} > 0$ is an exogenous shock to the productivity of investment (in the spirit of Greenwood, Hercowitz and Krusell (1997), Justiniano et al. (2007)); $\chi_{i,t}$ does not modify output at t, but affects future production; hence, $\chi_{i,t}$ is a 'news shock' about future output (see Beaudry and Portier (2006) and Rebelo and Jaimovich (2007) for analyses of 'new shocks'). We assume that $\chi_{i,t}$ is not perfectly correlated with the productivity shocks $\theta_{i,t}$. Both shocks have stochastic properties that are symmetric across countries.

In both countries, investment goods are generated using a CES aggregator of Home and Foreign inputs:

$$I_{H,t} = \left[a_I^{1/\phi_I}\left(i_{H,t}^H\right)^{(\phi_I-1)/\phi_I} + (1-a_I)^{1/\phi_I}\left(i_{F,t}^H\right)^{(\phi_I-1)/\phi_I}\right]^{\phi_I/(\phi_I-1)} \tag{8}$$

$$I_{F,t} = \left[a_I^{1/\phi_I}\left(i_{F,t}^F\right)^{(\phi_I-1)/\phi_I} + (1-a_I)^{1/\phi_I}\left(i_{H,t}^F\right)^{(\phi_I-1)/\phi_I}\right]^{\phi_I/(\phi_I-1)} \tag{9}$$

where $i_{j,t}^i$ is the quantity of the good produced by country j used for investment in country i. The associated (ideal) price indices of investment goods are given by

$$P_{H,t}^I = \left[a_I\left(p_{H,t}\right)^{1-\phi_I} + (1-a_I)\left(p_{F,t}\right)^{1-\phi_I}\right]^{1/(1-\phi_I)}, \tag{10}$$

$$P_{F,t}^I = \left[(1-a_I)\left(p_{H,t}\right)^{1-\phi_I} + a_I\left(p_{F,t}\right)^{1-\phi_I}\right]^{1/(1-\phi_I)}. \tag{11}$$

We assume a local bias for investment spending, $\frac{1}{2} < a_I < 1$. Home bias and the substitution elasticity between domestic and imported inputs may be different for investment and consumption: $a_I \neq a, \phi_I \neq \phi$.

3.3 Firms' decisions

Firms maximize profits, taking goods and factor prices as given. Due to the Cobb-Douglas technology, a share $(1-\varkappa)$ of total output is hence paid to workers. Thus, wage income in country i is given by:

$$w_{i,t} = (1-\varkappa)p_{i,t}y_{i,t}, \tag{12}$$

where $p_{i,t}$ is the price of the country i good. A share $\varkappa$ of country i output, net of physical investment spending, is paid as a dividend $d_{i,t}$ to shareholders:

$$d_{i,t} = \varkappa p_{i,t}y_{i,t} - P_{i,t}^I I_{i,t} \tag{13}$$

Investment decisions have two dimensions: firms choose aggregate investment spending $P_{i,t}^I I_{i,t}$, and they decide how to allocate that spending over Home and Foreign inputs. For country H, the allocation over the two inputs must satisfy the following first-order conditions:

$$\frac{i_{H,t}^H}{I_{H,t}} = a_I\left(\frac{p_{H,t}}{P_{H,t}^I}\right)^{-\phi_I} \tag{14}$$

$$\frac{i_{F,t}^H}{I_{H,t}} = (1-a_I)\left(\frac{p_{F,t}}{P_{H,t}^I}\right)^{-\phi_I} \tag{15}$$

Investment spending at date t must equalize the expected future marginal gain of investment to the marginal cost at date t. So at time time t, the first-order condition for investment in country i is:

$$1 = E_t \varrho^i_{t,t+1} \frac{\chi_{i,t}}{P^I_{i,t}} [p_{i,t+1}\theta_{i,t+1}\varkappa K^{\varkappa-1}_{i,t+1} + (1-\delta)\frac{P^I_{i,t+1}}{\chi_{i,t+1}}], \tag{16}$$

where $\varrho^i_{t,t+1}$ is a pricing kernel used by the firm at date t to value date $t+1$ payoffs (that are expressed in units of the country i final consumption good). An increases in date t investment efficiency $\chi_{i,t}$, in the (expected) future price of good i, and in future TFP $\theta_{i,t+1}$ induce higher investment $I_{i,t}$, while a higher price of investment goods $P^I_{i,t}$ discourages investment.

3.4 Financial markets, household decisions, market clearing

There is trade in stocks and bonds. Country i firm issues a stock that represents a share in future dividends $d_{i,t}$ (see below). The supply of each stock is normalized at unity. There is a bond denominated in the Home good, and a bond denominated in the Foreign good. Buying one unit of the Home (Foreign) bond in period t gives one unit of the Home (Foreign) good in all future periods. Both bonds are in zero net supply. Each household fully owns the local stock, at birth, and has zero initial foreign assets.[3] Let $S^i_{j,t}$ denote the number of shares of stock j held by country i at the end of period t, while $b^i_{j,t}$ represents claims held by i (at the end of t) to future unconditional payments of good j. At date t, the country i household faces the following budget constraint:

$$P_{i,t}C_{i,t}+S^i_{i,t}p^S_{i,t}+S^i_{j,t}p^S_{j,t}+p^b_{j,t}b^i_{j,t}+p^b_{i,t}b^i_{i,t} = w_{i,t}+S^i_{i,t-1}(d_{i,t}+p^S_{i,t})+S^i_{j,t-1}(d_{j,t}+p^S_{i,t})+(p_{i,t}+p^b_{i,t})b^i_{i,t-1}+(p_{j,t}+p^b_{j,t})b^i_{j,t-1} \tag{17}$$

where $p^S_{i,t}$ is the price of stock i and $p^b_{i,t}$ is the price of bond i.

The country i household selects selects portfolios and consumptions that maximize her life-time utility subject to the budget constraint (17).for $t \geq 0$. The following equations are first-order conditions of that decision problem for the country H household:

$$c^H_{H,t} = a\left(\frac{p_{H,t}}{P_{H,t}}\right)^{-\phi} C_{H,t}, \quad c^H_{F,t} = (1-a)\left(\frac{p_{F,t}}{P_{H,t}}\right)^{-\phi} C_{H,t} \tag{18}$$

$$1 = E_t\beta(\frac{C_{H,t+1}}{C_{H,t}})^{-\sigma}\frac{P_{H,t+1}}{P_{H,t}}\frac{p^b_{H,t+1}+p_{H,t+1}}{p^b_{H,t}}, \; 1 = E_t\beta(\frac{C_{H,t+1}}{C_{H,t}})^{-\sigma}\frac{P_{H,t+1}}{P_{H,t}}\frac{p^b_{F,t+1}+p_{F,t+1}}{p^b_{F,t}} \tag{19}$$

[3] This insures that both countries have equal wealth at birth and preserves the (ex ante) symmetry of the model.

$$1 = E_t\beta(\frac{C_{H,t+1}}{C_{H,t}})^{-\sigma}\frac{P_{H,t+1}}{P_{H,t}}\frac{p^S_{i,t+1}+d_{i,t+1}}{p^S_{i,t}},\ 1 = E_t\beta(\frac{C_{H,t+1}}{C_{H,t}})^{-\sigma}\frac{P_{H,t+1}}{P_{H,t}}\frac{p^b_{j,t+1}+p_{F,t+1}}{p^b_{j,t}} \tag{20}$$

Symmetric expressions hold for country F.

