Disconnect and Information Content of International Capital Flows: Evidence and Theory[1]

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Abstract

The relationship between asset prices and fundamentals is characterized by both disconnect and predictability: asset prices are largely disconnected from current publicly observed fundamentals and at the same time contain information about future fundamentals, even when conditioning on current fundamentals. Previous research has shown that both aspects can be explained by dispersed private information. In this paper we document these same features for international capital flows. We show that this can be explained by introducing information dispersion into recently developed open economy dynamic general equilibrium models encompassing portfolio choice. A calibration exercise shows that these features are quantitatively significant.

1   Introduction

It is well known that asset prices are not closely connected to observed fundamentals. For exchange rates this disconnect puzzle has lead to an extensive literature following the seminal work by Meese and Rogoff (1983). But the puzzle applies similarly to other asset prices.[1] A natural explanation for this asset price disconnect puzzle is that traders make decisions to a large extent based on private information. This explanation is consistent with the wide dispersion in asset price forecasts across investors as well as the close connection between asset prices and order flow.[2] It is also consistent with the predictability of future fundamentals by current asset prices after conditioning on current publicly observed fundamentals.[3] Bacchetta and van Wincoop (2006) show, in the context of exchange rates, that models with dispersed information can account both for the disconnect of asset prices from current fundamentals and the information content of asset prices.

In this paper we argue that these same features also apply to international capital flows, both for gross flows (capital outflows plus inflows) and net flows (capital outflows minus inflows). We show that, just like asset prices, capital flows are largely disconnected from observed macro variables and contain information about future macro fundamentals even when conditioning on current observed fundamentals. We show that these stylized facts can be understood in the context of a model with dispersed information. The similarity between asset prices and capital flows should not be surprising as they are both forward looking variables that reflect portfolio choice. To the extent that agents trade based on private information, this should affect not only prices but also quantities (capital flows).

We shed light on the evidence by developing a general equilibrium theory of in-

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[1] See for example Roll (1987) for equity prices.

[2] For exchange rates this was first documented by Evans and Lyons (2002), followed by many others. See Osler (2008) for a recent survey. For equity prices see for example Hasbrouck (1991). Albuquerque, de Francisco and Marques (2008) show that equity order flow for individual firms contains a component associated with market-wide private information (as opposed to firm-specific private information), which affects industry stock returns and exchange rates.

[3] See Engel and West (2005) and Evans and Lyons (2007) for exchange rates. In the absence of private information asset prices are entirely determined by the current publicly observed information set and therefore do not contain information about the future conditional on the public information set. Consistent with the private information content of asset prices, Evans and Lyons (2007) show that order flow in the foreign exchange market forecasts future macro variables such as output growth, money growth and inflation.

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ternational capital flows under dispersed information that integrates key elements of two distinct literatures. The first is the market microstructure literature in finance.[4] We adopt the two key features of noisy rational expectations (NRE) models from the market microstructure literature. First, agents have private information about future fundamentals. Second, there is "noise" in the form of unobserved portfolio shifts, which prevent asset prices from fully revealing the private information. The second is the dynamic stochastic general equilibrium (DSGE) macro literature. It is worth emphasizing the need to analyze capital flows in a general equilibrium framework. Portfolio shifts across countries affect relative asset prices, which affect expected returns, which in turn feed back to portfolio flows. In our model capital flows, expected returns, as well as the risk associated with asset returns, are all determined jointly within the context of a general equilibrium framework.

Figure 1 illustrates the essence of the theoretical contribution. The model contains four ingredients: information dispersion, portfolio choice, non-linearity and general equilibrium structure. Standard macro DSGE models only contain the last two ingredients. Recent contributions introducing portfolio choice in DSGE models include the last three ingredients, but not the first one.[5] By contrast, the models in the market microstructure literature in finance only contain the first two ingredients. In particular, NRE models are not general equilibrium frameworks as they assume that there is an infinite supply, in an unspecified location, of an asset with a constant riskfree return.[6] Moreover, they are entirely linear. While these aspects of NRE models facilitate their solution, they do not fit well with the open economy DSGE setups within which the literature on international capital flows is framed.

Capital flows in the model are driven by the same factors that drive portfolio allocation: changes in wealth, expected returns and risk. We show how through a variety of channels these factors are affected by two unobserved state variables: one related to private information about future fundamentals and one related to

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[4]See Brunnermeier (2001) for a nice review of the literature.

[5]See Devereux and Sutherland (2007), Tille and van Wincoop (2008) and Evans and Hnatkovska (2008), who have developed tractable methods for solving DSGE models with portfolio choice.

[6]Even when assets with a riskfree return exist (e.g. Treasury bills), in a general equilibrium framework the demand for such assets must equate their finite supply.

unobserved portfolio shifts (the "noise"). Both of these unobservables are critical as it is their interaction that drives the results. Either element alone is not sufficient. These unobserved fundamentals lead to a disconnect of capital flows from publicly observed macro fundamentals.[7] Moreover, capital flows help forecast future fundamentals, even after controlling for their current values. This reflects the role of private information about future fundamentals.

We also make a methodological contribution by solving a DSGE model with portfolio choice and information dispersion. We cannot directly rely on recently developed approximation methods for solving DSGE models with portfolio choice, as they abstract from information dispersion. Neither can we directly apply the standard methods for solving NRE models because of the linear, partial equilibrium, nature of these models. We develop a solution that extends the approximation methods used for solving DSGE models to encompass the key elements from the method used for solving NRE models. Even though the combined presence of DSGE and NRE features makes the model quite rich, we are nonetheless able to obtain an analytical solution. This facilitates transparency of the results.

The paper is related to a small set of papers that have introduced NRE asset pricing features into open economy models. These include Albuquerque, Bauer and Schneider (2007,2008), Bacchetta and van Wincoop (2004,2006), Brennan and Cao (1997), Gehrig (1993) and Veldkamp and van Nieuwerburgh (2008). These papers focus on a variety of issues, ranging from exchange rate puzzles to international portfolio home bias and the relationship between asset returns and portfolio flows. Together they show that information dispersion within and across countries can tell us a lot about a wide range of stylized facts related to international asset prices and portfolio allocation. However, none of these papers have implications for *aggregate* capital inflows and outflows or even net capital flows (the current account). This is not just because the focus is on other questions but more fundamentally because these are not true general equilibrium models due to the presence of a riskfree asset that is in infinite supply in an unspecified location.

The paper is organized as follows. Section 2 documents the two empirical features, namely the disconnect between capital flows and current macroeconomic fundamentals and the predictive power of capital flows for future fundamentals

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[7]This also includes public news variables that are featured in the literature on the impact of news shocks, such as Beaudry and Portier (2003), Devereux and Engel (2006), Jaimovich and Rebelo (2008) and Lorenzoni (2007).

in industrialized economies. Section 3 describes the model. The solution method is discussed in section 4. Section 5 derives implications for asset prices, portfolio allocation and capital flows, and shows how the model generates the two features documented in Section 2. The quantitative implications of the model are explored through a calibration exercise in Section 6. Section 7 concludes.

2   Capital Flows and Fundamentals: the Evidence

We are not the first to point out the weak link between capital flows and observed macro fundamentals. For example, Nason and Rogers (2005) observe "Current account fluctuations resist easy explanations. Large current account deficits have persisted in the U.S. through periods of large government budget deficits and surpluses, large and persistent real appreciations and depreciations of the dollar, and all phases of the business cycle."However, this disconnect of capital flows has never been explicitly documented as a puzzle. In this section we use data for industrialized countries to document both the disconnect between capital flows and observed fundamentals and the ability of capital flows to predict future fundamentals.

Our analysis considers quarterly data from 1977(1) to 2007(2) for the United States, Japan, Canada, United Kingdom, Germany and France, with the data sources described in Appendix C. We report results for both gross and net capital flows, scaling them by GDP. In terms of the publicly observed fundamentals, we consider the following variables: GDP growth, inflation, the interest rate (T-bill rate) and the fiscal deficit (scaled by GDP). These represent standard variables that cover the major aspects of the macro economy. Theory will tell us that gross capital flows (inflows plus outflows) are driven by global shocks. Our analysis of gross capital flows is therefore based on worldwide measures of the fundamentals, computed as a GDP-weighted average across all countries. Similarly, theory tells us that net capital flows (outflows minus inflows) are driven by relative shocks (one country relative to others). Our analysis of net capital flows is therefore based on the difference in the value of fundamentals between the specific country and the GDP-weighted average across the other countries.

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2.1 Disconnect from Publicly Observed Fundamentals

We assess the extent to which capital flows are linked to publicly observed fundamental by means of a VAR that evaluates the explanatory power of innovations in fundamentals for capital flow fluctuations. Identification of the innovations is achieved using the Choleski decomposition.[8] Three lags of all variables are included in the VAR. The analysis is conducted at the horizon of one, four and twelve quarters.

The results are reported in Table 1. The macro variables have very limited explanatory power for gross capital flows. At a one-quarter horizon only 6% of the variance of gross capital flows can be accounted for by innovations in the macro variables. Even at a 12-quarter horizon only 16% of the variance of gross capital flows is explained by innovations in the macro variables. Results are only slightly better for the current account, where respectively 7% and 32% of the variance of the current account at 1 and 12-quarter horizons can be explained by innovations in publicly observed macro variables.

It is possible that the limited explanatory power of publicly observed macro variables could be due to measurement error in capital flow data. Such measurement errors are likely to be more severe for quarterly data than for annual data. In the remainder of this section we therefore focus the analysis on annual data. In Table 2 we repeat the previous exercise using 30 annual observations from 1977 to 2006, including only one lag in the VAR. Consistent with the view that capital flows are better measured for annual than for quarterly data, we now find that a larger fraction of capital flow fluctuations can be accounted for by the macro variables. For gross capital flows we find that respectively 21% and 30% of the variance is explained by innovations in the macro variables at 1 and 3-year horizons. For the current account these numbers are 34% and 53%.

But this still leaves most gross and net capital flow fluctuations unexplained. Moreover, this significantly overstates the true explanatory power of publicly observed macroeconomic variables because of the small sample bias with only 30 annual observations. It needs to be compared to what we would get when the macro variables are generated by pure noise. To make this comparison, for each country we generate an artificial series of macro variables from an AR(1) process with the same persistence as the actual macro variables for that country and ran-

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[8]The ordering of the variables is: GDP growth, inflation, the interest rate, the fiscal deficit.

domly generated $N(0,1)$ innovations. We then compute the average variance decomposition based on 1000 estimations of the VARs with the randomly generated macro variables. We find that the fraction of the variance of gross flows explained at 1 and 3-year horizons by the random innovations in the macro variables is on average respectively 17% and 27%. For the current account these numbers are 18% and 29%. This implies that for gross capital flows the actual macro variables have virtually no explanatory power at all as the results in Table 2 are very close to what we would get if the macro variables were generated by pure noise. For net capital flows we find very limited true explanatory power as the fraction of the variance of net capital flows that can be explained by the actual macro variables is only 16 to 24 percentage points higher than that generated by random noise.

2.2 Information Content of Capital Flows

We now assess the extent to which capital flows contain information on future macroeconomic fundamentals by means of a regression analysis and Granger causality tests. Because capital flows reflect decisions by investors who care about asset payoffs instead of growth or inflation per se, we construct a macroeconomic measure of asset payoffs. Specifically, we compute the aggregate profit rate for each country by taking the difference between GDP and employee compensation, and scaling it by the capital stock. We then assess whether capital flows Granger cause this profit rate, which would imply that capital flows contain information about future asset payoffs. We conduct separate Granger causality tests for gross and net capital flows.

Information Content of Gross Capital Flows

We start by evaluating to what extent gross capital flows Granger cause the "world profit rate". The latter is defined as a GDP-weighted average of profit rates of all countries. The results are reported in Table 3, focusing on annual data which suffer less from measurement error than quarterly data. The second column reports results from a bivariate Granger causality test. We regress the world profit rate on one lag of itself and one lag of gross capital flows. We test the null hypothesis that lagged gross capital flows fail to cause the world profit rate. Rejection of the null hypothesis implies Granger causality. The table reports p-values for countries where we reject the null-hypothesis at a significance level of 10% or better. In four

of the six countries we find strong evidence of Granger causality. Moreover, in each of these four cases we find that the coefficient on the lagged gross capital flows is negative. This implies that a global retrenchment towards domestic markets (drop in inflows and outflows) predicts a higher future world profit rate, a remarkable finding that we will show is consistent with the theory.

The third and fourth columns of Table 3 confirm that these findings are robust to the inclusion of lagged values of other macro variables. We regress the world profit rate on its own lag and lagged values of gross capital flows and GDP-weighted averages of a set of additional macro variables. We again test whether the coefficient on lagged gross capital flows is significantly different from zero. This is the case for five of the six countries when including GDP-weighted averages of lags of real GDP growth, inflation and the T-bill rate and for four out of the six countries when additionally including a GDP-weighted average of budget deficits as a share of GDP. As before, the coefficient on lagged gross capital flows continues to be negative.[9]

Information Content of Net Capital Flows

We find less evidence of information content in net capital flows. To look at this, we consider the extent to which net capital flows Granger cause the relative profit rate, defined as the profit rate minus the GDP-weighted average profit rate of the other countries. The results are reported in Table 4. We first again conduct a bivariate Granger causality test. We regress the relative profit rate on its own lag and the lagged value of net capital outflows. We find that the coefficient on the lagged profit rate is significantly different from zero in two of the six countries. This is the case both when measuring net capital outflows as outflows minus inflows and as the current account. We find even less significance when introducing lags of other macro variables.