Market-clearing in goods and asset markets requires:

$$\begin{aligned} c^H_{H,t}+c^F_{H,t}+i^H_{H,t}+i^F_{H,t} &= y_{H,t}\ ,\quad c^F_{F,t}+c^H_{F,t}+i^F_{F,t}+i^H_{F,t}=y_{F,t}\ , && (21)\\ S^H_{H,t}+S^F_{H,t} &= S^F_{F,t}+S^H_{F,t}=1, && (22)\\ b^H_{H,t}+b^F_{H,t} &= b^F_{F,t}+b^H_{F,t}=0. && (23)\end{aligned}$$

3.5 Solving for equilibrium portfolios

In (recursive) equilibrium, the portfolio holdings chosen in period t $(S^i_{i,t}, S^i_{j,t}, b^i_{i,t}, b^i_{j,t})$ are functions of predetermined state variables, and of exogenous shocks at t. Devereux and Sutherland (2006) [DS] show how to compute $n-th$ order accurate approximations of those portfolio "policy functions" (equilibrium decision rules), in the neighborhood of a deterministic steady state of the economy; it appears that that approximation can be computed from a $(n+1)-st$ order approximation of household Euler equations, and an $n-th$ order approximation of the remaining equilibrium conditions, around the deterministic steady state. In this Section, we provide closed form solutions for portfolio decision rules, evaluated at steady state values of state variables; we refere to these portfolios as "steady state portfolios". DS show that those portfolios can be computed from a quadratic approximation of Euler equations and a linear approximation of all remaining equations.

Following DS, we express the budget constraint of country i as

$$NFA_{i,t} \;=\; NX_{i,t}+NFA_{i,t-1}R^{b,i}_t+\xi_{i,t}, \tag{24}$$

where $NFA_{i,t} \equiv (S^i_{i,t}-1)p^S_{i,t}+S^i_{j,t}p^S_{j,t}+p^b_{i,t}b^i_{i,t}+p^b_{j,t}b^i_{j,t}$, with $j\neq i$ and $NX_{i,t}\equiv p_{i,t}Y_{i,t}-P_{i,t}C_{i,t}-P_{i,t}I_{i,t}$.

$NFA_{i,t}$ is country $i\prime d$ net foreign asset position at the end of period t, while $NX_{i,t}$ are the country's net exports in period t.

$$\begin{aligned}\xi_{i,t} &\equiv (S^i_{i,t-1}-1)p^S_{i,t-1}(R^{S,i}_t-R^{b,i}_t)+S^i_{j,t-1}p^S_{j,t-1}(R^{S,j}_t-R^{b,i}_t)+b^i_{j,t-1}p^b_{j,t-1}(R^{b,j}_t-R^{b,i}_t)\\ \text{with}\quad R^{b,i}_t &\equiv (p_{i,t}+p^b_{i,t})/p^b_{i,t-1}\quad\text{and } R^{S,i}_t\equiv(p^S_{i,t}+d_{i,t})/p^S_{i,t-1}.\end{aligned}$$

$R_t^{b,i}$ is the (gross) rate of return on bond i, between periods $t-1$and t, while $R_t^{S,i}$ is the gross rate of return on stock i. $\xi_{i,t}$ is the "excess return" on the country's net foreign asset position (between $t-1$and t) relative to the return on bond i . [4]

Let variables without time indices represent values in the (deterministic) steady state, and let $\widehat{x_{i,t}} \equiv (x_{i,t}-x_i)/x_i$. Note that $NFA_i = 0$, $NX_i = 0$, $p_H^S = p_F^S$, $p_H^b = p_F^b$ due to the symmetric structure of the two countries; furthermore, $R^{S,H} = R^{S,F} = R^{b,H} = R^{b,F} = 1/\beta$. A linear approximation of (24) around steady state yields thus:

$$NFA_{i,t} = NX_{i,t}+NFA_{i,t-1}/\beta+(S_i^i-1)p^S\frac{1}{\beta}(\widehat{R_t^{S,i}}-\widehat{R_t^{b,i}})+S_j^i p^S\frac{1}{\beta}(\widehat{R_t^{S,j}}-\widehat{R_t^{b,i}})+b_j^i p_j^b\frac{1}{\beta}(\widehat{R_t^{b,j}}-\widehat{R_t^{b,i}}), \quad (25)$$

where $S_i^{i\prime}, S_j^i$ and b_j^i are steady state equity and bond holdings. The symmetric structure implies that $S \equiv S_i^{i\prime}$ for $i = H, F$; $S_j^i = 1-S$; $b_j^i = -b$, where S, b denote the locally owned fraction of a country's equity and a country's own-good bond position. Thus, the linearized budget constraint can be expressed as:

$$NFA_{i,t} = NX_{i,t}+NFA_{i,t-1}/\beta+\widetilde{\xi_{i,t}}, \quad \text{with } \widetilde{\xi_{i,t}} \equiv \ (S-1)p^S\frac{1}{\beta}(\widehat{R_t^{S,i}}-\widehat{R_t^{S,j}})+bp_j^b\frac{1}{\beta}(\widehat{R_t^{b,j}}-\widehat{R_t^{b,i}}). \quad (26)$$

Up to a first-order approximation, $E_t(\widehat{R_{t+\tau}^{S,i}}-\widehat{R_{t+\tau}^{S,j}}) = 0$, $E_\tau(\widehat{R_{t+\tau}^{b,j}}-\widehat{R_{t+\tau}^{b,i}}) = 0$ holds for all $\tau > 0$, as can readily be seen by linearizing the Euler equations (19), (20). Solving (26) forward gives thus:

$$E_t\sum_{\tau\geq 0}\beta^\tau(-NX_{i,t+\tau}) = NFA_{i,t-1}/\beta+(S-1)p^S\frac{1}{\beta}(\widehat{R_t^{S,i}}-\widehat{R_t^{S,j}})+bp_j^b\frac{1}{\beta}(\widehat{R_t^{b,j}}-\widehat{R_t^{b,i}}). \qquad (27)$$