We will see that this weaker evidence of information content in net capital flows is not necessarily inconsistent with the theory. In the calibration of the model we will show that the information content of gross capital flows is much stronger, and more robust, than that for net capital flows. It should therefore be much easier to detect in the data as well.

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[9]While not reported, these results continue to hold up when we include a linear time trend in the regressions. The justification for doing so is that gross capital flows have increased over our sample for reasons that are unrelated to our model.

3 The Model

The model that we develop is the result of a tradeoff. On the one hand it is necessarily quite rich in order to address the topic at hand. Agents make portfolio, consumption and investment decisions in the context of a two-country dynamic stochastic general equilibrium setup with dispersed private information. On the other hand though we make many simplifying assumptions to achieve analytic tractability and transparency of the results. For example, there is just one good, and we adopt an overlapping generation framework that simplifies portfolio choice and consumption decisions. Only one of the observed macro variables in the empirical section (GDP growth) will be present in the model. What matters is not exactly how many variables there are in the model, but rather the distinction between observed and unobserved state variables. The presence of unobserved state variables results from the private information in the model.

There are two countries, Home and Foreign, with a unit mass of atomistic agents in each country. Both countries produce the unique good using labor and capital. The good can be used for consumption or investment, the latter entailing an adjustment cost. We adopt a standard overlapping generation setup with agents living two periods. Young agents earn labor income and make consumption and portfolio decisions. They can invest in claims on capital in both countries. While these are claims on aggregate capital rather than residual claims, we refer to them as Home and Foreign equity for convenience. Old agents consume the return on their investment.

3.1 Production, Investment and Assets

The consumption good is taken as the numeraire. It is produced in both countries using a constant returns to scale technology in labor and capital:

$$Y_{i,t} = A_{i,t} K_{i,t}^{1-\omega} N_{i,t}^{\omega} \quad i = H, F \tag{1}$$

where H and F denote the Home and Foreign country respectively. Y_i is the output in country i, A_i is a country-specific exogenous stochastic productivity term, K_i is the capital input and N_i the labor input that we normalize to unity. Log productivity follows an autoregressive process:

$$a_{i,t+1} = \rho a_{i,t} + \varepsilon_{i,t+1} \quad i = H, F$$

where $\varepsilon_{i,t+1}$ has a $N(0, \sigma_a^2)$ distribution and is uncorrelated across countries.

The dynamics of the capital stock reflects depreciation at a rate δ and investment $I_{i,t}$:

$$K_{i,t+1} = (1 - \delta) K_{i,t} + I_{i,t} \quad i = H, F \tag{2}$$

A share ω of output is paid to labor, with the remaining going to capital. The wage rate in country i is then

$$W_{i,t} = \omega A_{i,t} (K_{i,t})^{1-\omega} \quad i = H, F \tag{3}$$

Capital is supplied by a competitive installment firm. In period t the firm produces $I_{i,t}$ units of new capital and sells them at a price $Q_{i,t}$ that it takes as given. The production of $I_{i,t}$ units of capital good requires purchasing $I_{i,t}$ units of the consumption good and incurring a quadratic adjustment cost, so the total cost in units of the consumption good is:

$$I_{i,t} + \frac{\xi}{2} \frac{(I_{i,t} - \delta K_{i,t})^2}{K_{i,t}} \tag{4}$$

The profit of installing $I_{i,t}$ units of capital in country i is then $Q_{i,t} I_{i,t}$ minus the cost (4). Profit maximization by the installment firm implies a standard Tobin's Q relation:

$$\frac{I_{i,t}}{K_{i,t}} = \delta + \frac{Q_{i,t} - 1}{\xi} \tag{5}$$

A unit of Home equity is a claim on a unit of Home capital. The equity price is equal to the cost of purchasing one unit of capital from the installment firm, $Q_{H,t}$. An investor purchasing a unit of Home equity at the end of period t gets a dividend of $(1 - \omega) Y_{H,t+1} / K_{H,t+1}$ in period $t+1$, and can sell the remaining $1 - \delta$ units of equity at a price $Q_{H,t+1}$. The returns on Home and Foreign equity are then

$$R_{H,t+1} = \frac{(1 - \omega) A_{H,t+1} (K_{H,t+1})^{-\omega} + (1 - \delta) Q_{H,t+1}}{Q_{H,t}} \tag{6}$$

$$R_{F,t+1} = \frac{(1 - \omega) A_{F,t+1} (K_{F,t+1})^{-\omega} + (1 - \delta) Q_{F,t+1}}{Q_{F,t}} \tag{7}$$

3.2 Private Information and Noise

We import the two key elements of NRE models: private information about future fundamentals and noise that prevents asset prices from completely revealing the

private information. We introduce these elements to the model as follows.

Private Information

Each agent receives private signals about next period's productivity innovations in both countries. The signals observed by Home investor j about respectively the log of Home and Foreign productivity are:

$$
\begin{aligned}
v_{j,t}^{H,H} &= \varepsilon_{H,t+1} + \epsilon_{j,t}^{H,H} & \epsilon_{j,t}^{H,H} &\sim N\left(0, \sigma_{HH}^2\right) & (8) \\
v_{j,t}^{H,F} &= \varepsilon_{F,t+1} + \epsilon_{j,t}^{H,F} & \epsilon_{j,t}^{H,F} &\sim N\left(0, \sigma_{HF}^2\right) & (9)
\end{aligned}
$$

Each signal consists of the true innovation and a stochastic error. Similarly, agent j in the Foreign country observes the signals:

$$
\begin{aligned}
v_{j,t}^{F,H} &= \varepsilon_{H,t+1} + \epsilon_{j,t}^{F,H} & \epsilon_{j,t}^{F,H} &\sim N\left(0, \sigma_{HF}^2\right) & (10) \\
v_{j,t}^{F,F} &= \varepsilon_{F,t+1} + \epsilon_{j,t}^{F,F} & \epsilon_{j,t}^{F,F} &\sim N\left(0, \sigma_{HH}^2\right) & (11)
\end{aligned}
$$

As is standard in NRE models, we assume that the errors of the signals average to zero across investors in a given country ($\int_0^1 \epsilon_{j,t}^{H,H} dj = \int_0^1 \epsilon_{j,t}^{H,F} dj = 0$).

Our setup is symmetric as the variance of signals on domestic productivity is the same for agents in the two countries, and so is the variance of signals on productivity abroad. We allow for an information asymmetry with agents receiving more precise signals about shocks in their own country than abroad: $\sigma_{HH}^2 \leq \sigma_{HF}^2$. A substantial literature has documented information differences across countries, with local investors having more reliable information than foreign investors.[10]

Noise

Noise takes the form of unobserved portfolio shifts between assets for reasons unrelated to expected returns. In the NRE literature the noise is usually simply introduced exogenously in the form of noise trade or liquidity trade. Some papers have introduced it endogenously in various forms of hedge trade and liquidity trade.[11] For our purposes the existence of a source of noise is more important than the exact nature of it.

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[10]See for example Bae, Stulz and Tan (2007), who document that earnings forecasts are more precise for local than foreign analysts. There is also evidence that agency problems are better monitored by locals, e.g. Leuz, Lins and Warnock (2008).

[11]See for example Bacchetta and van Wincoop (2006), Dow and Gorton (1995), Spiegel and Subrahmanyam (1992) and Wang (1994).

We introduce the noise through a time-varying cost of investing abroad. A Home agent j investing in the Foreign country receives the return (7) times an iceberg cost $e^{-\tau_{Hj,t}} < 1$. Similarly, a Foreign agent j investing in the Home country receives the return (6) times an iceberg cost $e^{-\tau_{Fj,t}} < 1$. The cost of investment abroad does not represent a loss in resources but is instead a fee paid to brokers from the investor's country.

This cost of investing abroad fluctuates around a level τ that is the same for all investors. The average cost τ generates portfolio home bias in the steady state of the model, with agents tilting their holdings toward domestic assets. There are two reasons for introducing portfolio home bias. First, it is a well known feature of the data. Second, we will see that the impact of information dispersion on capital flows depends on the extent of portfolio home bias.

Fluctations around τ include both agent-specific and country-specific components. The costs faced by Home investors in period t are distributed around an average value $\tau_{H,t} = \tau \left(1 + \varepsilon_t^\tau\right)$, where ε_t^τ has a $N(0, \theta\sigma_a^2)$ distribution. This average cost $\tau_{H,t}$ is unobserved. An individual investor making a portfolio decision at time t knows her own cost $\tau_{Hj,t}$, but we assume that this individual cost is an infinitely noisy signal of the average cost. This assumption can be relaxed but simplifies the analysis.[12] The average cost in the Foreign country is $\tau_{F,t} = \tau(1 - \varepsilon_t^\tau)$, which is also unobserved. For simplicity, our specification implies that the average of $\tau_{H,t}$ and $\tau_{F,t}$ is constant, and focuses on movements in the relative cost between the two countries. For instance, an increase in $\tau_t^D = \tau_{H,t} - \tau_{F,t} = 2\tau\varepsilon_t^\tau$ leads to a portfolio shift towards Home equity, as it is relatively more expensive for Home investors to invest abroad than for Foreign investors. Such unobserved portfolio shifts prevent the relative equity price from revealing private information.

3.3   Consumption and Portfolio Choice

Our assumption of an overlapping generation structure simplifies the model in two ways. First, it removes the well-known pitfall in open economy models that temporary income shocks can have a permanent effect on the distribution of wealth across countries when agents have infinite lives. The finite life assumption of OLG models leads to a stationary distribution of wealth. Second, investors have only a one period investment horizon and therefore do not face the issue of hedging

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[12]See Bacchetta and van Wincoop (2006) for a similar assumption.

against changes in future expected returns.

A young Home agent j at time t chooses her consumption and portfolio to maximize

$$\frac{\left(C_{y,t}^{Hj}\right)^{1-\gamma}}{1-\gamma} + \beta E_t^{Hj} \frac{\left(C_{o,t+1}^{Hj}\right)^{1-\gamma}}{1-\gamma} \tag{12}$$

where $C_{y,t}$ is consumption when young and $C_{o,t+1}$ is consumption when old. We assume $\gamma > 1$. Agent j maximizes (12) subject to the budget constraint and portfolio return, $R_{t+1}^{p,Hj}$:

$$C_{o,t+1}^{Hj} = (W_{H,t} - C_{y,t}^{Hj})R_{t+1}^{p,Hj}$$
$$R_{t+1}^{p,Hj} = z_{Hj,t}R_{H,t+1} + (1 - z_{Hj,t})e^{-\tau_{Hj,t}}R_{F,t+1} \tag{13}$$

where $z_{Hj,t}$ is the fraction of wealth invested in Home equity.

The first-order conditions for consumption and portfolio choice are:

$$\left(C_{y,t}^{Hj}\right)^{-\gamma} = \beta \left(W_{H,t} - C_{y,t}^{Hj}\right)^{-\gamma} E_t^{Hj} \left(R_{t+1}^{p,Hj}\right)^{1-\gamma} \tag{14}$$

$$E_t^{Hj} \left(R_{t+1}^{p,Hj}\right)^{-\gamma} \left(R_{H,t+1} - R_{F,t+1}e^{-\tau_{Hj,t}}\right) = 0 \tag{15}$$

(14) is the consumption Euler equation that links the marginal utility of current consumption with the expected marginal utility of future consumption, including the rate of return. (15) is the portfolio Euler equation that equates the expected discounted return (the expected product of the asset pricing kernel and asset returns) across assets. The asset pricing kernel is the marginal utility of future consumption, which is proportional to the return on the agent's portfolio. A central aspect of our model is that (14)-(15) are evaluated with expectations that can differ across individual agents.

Foreign agents face an analogous decision problem with portfolio return

$$R_{t+1}^{p,Fj} = z_{Fj,t}e^{-\tau_{Fj,t}}R_{H,t+1} + (1 - z_{Fj,t})R_{F,t+1} \tag{16}$$

The corresponding optimality conditions for a Foreign investor j are:

$$\left(C_{y,t}^{Fj}\right)^{-\gamma} = \beta \left(W_{F,t} - C_{y,t}^{Fj}\right)^{-\gamma} E_t^{Fj} \left(R_{t+1}^{p,Fj}\right)^{1-\gamma} \tag{17}$$

$$E_t^{Fj} \left(R_{t+1}^{p,Fj}\right)^{-\gamma} \left(R_{H,t+1}e^{-\tau_{Fj,t}} - R_{F,t+1}\right) = 0 \tag{18}$$

The average portfolio shares invested by Home and Foreign investors in Home equity are denoted $z_{H,t} = \int_0^1 z_{Hj,t}dj$ and $z_{F,t} = \int_0^1 z_{Fj,t}dj$.