Solving the Euler equations for stocks forward, gives $p_{i,t}^S = E_t\sum_{\tau\geq 1}\beta^\tau(\frac{C_{H,t+\tau}}{C_{H,t}})^{-\sigma}\frac{P_{H,t+\tau}}{P_{H,t}}d_{i,t+\tau}$.Linearizing the formulae for stocks returns, yields $\widehat{R_t^{S,i}}-\widehat{R_t^{S,j}} = (1-\beta)\widetilde{E_t}\sum_{\tau\geq 0}\beta^\tau(\widehat{d_{i,t+\tau}}-\widehat{d_{j,t+\tau}})$, .where $\widetilde{E_t}x \equiv E_t x - E_{t-1}x$ (revision of expectation between periods t and $t-1$). Similarly, $\widehat{R_t^{b,j}}-\widehat{R_t^{b,i}} = (1-\beta)\widetilde{E_t}\sum_{\tau\geq 0}\beta^\tau(\widehat{p_{i,t+\tau}}-\widehat{p_{j,t+\tau}})$..(27) implies $\widetilde{E_t}\sum_{\tau\geq 0}\beta^\tau(-NX_{i,t+\tau}) = (S-1)p^S\frac{1}{\beta}(\widehat{R_t^{S,i}}-\widehat{R_t^{S,j}})+bp_j^b\frac{1}{\beta}(\widehat{R_t^{b,j}}-\widehat{R_t^{b,i}})$. Hence,

[4] Note that $\xi_{i,t} = S_{i,t-1}^i(d_{i,t}+p_{i,t}^S)+S_{j,t-1}^i(d_{j,t}+p_{i,t}^S)+(p_{i,t}+p_{i,t}^b)b_{i,t-1}^i+(p_{j,t}+p_{j,t}^b)b_{j,t-1}^i-NFA_{i,t-1}R_t^{b,i}$. Thus, $\xi_{i,t}$ is the difference between country $i's$ beginning of period t actual net external wealth (cum dividend and coupon payments), minus the hypothetical value of $i's$ net external wealth at the beginning of t that would have obtained if i had fully invested her external wealth at the end of $t-1$ in the good i bonds.

$$\widetilde{E_t}\sum_{\tau\geq 0}\beta^\tau(-NX_{i,t+\tau}) = (S-1)d\widetilde{E_t}\sum_{\tau\geq 0}\beta^\tau(\widehat{d_{i,t+\tau}}-\widehat{d_{j,t+\tau}}) + bp\widetilde{E_t}\sum_{\tau\geq 0}\beta^\tau(\widehat{p_{i,t+\tau}}-\widehat{p_{j,t+\tau}}).\ ^5 \tag{28}$$

Complet markets

As shown below, there exists a portfolio (S, b) such that

$$-NX_{i,t} = (S-1)d\widehat{d_{i,t}} + bp(\widehat{p_{i,t}}-\widehat{p_{j,t}}) \tag{29}$$

holds (up to a first-order approximations), for quantities and prices that obtain in a Pareto efficient equilibrium (full risk sharing). It is clear that this portfolio satisfies (27) and .(28)

Up to a first-order approximation, the period t budget constraint under complete markets thus reduces to a static condition, in equilibrium (which makes it much easier to gain intuition about portfolios). (28) is equivanet to

$$P_{i,t}C_{i,t} = w_{i,t} + Sd_{i,t} + (1-S)d_{j,t} + p_{H,t}b - p_{F,t}b, \tag{30}$$

where we denote a country's holdings of local stock by S, and its holdings of bonds denominated in its local good by b_t. $S > \frac{1}{2}$ means that there is equity home bias, and $b < 0$ means that the country issues bonds denominated in its local good.

If markets are complete, then the ratio of Home and Foreign marginal utilities of aggregate consumption is linked to the consumption-based real exchange rate by the following, familiar condition:

$$\left(\frac{C_{H,t}}{C_{F,t}}\right)^{-\sigma} = \frac{P_{H,t}}{P_{F,t}} \tag{31}$$

Expressing the previous budget constraint in relative terms and log-linearizing, we get:

As shown below, the equilibrium Resource constraints in both countries are given by:

$$c^H_{H,t} + c^F_{H,t} + i^H_{H,t} + i^F_{H,t} = y_{H,t} \tag{32}$$

$$c^F_{F,t} + c^H_{F,t} + i^F_{F,t} + i^H_{F,t} = y_{F,t}. \tag{33}$$

These conditions imply:

$$c^H_{H,t} + c^F_{H,t} = p^{-\phi}_{H,t}\left[aC_{H,t}P^\phi_{H,t} + (1-a)\,C_{F,t}P^\phi_{F,t}\right] = y_{H,t} - (i^H_{H,t} + i^F_{H,t}) \tag{34}$$

$$c^F_{F,t} + c^H_{F,t} = p^{-\phi}_{F,t}\left[aC_{F,t}P^\phi_{F,t} + (1-a)\,C_{H,t}P^\phi_{H,t}\right] = y_{F,t} - (i^F_{F,t} + i^H_{F,t}) \tag{35}$$

[5] Note that $p^S = d\beta/(1-\beta)$, $p^b = p\beta/(1-\beta)$.

Using (31) and taking the ratio of these expressions gives as in Coeurdacier, Kollmann, Martin (2007), where $\Omega(x) = \frac{1+x(\frac{1-a}{a})}{x+(\frac{1-a}{a})}$:

$$q_t^{-\phi}\Omega\left[\left(\frac{P_{F,t}}{P_{H,t}}\right)^{\phi-1/\sigma}\right] = \frac{y_{H,t}-(i^H_{H,t}+i^F_{H,t})}{y_{F,t}-(i^F_{F,t}+i^H_{F,t})} = y_{C,t} \tag{36}$$

where $y_{C,t} = \frac{y_{H,t}-(i^H_{H,t}+i^F_{H,t})}{y_{F,t}-(i^F_{F,t}+i^H_{F,t})}$ is the ratio of demand of home goods over foreign goods by consumers.

3.6 Log-linearization of the model

Henceforth, we log-linearize the model around the symmetric steady state and write variables in relative terms. A variable x_t denotes Home over Foreign value, such that $x_t \equiv \frac{x_{H,t}}{x_{F,t}}$. We use $\widehat{x_t} \equiv log(x_t/\bar{x})$ to denote the log deviation of a variable x from its steady state value $\overline{x}$.

In particular, we write $y_t \equiv \frac{y_{H,t}}{y_{F,t}}, \Psi_t \equiv \frac{\Psi_{H,t}}{\Psi_{F,t}}$ and $I_t \equiv \frac{I_{H,t}}{I_{F,t}}$ to denote relative outputs, preference shocks and relative (real) investment. Denote Home terms of trade by $q_t \equiv \frac{p_{H,t}}{p_{F,t}}$.

The log-linearization of the Home country's welfare-based real exchange $RER_t \equiv \frac{P_{H,t}}{P_{F,t}}$ gives:

$$\widehat{RER_t} = \widehat{\frac{P_{H,t}}{P_{F,t}}} = (2a-1)\,\widehat{q_t} \tag{37}$$

As usual, the presence of Home bias in consumption triggers some fluctuations in the real exchange rate: an increase in the Home terms-of-trade appreciates the Home real exchange rate since Home consumers devote more resources towards Home goods.

As for the consumption index, up to the first-order, the relative price of investment goods at home and abroad is:

$$\widehat{\frac{P^I_{H,t}}{P^I_{F,t}}} = (2a_I-1)\,\widehat{q_t} \tag{38}$$

Up-to the first order, relative investment spending $\widehat{\frac{P^I_{H,t}I_{H,t}}{P^I_F I_{F,t}}}$ is then equal to $(2a_I-1)\,\widehat{q_t} + \widehat{I_t}$, where $I_t = \frac{I_{H,t}}{I_{F,t}}$ denotes relative (real) investment in both countries.

3.7 Efficient allocation and terms-of trade

Log linearizing (36) yields (see Coeurdacier (2005) and Coeurdacier, Kollmann, Martin (2007)):

$$\widehat{y_{C,t}} = -\left[\phi\left(1-(2a-1)^2\right) + (2a-1)^2\frac{1}{\sigma}\right]\widehat{q_t} \equiv -\lambda\widehat{q_t} \tag{39}$$

where $\lambda \equiv \phi(1-(2a-1)^2) + \frac{(2a-1)^2}{\sigma}$. Note that $\lambda > 0$ as $1/2 < a < 1$. An increase in the Home terms-of-trade raises consumption of the Foreign goods and the higher is ϕ, the stronger is the response of consumption to a relative price change.

The ratio of demands for Home and Foreign goods that are used for physical investment $y_{I,t} = \frac{i^H_{H,t}+i^F_{H,t}}{i^F_{F,t}+i^H_{F,t}}$ satisfies the following condition (from (14) and (15)):

$$q^{-\phi_I}\Omega\left(\frac{P^I_{H,t}{}^{\phi_I} I_{H,t}}{P^I_{F,tI}{}^{\phi_I} I_{F,t}}\right) = y_{I,t} \tag{40}$$

Log-linearization of this equation gives:

$$\widehat{y_{I,t}} = -\phi_I\left(1-(2a_I-1)^2\right)\widehat{q_t} + (2a_I-1)\widehat{I_t} \tag{41}$$

The demand for Home goods for investment purposes decreases with the Home terms-of-trade and like for consumption, the response is stronger when Home and Foreign investment inputs are closer substitutes (higher ϕ). The demand for Home investment goods also increases with aggregate real investment in the Home country since Home aggregate investment is biased towards Home goods ($a > \frac{1}{2}$).

Using the market clearing conditions (32) and (33) for $i = \{H, F\}$ and defining I as the steady-state ratio of investment over GDP, we get:

$$(1-I)\widehat{y_{C,t}} + I\widehat{y_{I,t}} = \widehat{y_t} \tag{42}$$

The goods market clearing condition can be rewritten as:

$$\widehat{y_t} = -[(1-I)\lambda + I\phi_I\left(1-(2a_I-1)^2\right)]\widehat{q_t} + I(2a_I-1)\widehat{I_t} \tag{43}$$

$$\widehat{y} = -\lambda^*\widehat{q_t} + I(2a_I-1)\widehat{I_t} \tag{44}$$

where $\lambda^* = (1-I)\lambda + I\phi_I\left(1-(2a_I-1)^2\right)$ [6].

Not surprisingly, Home terms-of-trade worsen when the relative supply of Home goods increases; by contrast, Home terms-of-trade improve when Home investment rises (due to home bias in investment spending). In a sense, an unanticipated increase in Home investment efficiency ($\chi_{H,t}$) acts as a demand shocks that raises the relative price of Home goods (the shock raises Home investment keeping the supply of local goods constant).

[6] When $\phi_I = \phi$ and $a_I = a$ then $\lambda^* = \phi(1-(2a-1)^2) + \frac{1-\bar{I}}{\sigma}(2a-1)^2$

3.8 Solving for equilibrium portfolios

We solve for equilibrium portfolios using the method developed by Devereux and Sutherland (1996) [DS]. Following DS, we express the budget constraint of country i as $NFA_{i,t} + P_{i,t}C_{i,t} + P_{i,t}I_{i,t} - p_{i,t}Y_{i,t} = NFA_{i,t-1}R_t^{b,i} + \xi_{i,t}$, where $NFA_{i,t} \equiv (S_{i,t}^i - 1)p_{i,t}^S + S_{j,t}^i p_{j,t}^S + p_{i,t}^b b_{i,t}^i + p_{j,t}^b b_{j,t}^i$ is the country i net foreign asset position at the end of period t. $R_t^{b,i} \equiv (p_{i,t} + p_{i,t}^b)/p_{i,t-1}^b$ is the (gross) rate of return on bond i, between periods t-1 and t. $\xi_{i,t}$ is the excess return on the country's external portfolio (relative to the return on bond i):

$$\xi_{i,t} \equiv (S_{i,t-1}^i - 1)p_{i,t-1}^S(R_t^{S,i} - R_t^{b,i}) + S_{j,t-1}^i p_{j,t-1}^S(R_t^{S,j} - R_t^{b,i}) + b_{j,t-1}^i p_{j,t-1}^b(R_t^{b,j} - R_t^{b,i})$$

DS show that an n–th order accurate approximation of the equilibrium portfolio $S_{i,t-1}^i, S_{j,t-1}^i, b_{i,t-1}^i, b_{j,t-1}^i$can be computed by solving an $(n+1)$-st order Taylor expansion of Euler equations and an n-th order approximation of the remaining equilibrium conditions, around a deterministic steady state of the model. [............]

When financial markets are *complete*, then a 1st order accurate approximation of the decision rule for portfolio holdings has the property that $dS_{i,t-1}^i p_i^S + dS_{j,t-1}^i p_{j,}^S + db_{i,t-1}^i p_i^b + db_{j,t-1}^i p_j^b = 0$, where variables without time subscripts denote steady state values. [Proof to be added]. This implies that, up to a first order approximation, the country i net foreign asset positions can be expressed as a function of zero-order approximation of the decision rules for portfolio holdings, $S_i^i, S_j^i, b_i^i, b_j^i$: $NFA_{i,t} = (S_i^i - 1)p_{i,t}^S + S_j^i p_{j,t}^S + p_{i,t}^b b_i^i + p_{j,t}^b b_j^i$. Up to first order, the portfolio excess return also solely depends on zero-order portfolio holdings: $\xi_{i,t} \equiv (S_i^i - 1)p_i^S(R_t^{S,i} - R_t^{b,i}) + S_j^i p_j^S(R_t^{S,j} - R_t^{b,i}) + b_j^i p_j^b(R_t^{b,j} - R_t^{b,i})$. Under complete markets, a first-order accurate approximation of the period t budget constraint thus only involves zero-order portfolio holdings, $S_i^i, S_j^i, b_i^i, b_j^i$ Up to a first-order approximation, the period t budget constraint thus reduces to a static condition, in equilibrium (which makes it much easier to gain intuition about portfolios):

$$P_{i,t}C_{i,t} = w_{i,t} + Sd_{i,t} + (1-S)d_{j,t} + p_{H,t}b - p_{F,t}b, \tag{45}$$

where we denote a country's holdings of local stock by S, and its holdings of bonds denominated in its local good by b_t. $S > \frac{1}{2}$ means that there is equity home bias, and $b < 0$ means that the country issues bonds denominated in its local good.