3.4 Asset and Goods Market Clearing

We assume that the brokers who receive the fees on investment abroad fully consume it. Owners of the installment firms also consume profits each period. The goods market equilibrium condition is:

$$
Y_{H,t+1} + Y_{F,t+1} = Q_{H,t+1}I_{H,t+1} + Q_{F,t+1}I_{F,t+1} + \int_0^1 C^{Hj}_{y,t+1}dj + \int_0^1 C^{Fj}_{y,t+1}dj
$$

$$
+ \int_0^1 (W_{H,t} - C^{Hj}_{y,t})\left(z_{Hj,t}R_{H,t+1} + (1 - z_{Hj,t})R_{F,t+1}\right)dj
$$

$$
+ \int_0^1 (W_{F,t} - C^{Fj}_{y,t})\left(z_{Fj,t}R_{H,t+1} + (1 - z_{Fj,t})R_{F,t+1}\right)dj
$$

The left hand side is world output. The first two terms on the right hand side represent investment. The next two terms represent consumption by young agents. The final two terms represent consumption by old agents and the brokers.[13]

Asset market clearing requires that the value of capital in a country is equal to the value of holdings of the country's equity by young agents. The financial wealth of respectively a Home and Foreign agent j is $W_{Ht} - C^{Hj}_{y,t}$ and $W_{Ft} - C^{Fj}_{y,t}$. The asset market clearing conditions are then

$$
Q_{H,t}K_{H,t+1} = \int_0^1 (W_{Ht} - C^{Hj}_{y,t})z_{Hj,t}dj + \int_0^1 (W_{Ft} - C^{Fj}_{y,t})z_{Fj,t}dj \qquad (19)
$$

$$
Q_{F,t}K_{F,t+1} = \int_0^1 (W_{Ht} - C^{Hj}_{y,t})(1 - z_{Hj,t})dj +
$$

$$
\int_0^1 (W_{Ft} - C^{Fj}_{y,t})(1 - z_{Fj,t})dj \qquad (20)
$$

4 Solution Method

The solution combines and extends methods for solving standard NRE models with recently developed local approximation methods for solving DSGE models with portfolio choice. NRE models are usually solved in three steps. The first step involves a conjecture for the equilibrium asset price. The second step computes the expectation of future asset payoffs by solving a signal extraction problem that uses public and private information as well as information from the equilibrium asset

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[13]The cost of investing abroad does not enter, as the income of the brokers exactly offsets the cost for old agents.

price. The last step invokes asset market equilibrium. The main difficulty here will be in the last step as we need to impose not just asset market equilibrium but the complete general equilibrium of the model in a highly non-linear environment.

We handle the last step by extending the local approximation method recently developed by Devereux and Sutherland (2007) and Tille and van Wincoop (2008) for DSGE models with portfolio choice. The method iteratively solves for the various components of the variables. A variable x_t can be decomposed into its components of all orders. The zero-order component, denoted $x(0)$, is the level of x_t when $\sigma_a \to 0$. The first-order component $x_t(1)$ is linear in model innovations, or in the standard deviation σ_a of model innovations. Higher orders are defined analogously.

We discuss each of these three steps in broad terms. The solution method is described further in the Appendix, with complete algebraic details left to a Technical Appendix that is available on request. We use lower case letters for logs and superscripts A and D to denote respectively the average and difference of a variable across the two countries ($x^D = x_H - x_F$, $x^A = (x_H + x_F)/2$).

4.1   Asset Price Conjecture

Only the relative equity price is affected by private information. The average equity price is driven by global asset demand and therefore global saving, which is not affected by private information. We make the following conjecture for the relative log equity price $q_t^D = q_{H,t} - q_{F,t}$:

$$q_t^D = f(S_t, x_t^D) \tag{21}$$

where

$$S_t = (a_t^D, a_t^A, k_t^D, k_t^A) \tag{22}$$

is the vector of publicly observed state variables and

$$x_t^D = \varepsilon_{t+1}^D + \lambda \tau_t^D / \tau \tag{23}$$

depends on the unobserved state variables ε_{t+1}^D and τ_t^D. Since we adopt a local approximation method, described below, the conjecture (21) is verified locally up to quadratic terms in observed and unobserved state variables.

The logic behind this conjecture is as follows. As in any DSGE model, the solution for control variables (including asset prices) will be a function of state

variables. Usually these state variables are publicly observed. In our model this is the case for the variables S_t. However, there are now also unobserved state variables. We conjecture that the unobserved state variables jointly affect the asset price through x_t^D. The relative future productivity innovation ε_{t+1}^D should affect the relative asset price through private information. The relative asset price should depend on τ_t^D as time variation in this unobserved relative friction leads to portfolio shifts between Home and Foreign equity.

4.2 Signal Extraction

This conjecture significantly simplifies signal extraction. While the function $f(.)$ will be non-linear in x_t^D, two aspects make simple linear signal extraction feasible. First, we have conjectured (and will verify) that the relative asset price depends on a variable x_t^D that is linear in the unknowns ε_{t+1}^D and τ_t^D. Second, locally q_t^D will depend on x_t^D with a positive slope. This means that we can extract x_t^D from knowledge of the relative asset price q_t^D and the publicly observed state space S_t. The asset price signal therefore translates into a signal that is linear in the future fundamental ϵ_{t+1}^D and the "noise" τ_t^D.

We then have three linear signals about next period's technology innovations: (i) the price signal, which tells us the level of $\varepsilon_{t+1}^D + \lambda \tau_t^D / \tau$ from (23), (ii) the private signals (8)-(11) and (iii) the public signals that $\varepsilon_{H,t+1}$ and $\varepsilon_{F,t+1}$ are drawn from independent $N(0, \sigma_a^2)$ distributions. We discuss the solution to this signal extraction problem in Appendix A.1. It gives conditional normal distributions of $\varepsilon_{H,t+1}$ and $\varepsilon_{F,t+1}$ that vary across agents. The expectation of future productivity innovations by agent j in the Home country takes the form

$$
E_t^{H,j} \left| \begin{array}{c} \varepsilon_{H,t+1} \\ \varepsilon_{F,t+1} \end{array} \right| = \left| \begin{array}{c} \alpha_{\varepsilon H,xD}^{Hj} x_t^D + \alpha_{\varepsilon H,vH}^{Hj} v_{j,t}^{H,H} + \alpha_{\varepsilon H,vF}^{Hj} v_{j,t}^{H,F} \\ \alpha_{\varepsilon F,xD}^{Hj} x_t^D + \alpha_{\varepsilon F,vH}^{Hj} v_{j,t}^{H,H} + \alpha_{\varepsilon F,vF}^{Hj} v_{j,t}^{H,F} \end{array} \right| \tag{24}
$$

The average expectation across Home agents, denoted by $\bar{E}_t^H$, is:

$$
\bar{E}_t^H \left| \begin{array}{c} \varepsilon_{H,t+1} \\ \varepsilon_{F,t+1} \end{array} \right| = \left| \begin{array}{c} \left(\alpha_{\varepsilon H,xD}^{Hj} + \alpha_{\varepsilon H,vH}^{Hj} \right) \varepsilon_{H,t+1} + \left(\alpha_{\varepsilon H,vF}^{Hj} - \alpha_{\varepsilon H,xD}^{Hj} \right) \varepsilon_{F,t+1} + \alpha_{\varepsilon H,xD}^{Hj} \lambda \tau_t^D / \tau \\ \left(\alpha_{\varepsilon F,xD}^{Hj} + \alpha_{\varepsilon F,vH}^{Hj} \right) \varepsilon_{H,t+1} + \left(\alpha_{\varepsilon F,vF}^{Hj} - \alpha_{\varepsilon F,xD}^{Hj} \right) \varepsilon_{F,t+1} + \alpha_{\varepsilon F,xD}^{Hj} \lambda \tau_t^D / \tau \end{array} \right| \tag{25}
$$

where we used (8)-(11) and (23). Analogous results apply to Foreign agents. Average expectations of future productivity therefore depend on future productivity

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levels themselves and on the noise τ_t^D. Through rational confusion an increases in τ_t^D raises the expectation of ε_{t+1}^D. This is because a rise in τ_t^D leads to a higher relative price of Home equity, which agents use as a signal of future relative productivity.

4.3 General Equilibrium

This section discusses the final step of the solution, namely the imposition of general equilibrium. This involves a fair amount of technicalities, and a reader interested primarily in the implications for asset prices and capital flows can skip to section 5.

The final step in the solution of NRE models involves imposing asset market equilibrium. In a DSGE model this step is more involved since we will need to invoke the full general equilibrium of the model, including multiple asset market and goods market clearing conditions and Euler equations for portfolio choice and consumption. Moreover, we need to do so in a highly non-linear environment.

We adopt and extend the local approximation method for DSGE models with portfolio choice developed by Devereux and Sutherland (2007) and Tille and van Wincoop (2008), from hereon DS and TvW. It provides an exact solution to the zero, first and second-order components of control and state variables. The only exception is $z_t^D = z_{H,t} - z_{F,t}$, for which the method delivers the zero and first-order components.

The method distinguishes between the difference across countries in portfolio Euler equations and all "other equations" and similarly between the difference z_t^D across countries in portfolio allocation and all "other variables". It first solves for the zero-order component of z_t^D and the first-order component of the "other variables" by jointly imposing the second-order component of the difference across countries in portfolio Euler equations and the first-order component of the "other equations". This step is subsequently repeated one order higher for all equations and variables in order to obtain the first-order component of z_t^D jointly with the second-order component of all "other variables". We refer to DS and TvW for detailed descriptions of the method.

In implementing and extending the method to our model, three issues need to be addressed that are specific to the introduction of information dispersion. These involve the order component of the errors of the private signals, the computation

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of expectations of equations and the computation of the parameter λ that captures the noise to signal ratio in the relative asset price in equation (23).

Errors in Private Signals

We assume that σ_{HH}^2 and σ_{HF}^2 are zero-order. It is important to distinguish between the volatility of the innovations in the model, captured by σ_a^2, and the uncertainty of the private signals about these innovations, captured by σ_{HH}^2 and σ_{HF}^2. We keep these two dimensions distinct. A reduction in the volatility of innovations is then not accompanied by an increased precision of the signals on the innovations.

This assumption implies that the private signals (8)-(11) entail a zero-order component (the errors of the signals) and a first-order component (the true future productivity innovations). It implies that the coefficients on the private signals in (24), $\alpha_{\varepsilon H,vH}^{Hj}$, $\alpha_{\varepsilon H,vF}^{Hj}$, $\alpha_{\varepsilon F,vH}^{Hj}$, $\alpha_{\varepsilon F,vF}^{Hj}$, are of order two. Differences in expected returns across individual investors are then second order, as they combine these second-order coefficients with the zero-order errors of the private signals in (8)-(11). The differences in expected returns being small, of order two or higher, ensures that the cross-sectional distribution of portfolio shares does not explode when risk becomes small. This is because expected returns are divided by the variance of the excess return in the optimal portfolios. If errors in private signals were first-order, differences in expectations would be first-order as well and the distribution of portfolio shares would explode for low levels of risk. For the same reason we assume that the average cost τ of investment abroad is second-order.

Computing Expectations

Consider the expected value of a term eq, which consists of one or several variables, $E\ eq$. In common knowledge models, computing the second-order component of this expectation simply entails taking the expectation of the second-order component of eq, so that $[E\ eq](2) = E[eq(2)]$. This is no longer the case here though,[14] and we need to be careful to first compute expectations of equations before splitting them into components of different orders. To compute expectations of equations, both the equations and the solution of control variables need to be in polynomial form. It is sufficient to use an o-order polynomial approximation when

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[14]As an example, $\varepsilon_{H,t+1}(2) = 0$, so that $E_t[\varepsilon_{H,t+1}(2)] = 0$. But $E_t(\varepsilon_{H,t+1})$ has a non-zero second-order component as the weight attached to private signals is of order two and higher.

the goal is to compute the o-order component of an equation or variable.

Equations are written as polynomials in S_t, x_t^D, x_{t+1}^D and $\varepsilon_{t+1} = (\varepsilon_{H,t+1}, \varepsilon_{F,t+1})'$. Control variables are conjectured as polynomial solutions in the observed and unobserved state variables S_t and x_t^D. A quadratic polynomial conjecture for the control variables is sufficient as we will only solve zero, first and second-order components of control variables. We therefore conjecture (for $h = D, A$)[15]

$$q_t^h = \alpha_{qh}S_t + \alpha_{5,qh}x_t^D + S_t'A_{qh}S_t + \beta_{qh}S_tx_t^D + \mu_{qh}\left(x_t^D\right)^2 + \kappa_{qh} \qquad (26)$$

$$c_{yt}^h = \alpha_{ch}S_t + \alpha_{5,ch}x_t^D + S_t'A_{ch}S_t + \beta_{ch}S_tx_t^D + \mu_{ch}\left(x_t^D\right)^2 + \kappa_{ch} \qquad (27)$$

$$k_{t+1}^h = \alpha_{kh}S_t + \alpha_{5,kh}x_t^D + S_t'A_{kh}S_t + \beta_{kh}S_tx_t^D + \mu_{kh}\left(x_t^D\right)^2 + \kappa_{kh} \qquad (28)$$

Expectations of equations are computed using the results from signal extraction. Invoking the order components of equations as in DS and TvW will then give the zero and first-order components of the parameters α (with various subscripts) in (26)-(28) and the zero-order component of all the other parameters.

Computing λ

In NRE models the signal to noise ratio λ in (23) can be solved by imposing asset market equilibrium. A version of that applies here as well. We need to impose the difference between the two asset market clearing conditions (19)-(20). This relates the average share invested in Home equity, z_t^A, to the share of Home equity supply. Combining the first-order components of (26)-(28) with that of (19)-(20) solves $z_t^A(1)$ by equating it to the first-order component from the supply side. In order to actually impose market equilibrium we need to compute $z_t^A(1)$ from a portfolio or demand perspective as well. This is done by using the third-order component of the average of the Euler equations for portfolio choice, (15) and (18). Equating $z_t^A(1)$ from the demand side to the Home equity share from the supply side yields a solution for λ, as discussed in Appendix A.2.

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[15]No conjectures will be needed for z_t^D and z_t^A. After all "other variables" are solved up to second order, $z_t^D(1)$ follows from the third-order component of the difference in portfolio Euler equations and $z_t^A(1)$, $z_t^A(2)$ follow from the first and second-order components of the difference of the asset market clearing conditions.

5 Asset Prices, Portfolio Allocation and Capital Flows

5.1 Asset Prices

The first-order solution of the relative asset price is

$$
\begin{aligned}
q_t^D(1) &= \alpha_{q,D}(0)S_t(1) + \alpha_{5,qD}(0)x_t^D(1) \\
&= \alpha_{1,qD}(0)\,a_t^D + \alpha_{3,qD}(0)\,k_t^D(1) + \alpha_{5,qD}(0)\left(\varepsilon_{t+1}^D + \lambda\tau_t^D(3)/\tau\right) \quad (29)
\end{aligned}
$$

with all parameters positive. The relative asset price is therefore driven by both publicly observed state variables, a_t^D and k_t^D, and by unobserved state variables ε_{t+1}^D and τ_t^D. Both of these unobserved state variables generate a disconnect between asset prices and publicly observed fundamentals, a fact that is widely documented.

In the absence of information dispersion the relative asset price would, to the first-order, be entirely determined by the publicly observed state variables S_t. This is because future productivity innovations cannot affect current equilibrium asset prices, and shocks to τ_t^D only have a third-order effect on asset prices. Recall that a rise in $\tau_t^D = 2\tau\varepsilon_t^\tau$ is third-order. This leads to a third-order increase in the expected excess return on Home equity. In order to clear financial markets there needs to be a third-order drop in the expected excess return on Home equity, which takes place through a third-order rise in the Home equity price.

At first it may seem surprising that τ_t^D and ε_{t+1}^D have a first-order effect on asset prices when we introduce information dispersion. As discussed above, shocks to τ_t^D are third-order. (25) also shows that private information alone leads to third-order changes in average expectations about ε_{t+1}^D, as first-order innovations are combined with the second-order coefficients on private signals.

The first-order impact of τ_t^D and ε_{t+1}^D in (29) reflects the role of the relative asset price as an information coordination mechanism. Imagine that agents ignored q_t^D as a source of information. The impact of τ_t^D and ε_{t+1}^D would then be third-order as discussed above. But because both are of the same order in their impact on the relative asset price, the price would contain much more precise information about ε_{t+1}^D than the private signals. After all, in the private signals the error terms are much larger (zero-order) than the productivity innovations themselves (first-order). It is this feature that explains why in equilibrium the weight attached to

the price signal in expectations of future productivity innovations is much larger (zero-order) than the weight attached to private signals (second-order).

The zero-order weight attached to the price signal implies that changes in τ_t^D and ε_{t+1}^D have a first-order effect on the expectation of $\varepsilon_{H,t+1}$ and $\varepsilon_{F,t+1}$, which leads to a first-order effect on asset prices.[16] It is through the information coordination role of the price signal that agents learn a lot more about ε_{t+1}^D, amplifying its impact from third to first-order. The impact of the noise τ_t^D is also amplified from third to first-order as it affects the expectation of future productivity innovations through the price signal (rational confusion). This amplified effect of the noise can make a huge difference. For example, Gennotte and Leland (1990) provide evidence that during the U.S. stock market crash of October 19, 1987, the impact of non-informational trade (noise) on the U.S. stock price was amplified by a factor greater than 100 as a result of the information content of the stock price.

5.2 Portfolio Allocation

We now discuss the implications of the model for portfolio allocation, a key determinant of international capital flows. We present the results in terms of the average portfolio share invested in Home equity, z_t^A, and the difference across countries in the portfolio share invested in Home equity, z_t^D, considering both their zero and first-order components.

In terms of zero-order components, the asset market clearing conditions (19)-(20) imply that $z^A(0) = 0.5$. The difference in zero-order portfolio shares, $z^D(0)$, which represents portfolio home bias, is computed from the second-order component of the difference in portfolio Euler equations (15) and (18), and reflects the mean level τ of international financial frictions:

$$z^D(0) = \frac{2\tau}{\gamma \left[E_t \left(er_{t+1}\right)^2\right](2)} \tag{30}$$

where $er_{t+1} = r_{H,t+1} - r_{F,t+1}$ is the difference in log returns or excess return.

It may be surprising that information asymmetry across countries does not affect the zero-order portfolio home bias. It only affects portfolio home bias to higher orders. While the quality of private signals about domestic productivity

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[16]In (24) this take place through zero-order coefficients $\alpha_{\epsilon H,xD}^{Hj}$ and $\alpha_{\epsilon F,xD}^{Hj}$ that multiply x_t^D in the expectations of future productivity innovations.

innovations is better than about productivity innovations abroad, both are weak in that the errors are zero-order. As discussed in section 3.3, this avoids an explosion of the cross-sectional distribution of portfolio shares for low levels of risk. As a result, the difference between Home and Foreign investors regarding the perceived variance of productivity innovations is small (of order four and higher).

We obtain expressions for the first-order component of the average and difference in optimal portfolio shares from the third-order component of respectively the average and difference in portfolio Euler equations (15) and (18)[17]:

$$z_t^A(1) = \frac{\tau_t^D(3)}{2\gamma \left[E_t(er_{t+1})^2\right](2)} + \frac{\left[\bar{E}_t^A er_{t+1}\right](3)}{\gamma \left[E_t(er_{t+1})^2\right](2)} \tag{31}$$
$$-\frac{\gamma-1}{\gamma} \frac{[var_t(r_{Ht+1})](3) - [var_t(r_{Ft+1})](3)}{2\left[E_t(er_{t+1})^2\right](2)}$$

$$z_t^D(1) = \frac{\left[\bar{E}_t^H er_{t+1}\right](3) - \left[\bar{E}_t^F er_{t+1}\right](3)}{\gamma \left[var_t(er_{t+1})\right](2)} - z^D(0)\frac{[var_t(er_{t+1})](3)}{[var_t(er_{t+1})](2)} \tag{32}$$

where $\bar{E}_t^A$ denotes the average expectation across agents from both countries and $\bar{E}_t^h$ the average expectations across agents from country h ($h = H, F$).

The first-order component of z_t^A is driven by three intuitive elements in (31). First, a rise in $\tau_t^D(3)$ leads to a portfolio shift towards Home equity as the cost of investment abroad rises for Home relative to Foreign investors. Second, a higher average expected excess return er_{t+1} on Home equity net of financial frictions also leads to a portfolio shift towards Home equity. The last term in (31) represents time-variation in second moments, which are captured by their third-order components.[18] A rise in the variance of the Home return relative to that of the Foreign equity return leads to a shift towards Foreign equity (assuming $\gamma > 1$).

The expression (32) for the difference $z_t^D(1)$ in portfolio shares captures time-variation in portfolio home bias. It is driven by two factors. First, an increase in the expected excess return on Home equity by Home investors relative to Foreign investors will lead to increased home bias. Second, an increase in the variance of the excess return reduces home bias. There is a tradeoff between investing at home due to the friction τ and achieving the gains from portfolio diversification. A higher variance of the excess return makes diversification more attractive, reducing home bias.

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[17]See the Technical Appendix for full derivations.

[18]See Tille and van Wincoop (2008) for a further discussion of this.

In the Technical Appendix we show that these moments affecting $z_t^D(1)$ take the form:

$$[\bar{E}_{H,t}er_{t+1}](3) - [\bar{E}_{F,t}er_{t+1}](3) = \delta_1 \sigma_a^2 \left[\frac{1}{\sigma_{HH}^2} - \frac{1}{\sigma_{HF}^2} \right] \varepsilon_{t+1}^A \qquad (33)$$

$$[var_t(er_{t+1})](3) = \delta_2 \sigma_a^2 S_t(1) \qquad (34)$$

where the parameters δ_i are zero-order and follow from the first and second-order solutions of the "other variables". To understand (33), assume that $\sigma_{HH}^2 < \sigma_{HF}^2$, so that agents have better quality signals about their domestic equity market. When productivity levels rise in both countries next period, agents from both countries expect that productivity in their own country will rise more because they have better quality information about their own productivity. As a result they both expect the return on their own country's equity to rise relative to that of the other country, which leads to increased portfolio home bias ($\delta_1 > 0$). (34) implies that changes in the variance of the excess return over time are driven only by changes in publicly observed state variables.[19]

5.3 International Capital Flows

After some straightforward balance of payments accounting outlined in Appendix B, and using the results on portfolio allocation discussed above, we obtain the following expressions for capital outflows and inflows:

$$
\begin{aligned}
outflows_t(1) = & \; (1 - z_H(0)) s_t^H(1) + \frac{z^D(0)}{2} \frac{\Delta[var_t(er_{t+1})](3)}{\left[E_t(er_{t+1})^2\right](2)} \\
& - \frac{\Delta \bar{E}_t^A er_{t+1}(3)^{IS}}{\gamma \left[E_t(er_{t+1})^2\right](2)} - \frac{1}{2} \frac{\Delta\left[\bar{E}_t^H er_{t+1}\right](3) - \Delta\left[\bar{E}_t^F er_{t+1}\right](3)}{\gamma \left[E_t(er_{t+1})^2\right](2)}
\end{aligned}
\qquad (35)
$$

$$
\begin{aligned}
inflows_t(1) = & \; (1 - z_H(0)) s_t^F(1) + \frac{z^D(0)}{2} \frac{\Delta[var_t(er_{t+1})](3)}{\left[E_t(er_{t+1})^2\right](2)} \\
& + \frac{\Delta \bar{E}_t^A er_{t+1}(3)^{IS}}{\gamma \left[E_t(er_{t+1})^2\right](2)} - \frac{1}{2} \frac{\Delta\left[\bar{E}_t^H er_{t+1}\right](3) - \Delta\left[\bar{E}_t^F er_{t+1}\right](3)}{\gamma \left[E_t(er_{t+1})^2\right](2)}
\end{aligned}
\qquad (36)
$$

The terms on the right hand side are related to saving, expected returns and risk. For each of them we now discuss their intuitive meaning and determinants.

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[19] Only the second and fourth elements of δ_2 are non-zero, so that only global state variables affect the variance of the excess return.

Portfolio Growth

The first term on the right hand side of (35)-(36) represents portfolio growth, which measures outflows and inflows when Home and Foreign saving are invested abroad at the steady state portfolio share $1 - z_H(0)$. The portfolio growth component depends entirely on Home and Foreign saving, which can be written as

$$s_t^H(1) = \alpha_{sH}\Delta S_t(1) - 0.5z^D(0)\Delta q_t^D(1) \tag{37}$$

$$s_t^F(1) = \alpha_{sF}\Delta S_t(1) + 0.5z^D(0)\Delta q_t^D(1) \tag{38}$$

where α_{sH} and α_{sF} are zero-order vectors. Home and Foreign saving depend both on changes in publicly observed state variables and changes in relative asset prices. The latter generate wealth effects that impact consumption of the old generations. When the relative price of Home equity rises, the old generation in the Home country will be relatively wealthy and will consume this additional wealth. This lowers Home saving.

Time-Varying Risk

The other three terms driving capital inflows and outflows (35)-(36) are a result of portfolio reallocation due to changes in risk and expected returns. The second term represents capital flows due to changes in the variance of the excess return. An increase in the variance of the excess return makes portfolio diversification more attractive and therefore leads to an increase in both capital inflows and outflows. As can be seen from (34), the variance of the excess return only depends on publicly observed state variables. Time variation in the variance of the Home return relative to that of the Foreign return does not affect capital flows. From (31), we see that these moments only affect average portfolio shares. When there is an average shift towards Home equity, the market will equilibrate through a third-order rise in the relative Home equity price. This leads to a third-order drop in the expected excess return on Home equity, causing a first-order portfolio shift back towards Foreign equity.[20] In the end capital flows remain unaffected.

Average Expected Excess Return

The third term on the right hand side of (35)-(36) represents capital flows due to the average change in the expected excess return. As discussed in detail in Tille and

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[20] As can be seen from (31) and (32), third-order changes in expected returns lead to first-order portfolio shifts as they are divided by a second-order variance of the excess return.

van Wincoop (2008), not all changes in expected excess returns generate capital flows. We have already discussed the example above where changes in expected returns equilibrate asset markets when there are time-varying second moments. No capital flows result from this. Another example is the adjustment following a rise in the relative price of Home equity. This raises the relative supply of Home equity and a third-order increase in the expected excess return on Home equity is necessary for investors to be willing to accept this shift in the composition of their portfolio. But no capital flows take place as a rise in the relative Home asset price automatically changes the portfolio composition without any asset trade.

The Technical Appendix derives the components driving changes in the equilibrium expected excess return. The only one that affects capital flows is denoted with an IS superscript in (35) and (36). It is related to changes in relative saving and investment and is equal to

$$\Delta \bar{E}_t^A er_{t+1}(3)^{IS} = \frac{\gamma \left[E_t \left(er_{t+1} \right)^2 \right] (2)}{4} \left[i_t^D(1) - z^D(0) s_t^D(1) \right] \tag{39}$$

When relative investment is high in the Home country, it raises the relative supply of Home equity. A higher expected excess return on Home equity is then needed to clear asset markets. This leads to increased capital inflows and lower capital outflows. When relative saving in Home is high, there will be an excess demand for Home equity due to portfolio home bias. A lower expected excess return is then needed to clear asset markets, which leads to larger outflows and smaller inflows.