Expressing the previous budget constraint in relative terms and log-linearizing, we get:

$$(1-I)(\widehat{P_{H,t}C_{H,t}}-\widehat{P_{F,t}C_{F,t}})=(1-I)(1-\frac{1}{\sigma})\underbrace{(2a-1)\,\widehat{q_t}}_{\widehat{RER_t}}=(1-\varkappa)\widehat{w_t}+(\varkappa-I)\,(2S-1)\,\widehat{d_t}+2b\widehat{q_t} \quad (46)$$

The first equality shows the Pareto optimal reaction of relative consumption spending to a change of the welfare based real exchange rate. This reaction depends on the coefficient of relative risk aversion. In a Pareto efficient equilibrium, a shock that appreciates the real exchange rate of country H, induces an increase in country H relative consumption spending when $\sigma > 1$ (as assumed in the analysis here). The risk-sharing condition (31) shows that when the real exchange rate appreciates by 1%, then relative aggregate country H consumption $\left(\frac{C_H}{C_F}\right)$ decreases by $1/\sigma$ %. Hence, efficient relative consumption spending by H $(\frac{P_H C_H}{P_F C_F})$ increases by $(1-\frac{1}{\sigma})$%. The expression to the right shows the change in country H relative income (compared to the income of F) necessary to obtain the Pareto optimal allocation. Given $\sigma > 1$, the efficient portfolio has to be such that a real appreciation is associated with an increase in relative spending and income.

Since labor incomes are a constant share of total sales, relative labor incomes verifies: $\widehat{w_t}=\widehat{q_t}+\widehat{y_t}$. Dividends are a constant share of total sales net of investment spending. Relative dividends $(\widehat{d_t})$ verify:

$$(\varkappa-I)\widehat{d_t}=\varkappa(\widehat{q_t}+\widehat{y_t})-I\widehat{P_t^I I_t}=\varkappa(\widehat{q_t}+\widehat{y_t})-I((2a_I-1)\,\widehat{q_t}+\widehat{I_t}). \quad (47)$$

Then, (46) can be rewritten as:

$$(1-I)(1-\frac{1}{\sigma})\,(2a-1)\,\widehat{q_t}=[(1-\varkappa)+\varkappa\,(2S-1)](\widehat{q_t}+\widehat{y_t})-I\,(2S-1)\,[(2a_I-1)\,\widehat{q_t}+\widehat{I_t}]+2b\widehat{q_t} \quad (48)$$

We now solve for equilibrium portfolios in economies with just two (relative) shocks $(\widehat{\theta}_t,\widehat{\chi}_t)$. As the dimension of relative shocks equals the dimension of relative assets (stocks and bonds), we can reproduce the complete market allocation (up to the degree of the approximation). In the case of complete markets, as in CKM, the correlation between shocks - as long as it is not perfect - does not matter for the results. Hence, in the case of complete markets, we assume that shocks are not perfectly correlated. With only output and shocks to the efficiency of investment, we can solve for optimal portfolios without any difficulty and portfolios are the same as in a world where investment is exogenous. In particular, we do not have to solve for investment as for each realization of $(\widehat{\theta}_t,\widehat{\chi}_t)$ there is a unique pair of relative change in the supply of goods and relative change in real investment $(\widehat{y_t},\widehat{I_t})$. This is why we will refer to investment shocks (changes in relative real investment $\widehat{I}_t$) rather than the fundamental sources of uncertainty driving this change.

Using the goods market equilibrium and relative budget constraints, we get the following equality (abstracting from time indices):

$$(1-I)(1-\frac{1}{\sigma})\,(2a-1)\,\widehat{q} = [(1-\varkappa)+\varkappa\,(2S-1)]((1-\lambda^*)\widehat{q}+I(2a_I-1)\widehat{I}) - I\,(2S-1)\,((2a_I-1)\widehat{q}+\widehat{I})+2b\widehat{q} \tag{49}$$

In a situation with just relative productivity shocks and relative investment technological change $(\widehat{\theta}_t, \widehat{\chi}_t)$, the following portfolio $(S,\, b)$ ensures the previous equation holds for arbitrary realizations of the shocks:

$$S = \frac{1}{2}\left[1+\frac{(2a_I-1)(1-\varkappa)}{1-(2a_I-1)\varkappa}\right] > \frac{1}{2}, \tag{50}$$

$$b = \frac{1}{2}\left[(1-I)(1-\frac{1}{\sigma})\,(2a-1)+[(1-\varkappa)+\varkappa\,(2S-1)](\lambda^*-1)+I\,(2S-1)\,(2a_I-1)\right] \tag{51}$$

Interestingly, the equity portfolio is independent of the degree of consumption home bias and of preference parameters. The equity portfolio is solely a function of the home bias in investment spending and of the capital share (k). Intuitively, equities are used solely to hedge investment risk. Why is the equity portfolio independent of risk aversion and the consumption substitution elasticity between domestic and local goods?

1) changing risk aversion σ induces some hedging of the real exchange rate but this is taken care of by the bonds in our model (term $(1-I)(1-\frac{1}{\sigma})\,(2a-1)$).

2) changing the consumption substitution elasticity ϕ changes the response of the terms of trade to output shocks; this too will be taken care of by the bonds (term $[(1-\varkappa)+\varkappa\,(2S-1)]((\lambda^*-1)$).

As a consequence the equity portfolio is independent of the preferences. See Coeurdacier and Gourinchas (2008) for a general discussion of conditions under which equity portfolios are independent of preferences (as shown there, an important condition is that there exist bonds whose relative returns perfectly track terms of trade movements).

Why do agents exhibit equity home bias? Intuitively, higher investment at home increases Home wages (by raising the terms-of-trade; remember that investment is biased towards local goods). So the burden of financing Home investment falls on Home investors since they have higher incomes, which is done by giving them a lot of local equity.

Once shocks to investment have been hedged by holding a disproportionate share of local equity, the remaining output risk can be hedged using the bond portfolio; this is so because changes in output induce terms of trade movements that affect the difference between the returns on Home and Foreign good bonds. But as in CKM, in an efficient equilibrium, an increase in Home output always worsens the Home terms of trade (q_t).

Interestingly, the above equity portfolio corresponds to that found by Heathcote and Perri (2007) , for a very special peculiar calibration of preferences, namely $\sigma = \phi = 1$. In contrast to the paper here, Heathcote and Perri consider a model with just TFP shocks and just trade in stocks (no investment efficiency shocks, no bonds). In their model, the equity portfolio is not robust to slight changes in risk aversion or the substitution across goods: when σ or ϕ are only slightly larger than unity, then generates equity foreign bias : households *short* the local stock.