Cross-country differences in saving and investment are equal to

$$s_t^D(1) = \Delta a_t^D(1) + (1 - \omega)\Delta k_t^D(1) - z^D(0)\Delta q_t^D(1) \tag{40}$$

$$i_t^D(1) = \frac{1}{\xi} q_t^D(1) \tag{41}$$

Relative asset prices affect relative saving through a wealth effect and relative investment through a standard Tobin's Q equation.

Differences in Expected Returns across Countries

The last term driving capital outflows and inflows in (35) and (36) represents changes in the average expected excess return of Home investors relative to Foreign investors. When investors from both countries become more optimistic about the expected excess return on their domestic equity, both capital outflows and inflows will drop. As can be seen from (33), this will happen when there is a positive future

world productivity innovation ε_{t+1}^A and investors have better quality information about domestic productivity innovations. Investors from both countries then believe that their own relative productivity will rise as they have better information on that, leading to a retrenchment towards domestic assets.

Impact of Information Dispersion on Capital Flows

In analyzing the impact of information dispersion on capital flows we will distinguish between gross capital flows, defined as outflows plus inflows, and net capital flows, defined as outflows minus inflows. The latter is also equal to the current account.[21] In the absence of information dispersion capital flows (35)-(36) are entirely determined by the publicly observed state variables $S_t(1)$. Even unobserved portfolio shifts associated with τ_t^D do not have a first-order effect on capital flows in that case.[22]

With dispersed information, both gross and net capital flows are also affected by state variables that are not publicly observed. Figure 2 illustrates the channels through which this happens. The arrows on the left hand side of Figure 2 illustrate the impact of the unobserved state variables τ_t^D and ε_{t+1}^D on net capital flows. We have already seen that they have a first-order effect on the relative asset price q_t^D in the presence of private information. This affects saving and investment through a wealth effect and a Tobin's Q effect, which in turn affects net capital flows both through changes in the equilibrium expected excess return and through portfolio growth.[23]

The right hand side of Figure 2 illustrates the impact of the unobserved state variable ε_{t+1}^A on gross capital flows. A rise in ε_{t+1}^A leads agents from both countries to become more optimistic about the relative return on the asset from their own country. The resulting retrenchment leads to a drop in both capital inflows and outflows and therefore gross flows.

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[21] It is easily seen from (35)-(36) that $outflows_t(1) - inflows_t(1) = 0.5(s_t^D(1) - i_t^D(1))$. Using the equality $s^H + s^F = i^H + i^F$, this is equal to $s_t^H(1) - i_t^H(1)$, which is the current account.

[22] A first-order portfolio shift from Foreign to Home leads to a third-order increase in the Home relative equity price. This leads to a third-order drop in the expected excess return on Home equity, which generates an entirely offsetting first-order portfolio shift back from Home to Foreign.

[23] To some extent these effects depend on portfolio home bias, which affects the impact of relative asset price changes on Home and Foreign saving and the impact of relative saving on the average expected excess return. See (37), (38) and (39).

We can summarize these results in the form of two implications that capture the impact of dispersed information on both gross and net capital flows:

Implication 1 *Capital flows are partially disconnected from current publicly observed fundamentals.*

Implication 2 *Capital flows help forecast future fundamentals, even after controlling for current fundamentals.*

These implications, relating to the disconnect and information content of capital flows, are consistent with the empirical evidence in Section 2. Also note that the predictive content of gross capital flows goes exactly in the direction found in the data. A drop in gross capital flows (retrenchment towards domestic markets) predicts a rise in future world productivity and therefore asset payoffs.

Discussion

We have derived these results in the context of a particular model with many simplifying assumptions. However, Implications 1 and 2 are broader than the specifics of our model. They do not really depend on assumptions we made about the production side of the economy or preferences. The OLG assumption simplifies consumption and portfolio choice, but is not central to the results. The implications also do not depend on how we introduced the noise in the economy through the cost of investing abroad; we could simply have introduced exogenous noise traders. The key assumption that drives Implications 1 and 2 is dispersed information. The specifics of how we introduced dispersed information are not important. We could for example have assumed that agents have private information about fundamentals further than one period into the future, as in Bacchetta and van Wincoop (2006, 2008),[24] or that within each country there are informed and uninformed agents (e.g. Wang (1994)).

While generalizing the model should not qualitatively change the impact of dispersed information as summarized in Implications 1 and 2, additional channels

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[24]Such an extension, as well as others, does not fundamentally change the solution method other than that a larger model with more state variables would call for a numerical rather than analytic solution. As shown in Bacchetta and van Wincoop (2006,2008), when agents have private information about fundamentals more than one period into the future asset prices are effected by higher order expectations of future fundamentals, but this does not change the solution method.

through which these implications come about are certainly possible. One example is an extension where agents work both periods of their life and have private information about their future labor income. Expectations of future labor income affect saving decisions, which affects capital flows through portfolio growth and the average expected excess return. Implication 1 will hold as this is private information. Implication 2 will hold as well as it is information about future labor income. This example also illustrates that asset prices are not necessarily the only channel through which private information can affect net capital flows.

A key question is whether there could be other types of models, without information dispersion, that lead to Implications 1 and 2. Assume therefore that there is no private information about future fundamentals. There could still be unobserved exogenous portfolio shifts, associated with τ_t^D. But we have already seen that these do not have a first-order effect on capital flows in the absence of private information about future fundamentals. It is possible though to generate a disconnect by allowing for asset price bubbles, which we have ruled out. But this would only impact net, not gross capital flows. Moreover, it would be inconsistent with the second implication of the model as bubbles have no information content.

A final possibility may be that there is publicly available news about future fundamentals that is not controlled for by the econometrician. In that case Implications 1 and 2 would appear to hold even when there is no information dispersion. Such an argument has long been around to explain the disconnect been exchange rates and publicly observed fundamentals. However, this argument has been put to rest by the contributions of Evans and Lyons (2002) and others that document a close connection between exchange rates and order flow. This connection would not exist if all information is public as order flow aggregates private information. Public news affects asset prices without any order flow at all.[25]

If Implication 2 is correct, it would be natural for the market to use capital flow information for decisions about portfolio allocation. This assumes of course that aggregate capital flow data are observed without delay, which is not the case. However, a component of the capital flows is available to a subset of investors. For example, State Street Corporation, as one of the largest global custodians, collects information on cross-border portfolio flows by institutional investors. Such

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[25]Public news can lead to order flow if agents disagree about the interpretation of the news. But that is another example of private information, in this case about the nature or parameters of the model.

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real time portfolio flow data are used by some investors, especially FX funds, for trading purposes. State Street itself uses these flow data to provide FX trading recommendations in its FX Global Strategy newsletters. This is consistent with Implication 2 of our model that capital flows have information content.

In the model investors do not use capital flows as a source of information. This may be seen as inconsistent both with the fact that capital flows have information content in the model and with the observation that some traders actively use the information in capital flows for trading purposes. However, there is less of an inconsistency than there appears to be. First, only information about gross capital flows would be relevant (provides information about ε_{t+1}^A). Net capital flows have the same information content in the model as the relative asset price, so observing net flows would make no difference. Second, aggregate capital flow data are only released with considerable delay. They therefore cannot be used by investors in real time to make portfolio decisions. Third, the real time portfolio flow data from institutions like State Street Corporation are only available to a limited set of investors and measure only a component of capital flows. We could extend the model by allowing agents to observe aggregate capital flows with noise. While this would affect the results quantitatively, it does not affect Implications 1 and 2 qualitatively. It would provide more information about ε_{t+1}^A. But it would not reveal ε_{t+1}^A, which is central to the results regarding gross capital flows.

6   Quantitative Assessment of the Model

Our analysis so far establishes that on a *qualitative* level the presence of dispersed information leads to the two implications listed in the previous section. We now assess the *quantitative* impact of dispersed information through a calibration exercise relying on data for 6 industrialized countries. We focus on the sensitivity of the results to key parameters linked to the dispersion of information (the extent of information dispersion, the extent of information asymmetry and the extent of noise). While the precise results are of course sensitive to the simplifying assumptions made for the sake of analytic tractability and transparency of the results, the exercise nonetheless provides us with a good quantitative sense of the two implications within the context of the model.

We calibrate the model to annual data over the period 1977-2006 for the United

States, Japan, Canada, United Kingdom, Germany and France, with the data sources described in Appendix C. Starting with the parameters related to production, we set the labor share ω equal to 0.54, which is the average ratio of employee compensation to GDP in our sample. We estimate the persistence ρ in the stochastic process for productivity by computing the Solow residuals and estimating a panel regression of a_{it} on its own lag and country-specific constants. This yields an estimate of ρ of 0.91. It also yields an estimate of the standard deviation σ_a of productivity innovations, but all moments we report below will be independent of the scale σ_a of innovations.

The last two parameters associated with the supply side of the economy are the adjustment cost parameter ξ and the rate of depreciation δ. We set ξ equal to 2.7 in order to match the standard deviation of annual real investment growth relative to the standard deviation of annual real GDP growth. This ratio is 2.8 in the data when averaged across the 6 countries and the sample 1977-2006. We set the rate of depreciation δ equal to 0.1, which is the standard assumption for annual data in the entire real business cycle literature (e.g. Backus, Kehoe and Kydland (1992)).

We choose the average cost τ of investment abroad in order to match the observed portfolio home bias in the data. The standard measure of portfolio home bias is

$$1 - \frac{share\ of\ foreign\ equity\ in\ portfolio\ of\ domestic\ investors}{share\ of\ foreign\ equity\ in\ world\ portfolio}$$

Fidora, Fratzscher and Thimann (2007) report this measure of home bias for a wide range of countries based on 2001-2003 data. This includes 5 of our industrialized countries (all but Canada). The average measure of home bias for those 5 countries is 0.73. They also report a measure of home bias for debt securities, which is virtually identical. We therefore set the cost τ of investment abroad such that the zero-order component of portfolio home bias in the model is equal to 0.73.[26] The level of τ depends on the rate of relative risk-aversion, which we set at 5. Holding the home bias constant, a change in the rate of risk-aversion has little effect on the results reported below.

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[26] In the steady state of our symmetric setup this measure of home bias is also equal to $z^D(0)$. We set τ in the expression (30) for $z^D(0)$ to match the 0.73 home bias in the data. It implies that both countries invest a fraction 0.865 in domestic equity.

While the parameters outlined above are standard in the literature, we also need to set values for three parameters that are specific to our model. These are the average dispersion of private signals across investors, $(\sigma_{HH} + \sigma_{HF})/2$, the relative precision of signals on domestic and foreign innovations, σ_{HF}/σ_{HH}, and the volatility of noise shocks relative to productivity innovations, θ.

We set the average dispersion of private signals, $(\sigma_{HH} + \sigma_{HF})/2$, to generate a cross-sectional dispersion of expected asset price changes that matches the evidence from surveys of forecasters. More specifically, we match the standard deviation of the cross-sectional distribution of $E_t^{Hj} q_{t+1}^H$, scaled by the unconditional variance of Δq_t^H. The advantage of scaling the cross-sectional distribution this way is that the result in the model does not depend on the scale of model innovations measured by σ_a.

We measure the dispersion of expected asset price changes by using a survey from the International Center for Finance at the Yale School of Management that reports expected stock price changes by a large number of financial institutions.[27] The survey has data for two countries, the United States and Japan. For both countries the survey asks about expected percentage change in the stock price (respectively Dow Jones Industrial Index and Nikkei Dow) over the next 1, 3, and 12 months, with our parametrization focusing on the 1-year ahead forecasts. For each country the survey is based on about 400 financial institutions.[28] The survey starts in 1989 with six-month interval surveys until 1998, after which monthly surveys are conducted.[29] We have collected the data through October 2004.

Since it is important to compare expectations at the same point in time, and financial institutions do not all respond to the survey on the same day, we only consider the cross sectional distribution of responses that take place on the same day.[30] The average cross-sectional standard deviation of the expected one-year percentage stock price change across respondents is 0.1278 for the U.S. and 0.1341

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[27]We would like to thank the International Center for Finance for making these data available to us.

[28]For Japan the survey is mailed to most of the major financial institutions, including 165 banks, 46 insurance companies, 113 security companies and 45 investment trust companies. For the U.S. about 400 randomly drawn institutions are selected from "Investment Managers "in the "Money Market Directory of Pension Funds and their Investment Managers ".

[29]See Shiller et al. (1996) and http://icf.som.yale.edu/confidence.index/explanations.html for more details.

[30]Moreover, we eliminate days were there were fewer than 5 responses.

for Japan. This is scaled by the variance of stock price changes. Here we use historical numbers of the standard deviation of stock price changes from Jorion and Goetzmann (1999), which are respectively 0.1584 and 0.1579 for the U.S. and Japan. Our scaled measure of dispersion of expected stock price changes is then 4.99 for the U.S. and 5.23 for Japan. In the model we set $(\sigma_{HH} + \sigma_{HF})/2 = 0.22$, which leads to a scaled measure of dispersion of expected stock price changes of 5.03, close to that for both the U.S. and Japan.

As σ_{HF}/σ_{HH} and θ are hard to calibrate, we vary them over a wide range. Under the benchmark we set $\theta = 100$ and $\sigma_{HF}/\sigma_{HH} = 1.5$. Holding $(\sigma_{HH} + \sigma_{HF})/2 = 0.22$ remains broadly consistent with the evidence on information dispersion even when we vary θ and σ_{HF}/σ_{HH} over a wide range.[31]

The results are reported in 6 panels in Figure 3. The top 3 panels relate to Implication 1. They report the fraction of the variance of gross and net capital flows explained by unobserved state variables, as a function of respectively $(\sigma_{HH} + \sigma_{HF})/2$, σ_{HF}/σ_{HH} and θ. The bottom three panels relate to Implication 2, and report the R^2 of a regression of ε_{t+1}^D on net capital flows at time t and ε_{t+1}^A on gross capital flows at time t.

For the benchmark parameterization the fraction of the variance of both gross and net capital flows explained by unobserved state variables is 49%.[32] As expected, panel A shows that the disconnect gradually disappears when the standard deviation of the errors in the signals becomes large. In that case the private signals have little information content and the dispersion of information goes away. The scaled measure of cross-sectional dispersion of expectations of asset price changes (not reported) goes to zero as well.

Panel B shows the disconnect as a function of the extent of information asymmetry across countries. This is not relevant for net capital flows, but the disconnect for gross capital flows relies entirely on the information asymmetry. We see that introducing only a very small degree of information asymmetry is sufficient to get close to the full impact on disconnect. It makes little difference for the disconnect

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[31] The scaled measure of dispersion of expected stock price changes varies from 4.3 to 5.6 when varying σ_{HF}/σ_{HH} from 1.01 to 2. The range is 3.8 to 6.4 when we vary θ from 1 to 1000.

[32] The disconnect would be even larger if we had introduced private information about fundamentals further into the future and persistence of the noise in the model. Both features are present in Bacchetta and van Wincoop (2006) in the context of a NRE model for exchange rate determination.

whether σ_{HF} is 5% or 100% higher than σ_{HH}.[33]

Panel C shows that the disconnect is virtually independent of the variance of the noise, which is proportional to θ. We report results for θ ranging from 1 to 1000. A higher θ reduces the contribution of ε_{t+1}^D to the variance of net capital flows while raising the contribution of the noise τ_t^D, leaving the overall contribution of these unobserved state variables almost unchanged. The reduced contribution of ε_{t+1}^D is a result of the reduced information content of the relative asset price due to the increased noise. Therefore less is known about ε_{t+1}^D.

Turning to Implication 2 of the model, panel D shows that the information content of both net and gross capital flows is negatively related to the standard deviaton of the errors of the private signals. It goes to zero when the private signals become very weak (panel D). More interesting though is the difference in the information content when comparing gross and net capital flows. The last two panels show that the explanatory power of *gross* capital flows at t for ε_{t+1}^A is quite robust. Panel E shows that only a small degree of information asymmetry is required, while panel F shows that it is not sensitive to θ.

By contrast, the explanatory power of *net* capital flows at t for ε_{t+1}^D is much more limited and less robust. This is due to the noise, which only affects net capital flows and reduces its information content. Panel F shows that adding more noise through a higher θ quickly evaporates the information content of net capital flows. The R^2 of a regression of ε_{t+1}^D on net capital flows falls with θ. This reflects both the increased importance of the noise and the reduced weight of ε_{t+1}^D due to the lower information content of the relative asset price. These results on the predictive content of capital flows are consistent with the data, where we found much stronger evidence for gross than for net capital flows in forecasting future asset payoffs.

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[33]Even under the benchmark parameterization, where $\sigma_{HF}/\sigma_{HH} = 1.5$, the average absolute forecast error of Home productivity innovations is only 0.14% higher for Foreign investors than for Home investors (based on the estimated $\sigma_a = 0.0127$). To provide some perspective, Bae, Stulz and Tan (2007) report that the absolute forecast error of annual earnings per share is 7.8% higher for foreign analysts than local analysts. This is not fully comparable to our model though as it refers to earnings forecasts of individual firms rather than the entire economy. Nonetheless it shows that the extent of information asymmetry in the model is not excessive by any means.

7 Conclusion

We have shown that international capital flows share two key features of asset prices: they are largely disconnected from current publicly observed fundamentals and contain information about future fundamentals after conditioning on current fundamentals. We have shown that these features can be understood in the context of an open economy dynamic general equilibrium portfolio choice model with private information. In the process of doing so we have also integrated two large but separate literatures: the market microstructure literature in finance and the open economy DSGE literature.

In the model we have made several simplifying assumptions for the sake of tractability and transparency. Many extensions are possible, which can provide further insight into the data. For example, including additional assets such as bonds would allow one to consider whether the disconnect and information content are more prominent for some categories of assets than others. One could also introduce more dynamics by allowing for private information about fundamentals further in the future, introducing persistence in the noise and longer horizons for the agents. Such extensions will enable the model to better address the issue of disconnect at different horizons. Consistent with evidence for asset prices, the evidence in section 2 indicates that the connection between fundamentals and capital flows becomes tighter for longer horizons.

Appendix

A   Solution method

We write the various equations of the model in terms of the logs of variables, denoted by lower-case letters. The worldwide average of a variable x_t is denoted by $x_t^A = 0.5\,(x_{H,t} + x_{F,t})$, and the cross-country difference is $x_t^D = x_{H,t} - x_{F,t}$. We focus on the main steps of the solution, leaving the detailed algebra to a Technical Appendix available on request.

A.1   Signal extraction

A Home investor j infers the Home and Foreign future productivity shocks, ε_{t+1}^H and ε_{t+1}^F from three signals: the relative asset price, q_t^D, which reveals x_t^D from (21), the set private signals $v_{j,t}^{H,H}$ and $v_{j,t}^{H,F}$ in (8)-(11), and the the unconditional distribution of ε_{t+1}^H and ε_{t+1}^F. The problem faced by a Foreign investor is similar. The signal extraction consists of inferring a vector $\xi_{t+1} = \left|\varepsilon_{H,t+1}, \varepsilon_{F,t+1}\right|'$ conditional on a vector of signals $Y_t^{Hj} = \left|x_t^D, v_{j,t}^{H,H}, v_{j,t}^{H,F}, 0, 0\right|'$ which are linked as follows:

$$Y_t^{Hj} = X^H \xi_{t+1} + v_t^{Hj}$$

where X^H is a 5 by 2 matrix of zeros an ones, and v_t^{Hj} is a vector of independent innovations with a diagonal variance matrix R^H that reflects the variance of productivity shocks, the cost of investing abroad, and the errors of private signals. ξ_{t+1} is normally distributed with mean $\hat{\xi}_{t+1}$ and variance $V\left(\hat{\xi}_{t+1}\right)$ corresponding to GLS estimation:

$$\hat{\xi}_{t+1} = \left[\left(X^H\right)'\left(R^H\right)^{-1} X^H\right]^{-1}\left(X^H\right)'\left(R^H\right)^{-1} Y_t^{Hj} \quad ; \quad V\left(\hat{\xi}_{t+1}\right) = \left[\left(X^H\right)'\left(R^H\right)^{-1} X^H\right]^{-1}$$

The Home investor's expectation of future productivities is then:

$$
\begin{aligned}
E_t^{Hj}\left(\varepsilon_{H,t+1}\right) &= \alpha_{\varepsilon H,xD}^{Hj} x_t^D + \alpha_{\varepsilon H,vH}^{Hj} v_{j,t}^{H,H} + \alpha_{\varepsilon H,vF}^{Hj} v_{j,t}^{H,F} \\
E_t^{Hj}\left(\varepsilon_{F,t+1}\right) &= \alpha_{\varepsilon F,xD}^{Hj} x_t^D + \alpha_{\varepsilon F,vH}^{Hj} v_{j,t}^{H,H} + \alpha_{\varepsilon F,vF}^{Hj} v_{j,t}^{H,F}
\end{aligned}
$$

where the coefficients are complex functions. We however only need to evaluate these coefficients up to a second-order. We can show that the coefficients on x_t^D only

have components of order zero and two, and the coefficients on the private signals only have components of order two. We can then compute the various orders of the Home investor's expectations of future productivities. Similarly, we can show that the elements of $V\left(\hat{\xi}_{t+1}\right)$ only have components of order two. This allows us to compute expectations of squared and cubic combinations of productivity innovations.

A.2 Zero and First order solution

After substituting the capital accumulation equations and the expressions for portfolio returns and individual asset returns, we are left with eight equations. These are the Home and Foreign versions of the Tobin's Q equation (5), the Home and Foreign consumption Euler equations (14) and (17), the Home and Foreign portfolio Euler equations (15) and (18) and the asset market clearing conditions (19)-(20). We take worldwide averages and cross-country differences of these equations. Correspondingly, we need to solve for eight variables: q_t^D, q_t^A, c_{yt}^A, c_{yt}^D, k_{t+1}^A, k_{t+1}^D, z_t^A, z_t^D. We only discuss their zero and first-order solution here. The Technical Appendix provides all algebraic details for the zero, first as well as second-order solution.

Following the local approximation method developed by DS and TvW, we distinguish between the difference across countries in the portfolio Euler equations and all "other equations" and between z_t^D and all "other variables". The zero-order solution for the "other variables" follows directly from the zero-order component of all "other equations" (setting $\sigma_a = 0$). The zero-order component of z_t^D is solved from the second-order component of the difference across countries in portfolio Euler equations. This gives

$$z^D\left(0\right) = \frac{2\tau}{\gamma\left[E_t\left(er_{t+1}\right)^2\right]\left(2\right)} = \frac{\tau}{\gamma\sigma_a^2}\frac{1}{\left(1 - r_q + r_q\alpha_{1,qD}\left(0\right)\right)^2}\frac{1}{\Gamma} \qquad (42)$$

where r_q is a zero-order coefficient and $\Gamma \in [0,1]$ is an increasing function of λ that converges to one when private signals are infinitely noisy $(\lambda \to \infty)$.

In order to solve for the first-order components of the "other variables", we first log-linearize the "other equations" around the zero-order components of all variables, then compute expectations using the results from signal extraction and finally compute the first-order components of the equations. This yields the first-order solution for all "other variables". The first-order components of q_t^A, c_{yt}^A

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and k_{t+1}^A all depend on world average state variables k_t^A and a_t^A. The first-order components of q_t^D, k_{t+1}^D and z_t^A depend on a_t^D, k_t^D and x_t^D and the first-order component of c_{yt}^D depends on a_t^D and k_t^D.

We still need to solve for the parameter λ that enters the expression for x_t^D and for the first-order component of z_t^D. These are solved from the third-order components of the portfolio Euler equations. To compute these, we take cubic expansions of the portfolio Euler equations around the zero-order components of all variables, then compute expectations using the results from signal extraction and finally compute the third-order components. The third-order component of the average across countries of the portfolio Euler equations gives a relation in which the unobserved state variables ε_{t+1}^D and $\tau_t^D(3)/\tau$ enter both separately (in linear form) and jointly through x_t^D. We obtain λ by imposing the restriction that ε_{t+1}^D and $\tau_t^D(3)/\tau$ must enter in the same linear form as in x_t^D. This implies

$$[1 - r_q + r_q \alpha_{1,qD}(0)] \frac{\sigma_{H,H}^2 + \sigma_{H,F}^2}{\sigma_{H,H}^2 \sigma_{H,F}^2} \lambda = \frac{1 + 2\lambda^2 \theta}{2\lambda^2 \theta} \frac{\tau}{\sigma_a^2} \tag{43}$$

The first-order portfolio difference $z_t^D(1)$ is obtained from the third-order component of the difference across countries in portfolio Euler equations. Substantial algebra leads to the following solution:

$$z_t^D(1) = \frac{\left[\bar{E}_t^H er_{t+1}\right](3) - \left[\bar{E}_t^F er_{t+1}\right](3)}{\gamma \left[E_t(er_{t+1})^2\right](2)} - z^D(0) \frac{\left[E_t(er_{t+1})^2\right](3)}{\left[E_t(er_{t+1})^2\right](2)} \tag{44}$$

where $\left[\bar{E}_t^H er_{t+1}\right](3) - \left[\bar{E}_t^F er_{t+1}\right](3)$ and $\left[E_t(er_{t+1})^2\right] = [var_t(er_{t+1})](3)$ are given by (33) and (34).