4 Model variants with incomplete markets

We also consider model variants with incomplete financial markets; specifically, we make marjets incomplete by introducing an additional disturbance–a multiplicative preference shock; in these variants, the lifetime utility function is assumed to be given by: $U_{i,t} = \sum_{s=t}^{\infty} \beta^{s-t} \Psi_{i,t-s} \frac{C_{i,s}^{1-\sigma}}{1-\sigma}$, where $\Psi_{i,t-s} > 0$. The incomplete markets model too is solved using the method of Devereux and Sutherland (2007). [...]

5 Calibration and simulation results (VERY incomplete)

We adopt a standard model calibration. In the current version of the paper, we set the degrees of consumption and investment home bias at the same value: $\alpha = \alpha_I = 0.8$, which implies that the trade share (imports/GDP ratio) is 20% in the (deterministic) steady state. [Using input-output tables, Bussière (2007) documents that investment home bias is smaller than consumption home bias, in OECD economies; future versions of the paper will assume $\alpha > \alpha_I$.] Empirically, the labor share (ratio of wage earnings to GDP) is about 60% in OECD countries; accordingly, we set $\varkappa = 0.4$.

The risk aversion coefficient and the substitution elasticity between domestic and foreign goods are set at $\sigma = 2$, $\phi = \phi_I = 1.5$,respectively (see Coeurdacier, Kollmann and Martin (2007) for a detailed justification).

The model is calibrated to annual data. As is standard in annual macro models, we set the subjective discount factor and the depreciation rate of capital at $\beta = 0.96$ and $\delta = 0.1$, respectively. This implies that, in steady state, the return on equity is about 4.16% p.a, the capital output ratio is 2.92, and 28% of GDP is used for investment. We set the steady state TFP and investment efficiency parameters at $\theta = 0.66$ and $\chi = 1$. This implies that steady state GDP is unity in each country.

The exogenous variables follow independent AR(1) processes: $\log(\theta_{i,t}/\theta) = \rho^{\theta}\log(\theta_{i,t-1}/\theta) + \varepsilon^{\theta}_{i,t}$, $\log(\chi_{i,t}) = \rho^{\chi}\log(\chi_{i,t-1}) + \varepsilon^{\chi}_{i,t}$, $\log(\Psi_{i,t}) = \rho^{\Psi}\log(\Psi_{i,t-1}) + \varepsilon^{\Psi}_{i,t}$. We set the autocorrelations of the forcing variables at $\rho^{\theta} = \rho^{\chi} = \rho^{\Psi} = 0.95$; the standard deviations of exogenous innovations $\varepsilon^{\theta}_{i,t}, \varepsilon^{\chi}_{i,t}, \varepsilon^{\Psi}_{i,t}$ are set at 1.5%.

Equilibrium portfolios

For these parameter values, the structure with TFP and investment efficiency shocks (complete markets) implies that the locally held equity share is $S = 0.73$; thus, 73% of a country's capital stock is predicted to be held by local investors, which is broadly in line with the current degree of equity home bias in OECD countries; see discussion above. (The local-good bond position is $b = 0.17$.)

The model variant with three shocks generates the following (zero-order) portfolio: $S = 0.84, b = 0.17$.Hence, equity home bias is slightly stronger when there are taste shocks. This is due to the fact that a positive Home taste shock improves Home terms of trade, as the shock makes the Home household more eager to consume; this terms of trade effect raises the relative return on Home equity; thus, Home equity returns are high in states of the world in which the Home household is eager to consume a lot–which makes it more attractive to hold local equity.

NFA dynamics

Table 3 reports stochastic simulation results, based on a simulation run of 1000 periods. All statistics are based on time series that were passed through the Hodrick-Prescott filter (GDP, consumption and physical investment series were logged before applying the filter). Cols. 1-3 of the Table shows results for the complete markets case (just shocks to TFP and to investment efficiency), while Cols. 4-6 assume incomplete markets (TFP, investment efficiency and taste shocks). Throughout, the good produced by country H is used as a numeraire.

The change in country i foreign equity assets and foreign equity liabilities, as well as the equity and bond components of the change of NFA positions are defined as: $\Delta FEA_{i,t} = p^S_{j,t} S^i_{j,t} - p^S_{j,t-1} S^i_{j,t-1}$, $\Delta FEL_{i,t} = p^S_{i,t} S^j_{i,t} - p^S_{i,t-1} S^j_{i,t-1}$, $ECA_{i,t} = \Delta FEA_{i,t} - \Delta FEA_{i,t}$, $BCA_{i,t} = p^b_{j,t} b^i_{j,t} + p^b_{i,t} b^i_{i,t} - (p^b_{j,t-1} b^i_{j,t-1} + p^b_{i,t-1} b^i_{i,t-1})$. Recall that $\Delta NFA_{i,t} = ECA_{i,t} + BCA_{i,t}$.We also define a (conventional) current account measure for country i: $CA^i_t = (S^i_{j,t} - S^i_{j,t-1}) p^S_{j,t} - (S^j_{i,t} - S^j_{i,t}) p^S_{i,t} + (b^i_{j,t} - b^i_{j,t-1}) p^b_{i,t} - (b^j_{i,t} - b^j_{i,t-1}) p^b_{i,t}$.

Table 3 shows that the model here reproduces well-known macroeconomic stylized facts: e.g., consumption is predicted to be less volatile than GDP, while physical investment is more volatile than GDP; consumption and investment undergo persistent fluctuations, and are positively correlated with domestic GDP. Consistent with the data, the model predicts that the change (first-difference) of a country's net foreign asset position (NFA) is more volatile than GDP and (basically) serially uncorrelated; $\Delta FEA_{i,t}$, $\Delta FEL_{i,t}$, ECA^i_t and BCA^i_t are likewise predicted to be more volatile than GDP and serially uncorrelated. Note that $\Delta NFA_{i,t}$ is countercyclical, in the model, which is likewise consistent with the data.

These key predictions hold both in the complete and incomplete markets variants of the model. As discussed above, the complete markets structure has the property that (up to a first-order approximation), the (conventional) current account is zero; in that structure, there are sizable asset transactions: e.g. the standard deviation of the locally owned equity share $\left(S^i_{i,t}\right)$ has a standard deviation of 3.5%; yet, net equity and bond purchases made in a given period off-set each other (hence, *CA=0*).

By contrast, the *incomplete markets* structure generates non-negligible current account fluctuations (standard deviation of $CA : 0.24\%$).As equity home bias is lower in that structure, the equity component of NFA changes (ECA) is less volatile than in the structure with two shocks.