B   Balance of Payments Accounting

Saving and investment

Saving is equal to income minus consumption, and is measured net of capital depreciation. The first-order components of savings (scaled by steady state wealth)

are

$$s_t^H(1) = \frac{1}{1-\bar{c}}\left[\Delta a_{H,t}(1) + (1-\omega)\Delta k_{H,t}(1)\right]$$
$$-\frac{\bar{c}}{1-\bar{c}}\Delta c_{y,t}^H(1) - \Delta q_t^A(1) - \frac{z^D(0)}{2}\Delta q_t^D(1)$$
$$s_t^F(1) = \frac{1}{1-\bar{c}}\left[\Delta a_{F,t}(1) + (1-\omega)\Delta k_{F,t}(1)\right]$$
$$-\frac{\bar{c}}{1-\bar{c}}\Delta c_{y,t}^F(1) - \Delta q_t^A(1) + \frac{z^D(0)}{2}\Delta q_t^D(1)$$

where $\Delta g_t(1) = g_t(1) - g_{t-1}(1)$. Using the first-order solution for consumption of young agents, saving is affected by information dispersion only through relative equity prices:

$$s_t^H(1) = \alpha_{sH}\Delta S_t(1) - \frac{z^D(0)}{2}\Delta q_t^D(1)$$
$$s_t^F(1) = \alpha_{sF}\Delta S_t(1) + \frac{z^D(0)}{2}\Delta q_t^D(1)$$
$$s_t^D(1) = \Delta a_t^D(1) + (1-\omega)\Delta k_t^D(1) - z^D(0)\Delta q_t^D(1)$$

where $s_t^D(1) = s_t^H(1) - s_t^F(1)$. Investment is also defined net of capital depreciation. Using the log-linearized capital accumulation and Tobin's Q equations, the first-order component of net investment (scaled by steady state wealth) is

$$i_t^{D,net}(1) = \Delta k_{t+1}^D(1) = \frac{1}{\xi}q_t^D(1)$$

Capital flows

The passive portfolio share combines the steady-state holdings of quantities of assets with the actual asset prices. Its first-order component is the same for all investors and reflects the relative asset price:

$$z_t^p(1) = z_H(0)(1 - z_H(0))q_t^D(1)$$

Using the difference between the first-order components of the asset market clearing conditions (19)-(20) we get:

$$\Delta z_t^A(1) - \Delta z_t^p(1) = \frac{1}{4}\left[i_t^{D,net}(1) - z^D(0)s_t^D(1)\right] \tag{45}$$

Gross capital outflows and inflows reflect the changes in the value of cross-border asset holdings, evaluated at current prices. The first-order components of capital outflows and inflows are

$$outflows_t(1) = (1 - z_H(0))s_t^H(1) - (\Delta z_t^H(1) - \Delta z_t^p(1)) \qquad (46)$$

$$inflows_t(1) = (1 - z_H(0))s_t^F(1) + (\Delta z_t^F(1) - \Delta z_t^p(1)) \qquad (47)$$

The first term reflects portfolio growth, while the second term reflects portfolio reallocation (changes in portfolio shares in deviation from the passive share). Using $\Delta z_t^H(1) - \Delta z_t^p(1) = (\Delta z_t^A(1) - \Delta z_t^p(1)) + 0.5 z_t^D(1)$, and substituting the expressions for $z_t^D(1)$ and $\Delta z_t^H(1) - \Delta z_t^p(1)$ from (44) and (45), gives the first-order expression (35) for capital outflows. The first-order expression (36) for capital inflows follows analogously, using that $\Delta z_t^F(1) - \Delta z_t^p(1) = (\Delta z_t^A(1) - \Delta z_t^p(1)) - 0.5 z_t^D(1)$.

C Data Appendix

Here follows a description of the data used in section 5.

Capital Flows: Quarterly data on capital flows are obtained from the IMF International Financial Statistics (IFS). Capital outflows are computed as the sum of direct investment abroad, portfolio investment assets and other investment assets. Capital inflows are the sum of direct investment liabilities, portfolio investment liabilities and other investment liabilities. Net capital flows is alternatively computed as capital outflows minus inflows or the current account (also from the IFS). All capital flow data are converted from dollars to the local currency by multiplying with the quarterly exchange rate (IFS), and are scaled by the gross domestic product (IFS, seasonally adjusted). When computing annual net and gross capital flows we first aggregate over the quarterly data before dividing by annual GDP. These data are used in the VAR analysis and Granger causality tests.

interest rates: We use the Treasury bill rate from the IFS, with the exception of France, where the short-term rate from the OECD Economic Outlook is used. The latter is very close to the Treasury bill rate from the IFS, but that series is not available after Q3, 2004. Annual interest rates are computed by averaging over the quarterly data. These data are used in the VAR analysis and Granger causality tests.

real GDP growth: Quarterly GDP growth is computed as the change in the log seasonally adjusted GDP volume from the IFS. Annual GDP growth is based on annual GDP volume data from the IFS. They are used in the VAR analysis and Granger causality tests.

real investment growth: Annual investment growth is computed as the growth rate of annual total gross fixed capital formation (volume) from the OECD Economic Outlook. These data are used in the calibration of the model, which matches the standard deviation of average real investment growth relative to annual real GDP growth, with the latter also computed with OECD Economic Outlook data.

inflation: Quarterly inflation is computed as the quarterly change in the log CPI from the IFS. Annual inflation is computed after first averaging the price indices for each quarter. These data are used in the VAR analysis and Granger causality tests.

budget deficit: We use quarterly data on government net lending as a percentage of GDP, from the OECD Economic Outlook, as a measure of the budget deficit. These data are not available for Germany and France, for which we therefore omit the budget deficit from the quarterly VAR analysis. Annual data are available from the OECD Economic Outlook for all countries and are used in the annual VAR analysis and Granger causality test.

profit rate: The annual profit rate is computed as nominal GDP minus employee compensation, divided by the value of the capital stock. The latter is computed as the product of the volume of the capital stock for the total economy and the deflator of total gross fixed capital formation. All data are from the OECD Economic Outlook. These data are used in the Granger causality tests.

labor share: The labor share is computed as the ratio of total employee compensation to nominal GDP, both from the OECD Economic Outlook. These data are used for the calibration of the model, which matches the average labor share in the data.

Solow Residual: Annual Solow residuals are computed using data on GDP volume, total employment and the volume of the capital stock for the total economy, all from the OECD Economic Outlook. The log Solow residual is then computed as $a_{it} = y_{it} - \omega n_{it} - (1 - \omega)k_{it}$, where y_{it}, n_{it} and k_{it} are respectively log GDP, log

employment and log capital stock and ω is the estimated labor share. These data are used to compute the persistence of a_{it} in the calibration of the model.

References

[1] Albuquerque, Rui, Gregory H. Bauer and Martin Schneider (2008), "Global Private Information in International Equity Markets,"*Journal of Financial Economics*, forthcoming.

[2] Albuquerque, Rui, Gregory H. Bauer and Martin Schneider (2007), "International Equity Flows and Returns: A Quantitative Equilibrium Approach,"*Review of Economic Studies* 74(1), 1-30.

[3] Albuquerque, Rui, Eva de Francisco and Luis B. Marques (2008), "Marketwide Private Information in Stocks: Forecasting Currency Returns,"*Journal of Finance* 63(5), 2297-2343.

[4] Bacchetta, Philippe and Eric van Wincoop (2004), "A Scapegoat Model of Exchange Rate Fluctuations,"*American Economic Review, Papers and Proceedings*, May 2004, 114-118.

[5] Bacchetta, Philippe and Eric van Wincoop (2006), "Can Information Heterogeneity Explain the Exchange Rate Determination Puzzle? ," *American Economic Review* 96(3), 552-576.

[6] Bacchetta, Philippe and Eric van Wincoop (2008), "Higher Order Expectations in Asset Pricing," *Journal of Money, Credit and Banking* 40(5), 837-866.

[7] Backus, David K., Patrick J. Kehoe and Finn E. Kydland (1992), "International Real Business Cycles," *Journal of Political Economy* 100(4), 745-775.

[8] Bae, Kee-Hong, Hongping Tan and Rene M. Stulz (2007), "Do Local Analysts Know More? A Cross-Country Study of Performance of Local Analysts and Foreign Analysts," *Journal of Financial Economics*, forthcoming.

[9] Beaudry, Paul and Franck Portier (2003), Stock Prices, News and Economic Fluctuations, NBER working paper 10548.

[10] Brennan, Michael J. and H. Henry Cao (1997), "International Portfolio Investment Flows," *The Journal of Finance* 52, 1851-1880.

[11] Devereux, Michael B. and Charles Engel (2006), Expectations and Exchange Rate Policy, NBER working paper 12213.

[12] Devereux, Michael B. and Alan Sutherland (2007), "Country Portfolio Dynamics," working paper, University of British Columbia.

[13] Dow, James and Gary Gorton (1995), "Profitable Informed Trading in a Simple General Equilibrium Model of Asset Pricing," *Journal of Economic Theory* 67, 327-369.

[14] Evans, Martin D. D., and Richard K. Lyons (2002), "Order Flow and Exchange Rate Dynamics," *Journal of Political Economy* 110, 170-180.

[15] Evans, Martin D. D., and Richard K. Lyons (2007), "Exchange Rate Fundamentals and Order Flow," working paper, Georgetown University.

[16] Evans, Martin D.D. and Viktoria Hnatkovska (2008), "Solving General Equilibrium Models with Incomplete Markets and Many Financial Assets," working paper, Georgetown University.

[17] Fidora, Michael, Marcel Fratzscher and Christian Thimann (2007), "Home Bias in Global Bond and Equity Markets: The Role of Real Exchange Rate Volatility," *Journal of International Money and Finance* 26, 631-655.

[18] Gehrig, Thomas (1993), "An Information Based Explanation of the Domestic Bias in International Equity Investment, "*Scandinavian Journal of Economics* 95(1), 97-109.

[19] Gennotte, Gerard and Hayne Leland (1990), "Market Liquidity, Hedging and Crashes," *The American Economic Review* 80(5), 999-1021.

[20] Hasbrouck, Joel (1991), "Measuring the Information Content of Stock Trades," *Journal of Finance* 46, 179-207.

[21] Jaimovich, Nir and Sergio Rebelo (2008), Can news About the Future Drive the Business Cycle?, working paper, Northwestern University.

[22] Jorion, Philippe, and Will Goetzmann (1999), "Global Stock Markets in the Twentieth Century," *Journal of Finance* 54, 953-980.

[23] Leuz, Christian, Karl V. Lins, and Francis E. Warnock (2008), "Do Foreigners Invest Less in Poorly Governed Firms?, "*Review of Financial Studies*, forthcoming.

[24] Lorenzoni, Guido (2007), News Shocks and Optimal Monetary Policy, NBER Working paper 12898.

[25] Osler, Carol (2008), "Foreign Exchange Microstructure: A Survey," forthcoming in *Encyclopedia of Complexity and System Science.*

[26] Shiller, Robert J., Fumiko Kon-Ya and Yoshiro Tstsui (1996), "Why did the Nikkei Crash? Expanding the Scope of Expectations Data Collection," *Review of Economics and Statistics* 78(1), 156-164.

[27] Spiegel, M. and A. Subrahmanyam (1992), "Informed Speculation and Hedging in a Noncompetitive Securities Market," *The Review of Financial Studies* 5, 307-329.

[28] Tille, Cedric and Eric van Wincoop (2008), "International Capital Flows," CEPR Discussion paper 6705.

[29] Veldkamp, Laura and Stijn van Nieuwerburgh (2008), "Information Immobility and the Home Bias Puzzle, "*Journal of Finance*, forthcoming.

[30] Wang, Jiang (1994), "A Model of Competitive Stock Trading Volume," *Journal of Political Economy* 102, 127-168.

Figure 1 Modeling Contribution

Info dispersion   Portfolio choice   GE   Non linearity

standard DSGE

NRE   DSGE with portfolio

Our model
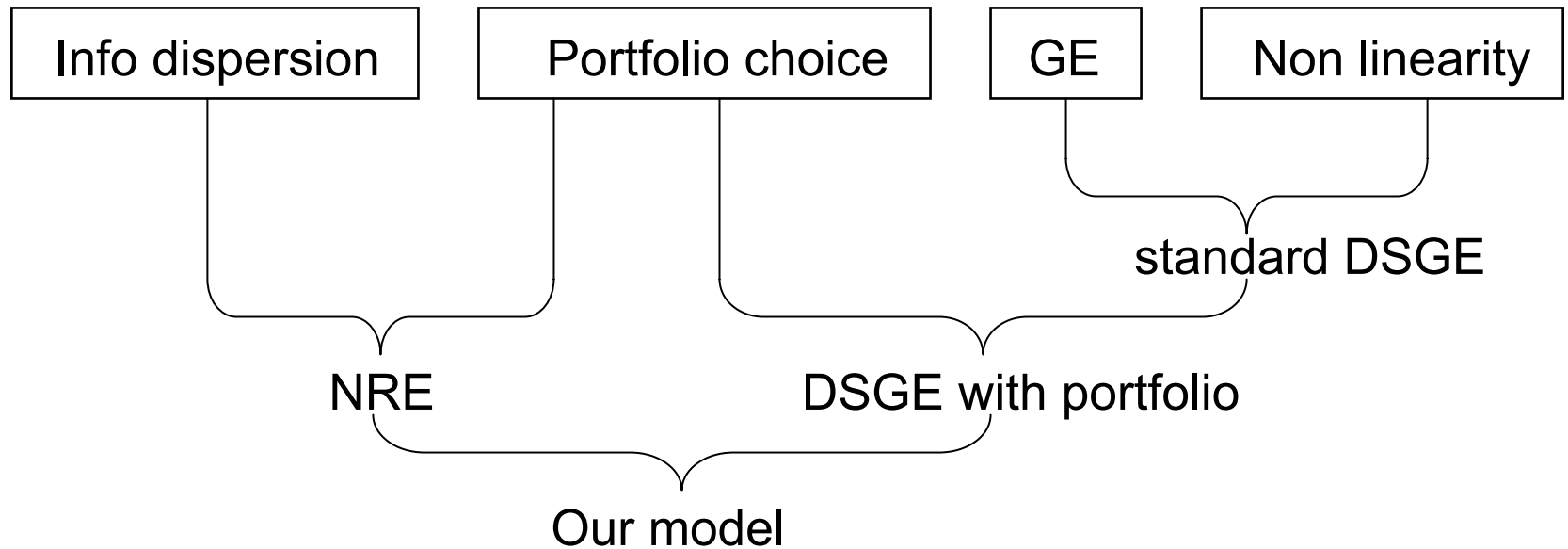
Figure 2 Role of Information Dispersion

$$\tau_t^D \qquad \qquad \varepsilon_{t+1}^D \qquad \qquad \qquad \qquad \varepsilon_{t+1}^A$$

$$q_t^D \qquad \qquad [\bar{E}_t^H er_{t+1}](3) - [\bar{E}_t^F er_{t+1}](3)$$

saving, investment

portfolio growth $\qquad [\bar{E}_t^A er_{t+1}]^{IS}(3)$

| Net Capital Flows | Gross Capital Flows |

Figure 3 Results From Model Simulation*

Panel A Share of Variance Explained by Unobserved Fundamentals

gross capital flows

net capital flows

$(\sigma_{HH}+\sigma_{HF})/2$

Panel B Share of Variance Explained by Unobserved Fundamentals

net capital flows

gross capital flows

σ_{HF}/σ_{HH}

Panel C Share of Variance Explained by Unobserved Fundamentals

gross capital flows

net capital flows

θ

Panel D R^2 of regression of $\varepsilon_{t+1}^{D}, \varepsilon_{t+1}^{A}$ on respectively net and gross capital flows

gross capital flows

net capital flows

$(\sigma_{HH}+\sigma_{HF})/2$

Panel E R^2 of regression of $\varepsilon_{t+1}^{D}, \varepsilon_{t+1}^{A}$ on respectively net and gross capital flows

gross capital flows

net capital flows

σ_{HF}/σ_{HH}

Panel F R^2 of regression of $\varepsilon_{t+1}^{D}, \varepsilon_{t+1}^{A}$ on respectively net and gross capital flows

gross capital flows

net capital flows

θ

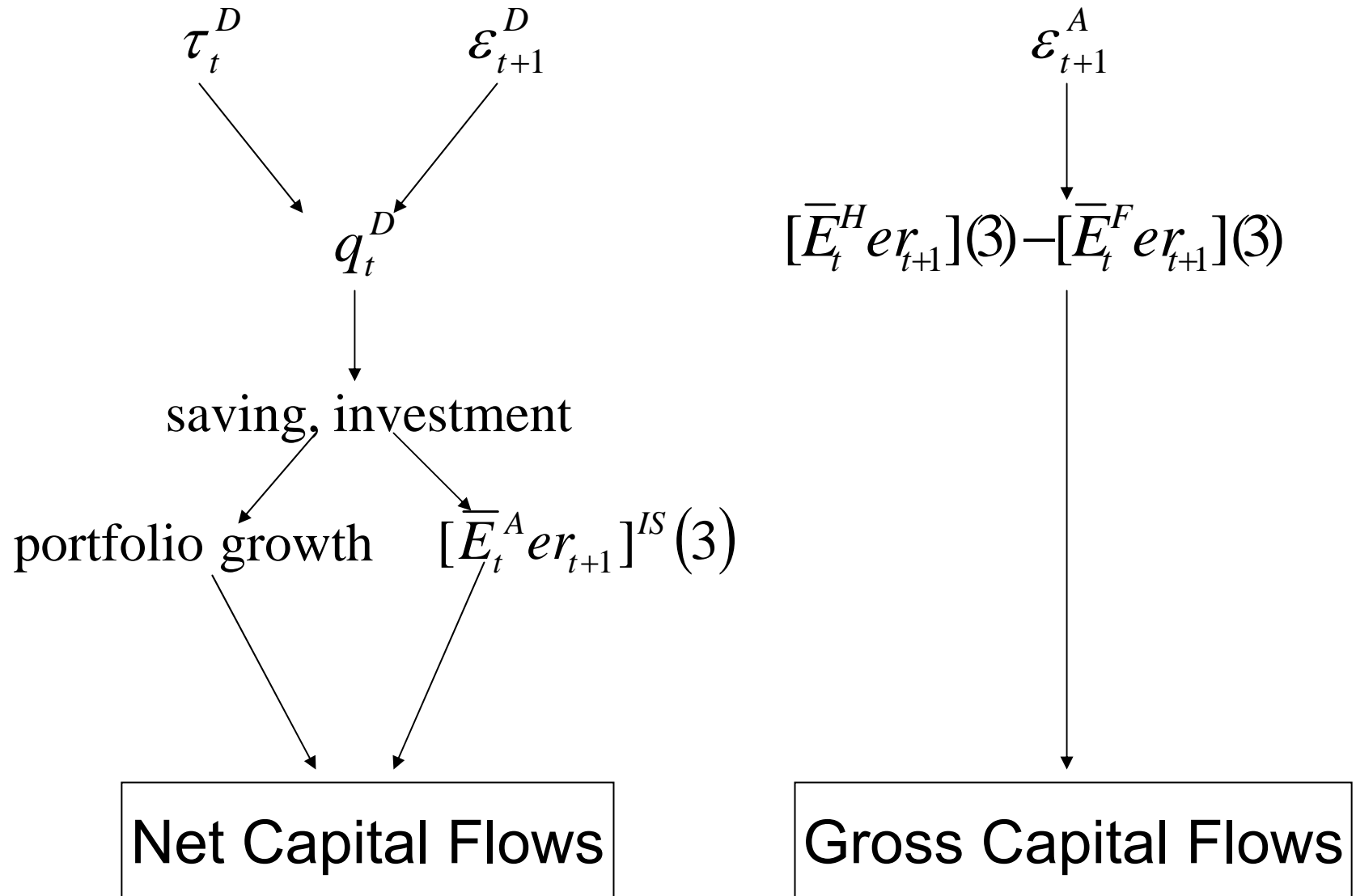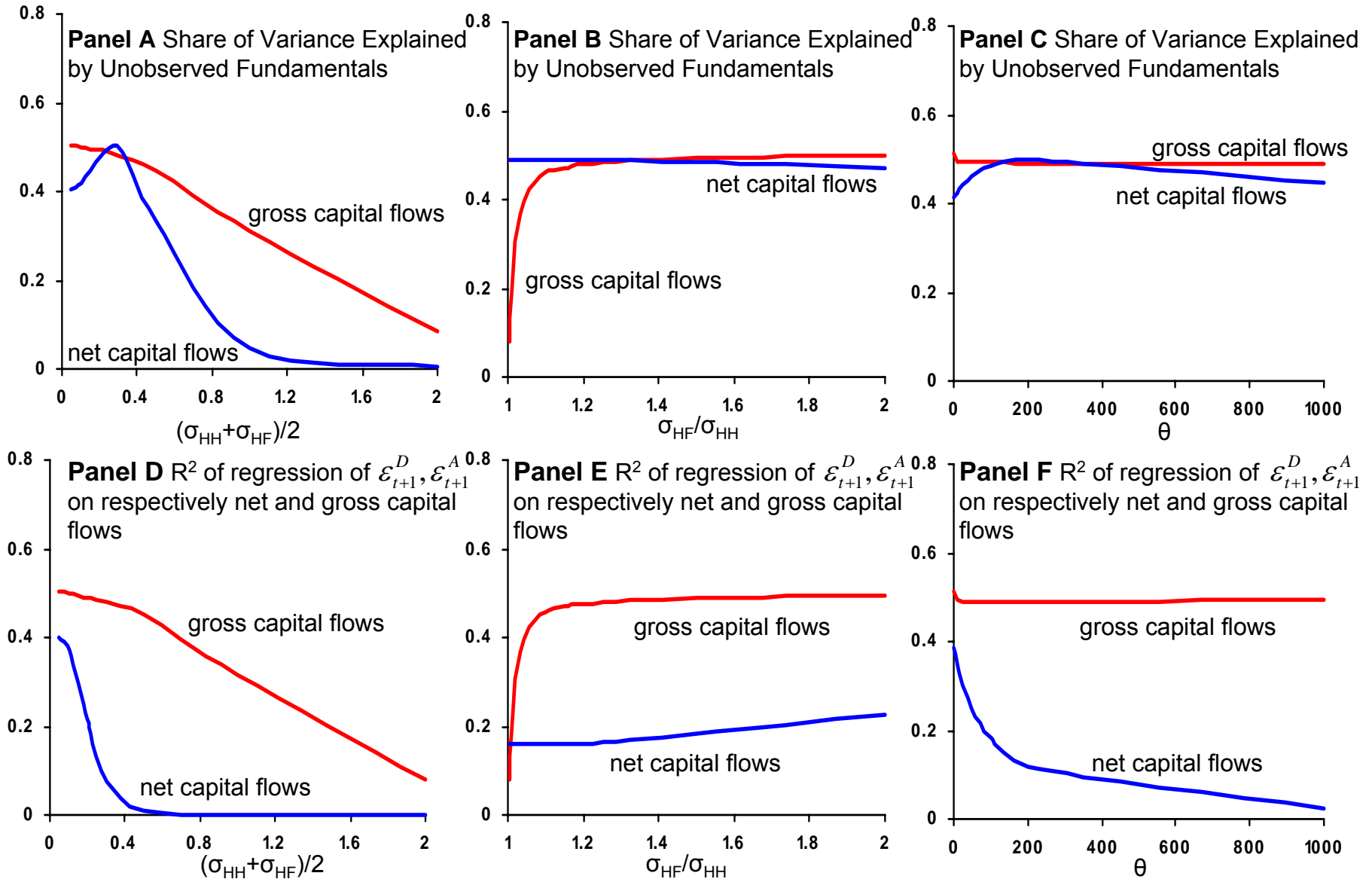*Gross Capital flows=capital outflows+capital infows; Net capital flows=capital outflows-capital inflows. Results are based on a simulation of the model over 100,000 periods.

Table 1. Percentage Variance of Gross and Net Capital Flows Accounted for by Macro Fundamentals: Quarterly Data, 1977(1)-2007(2)

Capital flow measure	Outflows+Inflows (% GDP)			Current Account (% GDP)		
Horizon	1 quarter	4 quarters	12 quarters	1 quarter	4 quarters	12 quarters
United States	4	11	16	17	36	48
Japan	1	9	14	5	37	55
Canada	4	18	22	4	18	35
United Kingdom	11	14	18	9	10	13
Germany	13	10	16	5	22	33
France	2	7	11	2	6	10
Average	**6**	**12**	**16**	**7**	**22**	**32**

Table 2. Percentage Variance of Gross and Net Capital Flows Accounted for by Macro Fundamentals: Annual Data, 1977-2006

Capital flow measure	Outflows+Inflows (%GDP)			Current Account (%GDP)		
Horizon	1 year	2 years	3 years	1 year	2 years	3 years
United States	33	38	47	53	63	69
Japan	10	20	32	51	55	56
Canada	35	39	40	44	61	68
United Kingdom	10	10	17	10	25	33
Germany	25	29	34	28	56	65
France	10	7	7	16	22	26
Average	**21**	**24**	**30**	**34**	**47**	**53**

Notes. The tables report the contribution of macro variables to gross and net capital flows. It is based on a VAR of real GDP growth, the inflation rate, the T-bill rate, the budget deficit as a fraction of GDP and the measure of gross or net capital flows in the first row of the tables (as fraction of GDP). Identification is achieved using the Cholesky decomposition with the ordering of the variables as in the previous sentence. For VARs including gross capital flows (sum of capital inflows and outflows), the macro-variables are computed as a GDP-weighted average of the six countries in the sample. For the VARs including net capital flows (the current account), the macro-variables are equal to that variable in the country minus a GDP-weighted average of that in the other countries. The results of table 1 are based on 122 quarterly observations from 1977(1) to 2007(2), with three lags of each variable. The table reports the total contribution of innovations of all four macro fundamentals to the variance of gross and net capital flows over 1, 4 and 12-quarter horizons. The results of table 2 are based on 30 annual observations from 1977 to 2006, with one lag of each variable. The table reports the total contribution of innovations of all four macro fundamentals to the variance of gross and net capital flows over 1, 2 and 3-year horizons.

Table 3. Granger Causality Test of "World Profit Rate" by Capital Inflows+Outflows (% GDP): Annual Data, 1977-2006

Control variables	Bivariate	Multivariate	
		World GDP Growth, interest rate, inflation	World GDP Growth, interest rate, inflation, budget deficit
United States	-	2.9	-
Japan	-	-	-
Canada	0.1	0.2	4.5
United Kingdom	2.3	1.3	6.9
Germany	2.9	0.0	4.7
France	1.7	0.4	9.4
# significant at 10%	**4**	**5**	**4**

Table 4. Granger Causality Test of "Relative Profit Rate" by Net Capital Flows: Annual Data, 1977-2006.

Control variables	Bivariate		Multivariate			
			Relative GDP growth, interest rate, inflation		Relative GDP growth, interest rate, inflation, budget deficit	
Capital flow measure	CA	outflows-inflows	CA	outflows-inflows	CA	outflows-inflows
United States	-	-	-	-	-	-
Japan	-	-	-	-	-	-
Canada	-	-	-	-	-	-
United Kingdom	1.3	1.6	1.0	-	2.8	-
Germany	-	-	-	-	-	-
France	3.5	5.0	-	-	-	-
# significant at 10%	**2**	**2**	**1**	**0**	**1**	**0**

Notes. Table 3 reports p-values (in %) from the F-test that the sum of inflows and outflows (scaled by GDP) does not Granger cause the world profit rate. Table 4 reports p-values (in %) from the F-test that net capital flows do not Granger cause the relative profit rate. A value of 2.5 for example indicates that the null of no Granger causality is rejected at the 2.5% level. The results are based on annual data from 1977 to 2006 with one lag for all variables. The profit rate is equal to GDP minus employee compensation, divided by the capital stock. The wor1d profit rate used in table 3 is defined as a GDP-weighted average of profit rates of all 6 countries. The relative profit rate used in table 4 is defined as the profit rate in a country relative to a GDP-weighted average of that in the other countries. The tables only report p-values for countries where there is significance at the 10% level or better. The multivariate Granger Causality test results in columns 3 and 4 introduce respectively 3 and 4 control variables. These are real GDP growth, the T-bill rate and the CPI inflation rate (column 3), with the budget deficit as a share of GDP added in column 4. Table 3 takes GDP-weighted averages of these variables, while table 4 takes values relative to the other countries.