6 Conclusion

To be added

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Table 1. Data: external equity holdings and trade shares

	(Foreign equity liabilities)/ (capital stock)	(Foreign equity assets)/GDP		(Foreign equity liabilities)/GDP	
	1997	1997	2003	1997	2003
	(1)	*(2)*	*(3)*	*(4)*	*(5)*
Australia	0.11	0.39	0.37	0.45	0.56
Austria	0.05	0.13	0.36	0.17	0.30
Canada	0.06	0.36	0.48	0.27	0.35
Switzerland	0.14	1.26	1.81	1.23	1.63
Germany	0.03	0.26	0.48	0.18	0.38
Denmark	0.09	0.30	0.74	0.26	0.56
Spain	0.07	0.11	0.38	0.27	0.53
Finland	0.06	0.20	0.62	0.32	0.80
France	0.07	0.50	0.74	0.44	0.63
UK	0.14	0.61	0.95	0.58	0.78
Italy	0.03	0.13	0.34	0.10	0.12
Japan	---	0.10	0.13	0.07	0.14
Netherlands	0.12	0.88	1.51	0.95	1.21
Norway	0.16	---	---	---	---
New Zealand	0.11	0.19	0.25	0.65	0.57
Portugal	0.09	0.11	0.30	0.32	0.53
Sweden	0.13	0.54	0.89	0.50	0.64
US	0.05	0.35	0.42	0.31	0.37
Median	**0.07**	**0.29**	**0.48**	**0.32**	**0.56**
Mean	**0.09**	**0.37**	**0.63**	**0.42**	**0.59**

Notes: "Capital stock" (Col.1): physical capital stock; Foreign equity assets (liabilities): sum of FDI assets (liabilities) and portfolio equity assets (liabilities); C: private consumption; G: government purchases; I: physical investment; X: exports. Data sources: Col. (1) based on data from Kraay et al. (2005); portfolio data for Cols. (2)-(6) are from the International Investment Positions (IIP) data base (IMF). GDP, C, G, I, X data are from IFS.

Table 2. Cyclical properties of changes in Net Foreign Assets (NFA)

	Standard deviations (%)								Autocorrelations						
	t1	*Y*	*ΔNFA*	*ΔFEA*	*ΔFEL*	*ECA*	*BCA*	*CA*	*Y*	*ΔNFA*	*ΔFEA*	*ΔFEL*	*ECA*	*BCA*	*CA*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
AU	86	1.70	9.53	4.82	8.57	5.38	5.23	2.24	**0.38**	-0.04	-0.30	**-0.25**	-0.02	-0.07	0.04
AT	80	1.64	5.85	4.07	2.68	3.12	5.93	2.43	**0.48**	**-0.38**	-0.13	**-0.42**	**0.34**	-0.22	**0.56**
CA	72	2.55	5.05	3.29	3.88	2.55	4.35	2.44	**0.69**	-0.23	**0.30**	0.13	-0.03	-0.30	0.29
CH	83	2.59	11.34	13.07	21.16	15.41	15.76	2.15	**0.56**	**-0.28**	-0.00	**-0.33**	**-0.63**	**-0.34**	-0.01
DE	80	1.96	4.10	3.94	4.09	2.30	4.72	2.62	**0.58**	0.07	**0.36**	0.22	**0.27**	0.23	**0.74**
DK	91	1.92	9.88	10.53	9.65	6.54	6.25	2.97	0.09	**-0.31**	-0.20	**-0.64**	-0.05	**-0.25**	**0.56**
ES	81	2.71	5.13	5.56	5.53	6.16	3.66	3.03	**0.45**	**0.37**	**0.31**	**0.19**	0.18	0.18	**0.74**
FI	86	4.21	55.18	8.16	60.44	57.69	8.17	5.10	**0.59**	**0.30**	0.06	**0.31**	**0.25**	-0.11	**0.76**
FR	89	1.68	6.94	14.06	14.39	7.49	5.09	1.30	0.07	-0.07	0.09	0.21	-0.13	0.18	**0.52**
UK	80	2.37	8.57	13.86	11.05	7.64	3.86	2.46	**0.53**	-0.17	0.09	**0.36**	-0.19	0.08	**0.67**
IT	86	1.66	5.19	7.00	2.43	7.25	5.78	2.60	**0.65**	0.07	**0.22**	0.09	0.08	**0.34**	**0.69**
JA	95	2.43	6.44	1.17	8.61	7.87	2.41	1.18	**0.59**	**-0.39**	-0.08	**-0.24**	**-0.28**	0.15	**0.60**
NL	82	2.26	16.28	11.02	10.56	10.36	13.58	2.21	**0.48**	**-0.44**	-0.10	**0.54**	-0.15	**-0.14**	**0.48**
NZ	90	2.60	20.08	6.53	13.88	12.85	12.62	4.61	**0.28**	-0.08	0.02	**0.40**	**0.25**	**-0.32**	**0.38**
PT	96	3.10	4.48	3.99	9.29	10.82	8.21	6.07	**0.42**	0.06	-0.19	-0.18	0.19	0.10	**0.45**
SW	82	2.13	7.47	10.69	10.58	8.52	11.40	3.39	**0.48**	0.11	-0.05	0.24	0.09	0.14	**0.59**
US	80	2.08	4.94	7.44	7.51	3.48	2.53	2.01	**0.67**	-0.02	0.05	0.23	0.09	-0.01	**0.79**
Median		2.26	6.94	7.00	9.29	7.49	5.78	2.46	0.48	-0.08	0.02	0.19	0.08	-0.01	0.56
Mean		2.22	10.97	7.60	12.01	10.32	7.03	2.87	0.47	-0.08	0.02	0.05	0.02	-0.02	0.52

	Output:		Corrs. with domestic output						Correlations with foreign output						
	%Std	*Autocor.*	*ΔNFA*	*ΔFEA*	*ΔFEL*	*ECA*	*BCA*	*CA^{bkv}*	*Y*	*ΔNFA*	*ΔFEA*	*ΔFEL*	*ECA*	*BCA*	*CA^{bkv}*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
AU	1.70	**0.53**	-0.11	0.03	0.05	-0.05	-0.14	**-0.35**	**0.57**	**0.39**	-0.29	**-0.46**	**0.46**	**0.23**	0.00
AT	1.64	**0.38**	0.07	0.01	-0.25	**0.22**	-0.04	-0.24	**0.51**	-0.26	0.17	0.00	**0.23**	**-0.38**	-0.30
CA	2.55	**0.68**	-0.11	0.17	0.19	-0.06	-0.09	-0.24	**0.55**	0.06	**0.22**	0.15	0.06	0.03	**-0.53**
CH	2.59	**0.67**	**-0.28**	**-0.29**	**-0.17**	-0.01	**-0.18**	**-0.38**	**0.51**	**-0.43**	-0.04	-0.06	0.04	**-0.35**	-0.18
DE	1.96	**0.63**	**-0.25**	-0.01	-0.24	**0.42**	**-0.43**	**-0.52**	**0.68**	**0.40**	0.20	0.12	0.13	0.28	0.21
DK	1.92	**0.53**	-0.12	**0.37**	**0.32**	0.11	**-0.32**	**-0.84**	**0.43**	**0.17**	**0.59**	**0.60**	0.06	0.19	0.02
ES	2.71	**0.77**	**-0.51**	0.18	**0.38**	-0.17	**-0.42**	**-0.87**	**0.53**	-0.08	**0.30**	0.32	-0.01	-0.09	**-0.47**
FI	4.21	**0.80**	-0.06	**0.43**	0.04	0.01	**-0.54**	**-0.25**	**0.31**	**-0.13**	**0.40**	0.10	-0.05	**-0.58**	**-0.47**
FR	1.68	**0.65**	**-0.36**	**-0.39**	**-0.44**	0.12	**-0.68**	**-0.51**	**0.62**	0.08	0.18	-0.02	**0.39**	**-0.46**	0.03
UK	2.37	**0.66**	**-0.31**	**0.11**	**0.22**	-0.11	**-0.46**	**-0.74**	**0.66**	-0.08	0.07	0.13	-0.05	-0.07	**-0.62**
IT	1.66	**0.42**	**-0.47**	-0.04	-0.17	0.01	**-0.44**	**-0.54**	**0.72**	-0.20	**0.31**	0.01	**0.29**	**-0.56**	**-0.45**
JA	2.43	**0.71**	**0.57**	-0.02	**-0.54**	**0.59**	-0.41	**-0.34**	**0.36**	0.26	0.21	-0.07	0.11	0.33	-0.13
NL	2.26	**0.64**	-0.03	-0.06	**0.37**	**-0.45**	0.30	-0.33	**0.51**	0.05	-0.03	0.00	-0.03	0.09	**-0.47**
NZ	2.60	**0.48**	**-0.80**	**0.30**	**0.62**	**-0.51**	**-0.74**	-0.30	0.01	**0.59**	0.01	**-0.73**	**0.80**	0.12	**0.33**
PT	3.10	**0.56**	**0.59**	**0.54**	**-0.85**	**0.94**	**-0.90**	**-0.45**	**0.65**	**0.47**	**0.72**	**-0.50**	**0.70**	**-0.65**	-0.02
SW	2.13	**0.54**	-0.08	**0.40**	0.07	**0.41**	**-0.37**	**0.49**	0.09	-0.02	0.17	-0.14	**0.41**	-0.32	**-0.50**
US	2.08	**0.55**	**-0.21**	0.05	0.17	-0.25	-0.07	**-0.42**	**0.49**	**-0.20**	-0.17	0.00	**-0.39**	0.13	**0.48**
Median	2.26	0.63	-0.12	0.05	0.05	0.01	-0.41	-0.38	0.51	0.05	0.18	0.01	0.11	-0.07	-0.18
Mean	2.33	0.60	-0.14	0.10	-0.01	0.07	-0.35	-0.40	0.49	0.06	0.18	-0.03	0.18	-0.12	-0.18

Notes: All data are annual. All statistics pertain to Hodrick-Prescott filtered series (Y: logged). The sample period for current accounts differs across countries: the Col. (1) (labeled "t1") in Panel (a) denotes the first year; the sample ends in 2003, except for DK ('01) and SW ('02). Sample period for *CA*: 1980-2003 (for DK: 1981-2003). Statistics that just involve output are based on 1972-2003 data.

See Appendix for definitions of $\Delta NFA, \Delta FEA, \Delta FEL, ECA, BCA, CA$; for country *i*, these variables are expressed in units of foreign output, and normalized by a fitted deterministic geometric trend of country *i* output (also expressed in units of foreign output). Column labeled $Corr(\Delta FEA, \Delta FEL)$ shows correlations between ΔFEA and ΔFEL.

Underlined correlations are statistically significant at a 10% level (two-sided test, GMM based, assuming 5-th order serial correlation in residuals).

AU: Australia; AT: Austria; CA: Canada; CH: Switzerland; DE: Germany; DK: Denmark; ES: Spain; FI: Finland; FR: France; UK: United Kingdom; IT: Italy; JA: Japan; NL: Netherlands; NZ: New Zealand; PT: Portugal; SW: Sweden.

Table 3. Model predictions

	Complete markets (θ, χ shocks)			Incomplete markets (θ, χ, ψ shocks)		
	Std%	ρ_Y	ρ_{-1}	**Std%**	ρ_Y	ρ_{-1}
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Y	1.59	1.00	0.61	1.59	1.00	0.61
C	0.83	0.78	0.62	0.89	0.72	0.61
I	4.91	0.62	0.53	4.95	0.61	0.53
ΔNFA	4.15	-0.28	-0.06	4.16	-0.26	-0.05
ΔFEA	8.44	-0.23	-0.08	2.11	-0.27	-0.05
ΔFEL	9.28	-0.30	-0.08	2.77	-0.38	-0.03
ECA	17.58	-0.27	-0.08	4.59	-0.35	-0.04
BCA	13.47	0.26	-0.08	2.57	0.20	-0.08
CA	0.00	--	---	0.24	-0.21	0.54
S	3.54	-0.70	0.64	0.77	-0.63	0.67
b	0.44	0.89	0.61	0.18	0.85	0.57

Notes: **Std%**: standard deviations (in %); ρ_Y : correlation with domestic output; ρ_{-1} : autocorrelation. *Y*: GDP; *C*: aggregate consumption; *I*: investment; ΔFEA {ΔFEA} [ΔFEL]**:** change in net foreign asset position {foreign equity assets} [foreign equity liabilities]; $ECA \equiv \Delta FEA - \Delta FEL$; BCA : change in net foreign bond holdings; CA : conventional current account measure; S : locally held fraction of stock; *b*: holding of bond denominated in locally produced good.

Appendix

Data sources, definitions of variables in Tables 1 and 2

Let G21 denote the set of 17 OECD countries listed in Table 2, plus Belgium, Ireland, Mexico and Norway (no current account series for these countries are constructed because of gaps in portfolio data). The portfolio data used in Table 2 are from the IMF's IIP database. All other data are from International Financial Statistics (IMF).

"Foreign" output from country i's viewpoint is aggregated using real exchange rates based on GDP deflators. Let $RER^{GD}_{i/j,t}$ and $RER^{GD}_{i,t}$ denote the bilateral real exchange rate between countries *i* and *j*, and the real exchange rate between *i* and the rest of the G21, based on GDP deflators. Foreign output from country *i*'s perspective, $Y^*_{i,t}$, is total output in the rest of the G21, aggregated at real exchange rates (based on GDP deflators) in the reference year T_0=1993 (median year in sample):

$$Y^*_{i.t} \equiv \sum\nolimits_{j\in \text{G21},\, j\neq i} [(GDP^{nom}_{j,t} - I^{nom}_{j,t} - G^{nom}_{j,t})/P^{GD}_{j,t}] \times RER^{GD}_{i/j,T_0}.$$

In Tables 1-2, a country's foreign equity assets, *FEA*, represent the sum of its FDI assets and external portfolio equity assets; foreign equity liabilities, *FEL*, are the sum of FDI liabilities and external portfolio equity liabilities. A country's net foreign bond holdings, *NB*, are constructed as *NB*≡*NFA*-*FEA*-*FEL*, from data on *FEA*, *FEL* and net foreign assets, *NFA*.