International Capital Flows and Asset Prices: Two Peas in a Pod[1]

Cedric Tille
Geneva Graduate Institute HEID and CEPR

Eric van Wincoop
University of Virginia and NBER

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Abstract

It is a well established fact that asset prices are determined by both public information and private information that is widely dispersed among investors. In this paper we argue that international capital flows are similarly affected by both public and private information. Agents trade based on private information, which affects both prices and quantities (i.e. capital flows). We shed light on the role of private information in determining capital flows by developing a two-country DSGE model with dispersed private information. We show that dispersed information has many substantial implications for capital flows: it increases the volatility of both net and gross capital flows; it leads to a high correlation between capital inflows and outflows; it leads to a disconnect of capital flows from observed macro fundamentals; and it implies that capital flows contain information about the future state of the economy. In a calibration of the model we show that these implications are quantitatively large.

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1 Introduction

Asset prices are determined by both public information and information that is widely dispersed among investors. This implies that asset prices cannot be fully explained by current and past publicly available information alone.[1] Moreover, asset prices contain information about the future beyond that available from public information. A large literature has investigated models with dispersed private information and shown that such models connect well with the data in many respects.[2] In this paper we argue that dispersed information should similarly affect international capital flows, as agents' trades affect both prices and quantities (i.e. capital flows). We shed light on the impact of dispersed information on international capital flows by developing a general equilibrium open economy model that integrates the literature on "noisy rational expectation" (NRE) models, standard macro DSGE models and recent advances in the modeling of international portfolio choice.

A substantial literature has rejected present value current account (net capital flow) models that are based on public information.[3] Broner et.al. (2010) argue that gross capital flows are inconsistent with a model where domestic and foreign agents have the same information. Expected returns then move in the same direction for domestic and foreign investors, and so will their portfolio flows. This stands in stark contrast to the data, where capital inflows and outflows are highly positively correlated. Also, when all agents have identical public information, it is hard to explain the large simultaneous buying and selling of foreign securities by U.S. investors (Albuquerque, Bauer and Schneider, 2007).

We show that dispersed information has important implications for gross and net capital flows.[4] First, it implies that capital flows contain information about the

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[1] The disconnect between asset prices and public information has received a lot of attention in the exchange rate literature. But it also applies to equity prices (e.g. Roll ,1988).

[2] See Brunnermeier (2001) for a survey of the literature. Among many others, it can explain trading volume and its connection to asset prices, asset price bubbles and crashes, herd behavior and the relationship between asset prices and order flow.

[3] See Sheffrin and Woo (1990), Otto (1992), Ghosh (1995), Bergin and Sheffrin (2000), Nason and Rogers (2006). In a previous version of this paper, Tille and van Wincoop (2009), we show that for 6 industrialized countries standard macro variables such as GDP growth, interest rates, inflation and the budget deficit can on average account for only 22% of the variance of the current account over a 4-quarter horizon.

[4] Gross outflows are net purchases of foreign assets by domestic residents. Gross inflows are

future state of the economy beyond what can be learned from publicly available information alone. Second, it implies that capital flows cannot be fully explained by publicly observed macro developments. Third, we show that dispersed information substantially increases the volatility of capital flows. Finally, we show that it generates a strongly positive correlation between capital inflows and outflows as seen in the data.

We shed light on the role of dispersed information in impacting international capital flows by integrating three literatures. The first is the NRE literature in finance. As in standard NRE models, we assume that agents have both private information about future fundamentals (hence asset payoffs) and private information unrelated to future fundamentals. The latter generates "noise" in the form of unobserved portfolio shifts, which prevent asset prices from fully revealing the private information about future fundamentals.

The second literature is the standard DSGE literature in macroeconomics within which the existing literature on international capital flows is framed. 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.

The third literature has developed only recently and introduces portfolio choice into open economy DSGE models in which financial markets are generally incomplete.[5] This allows us to relate international capital flows to changes in expected returns, risk and wealth.[6] New solution techniques have been developed to handle such models.

Figure 1 further illustrates the connection to these three literatures. Our model contains four ingredients: information dispersion, portfolio choice, non-linearities and a general equilibrium structure. Standard macro DSGE models only con-

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net purchases of domestic assets by foreign residents. Net flows are the difference between the two.

[5] See for example Devereux and Sutherland (2010), Tille and van Wincoop (2010) and Evans and Hnatkovska (2005), Coeurdacier and Gourinchas (2009) and Coeurdacier et.al. (2010).

[6] Most of the prior literature assumed either trade in just a riskfree bond or complete financial markets. Obstfeld and Rogoff (1996) argue that under complete financial markets capital flows are "...merely an accounting device for tracking the international distribution of new equity claims foreigners must to maintain the efficient global pooling of national output risks."

tain the last two ingredients. Recent contributions introducing portfolio choice in DSGE models include the last three ingredients, but not the first one. NRE models only contain the first two ingredients. They 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.[7] 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 international capital flows have been analyzed in the literature.

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 (2007,2009), Bacchetta and van Wincoop (2004,2006), Brennan and Cao (1997), Gehrig (1993) and Veldkamp and van Nieuwerburgh (2009). 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 describes the model. The solution method is discussed in a companion paper, Tille and van Wincoop (2011). Section 3 derives implications for asset prices and portfolio allocation. Section 4 derives implications for gross and net capital flows and discusses the impact of dispersed information on capital flows. Section 5 calibrates the model in order to quantitatively assess the impact of dispersed information on the volatility of capital flows, the correlation between capital inflows and outflows, the disconnect from observed fundamentals and the predictive content about future fundamentals. Section 6 concludes.

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[7] 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.

2 The Model

The model 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, 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 and consumption decisions. We also keep the number of state variables small for simplicity. What matters is not how many state variables there are, but rather the distinction between observed and unobserved state variables. Unobserved state variables are a direct result of 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 same 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.

2.1 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 entails a quadratic adjustment cost and requires the following amount in units of the consumption good:

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

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

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

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

2.2 Private Information

We import the two key elements of NRE models: private information about future fundamentals and private information unrelated to future fundamentals. We introduce these elements to the model as follows.

Private Information About Future Fundamentals

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

$$v_{j,t}^{H,H} = \varepsilon_{H,t+1} + \epsilon_{j,t}^{H,H} \qquad \epsilon_{j,t}^{H,H} \sim N\left(0, \sigma_{HH}^2\right) \tag{8}$$

$$v_{j,t}^{H,F} = \varepsilon_{F,t+1} + \epsilon_{j,t}^{H,F} \qquad \epsilon_{j,t}^{H,F} \sim N\left(0, \sigma_{HF}^2\right) \tag{9}$$

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

$$v_{j,t}^{F,H} = \varepsilon_{H,t+1} + \epsilon_{j,t}^{F,H} \qquad \epsilon_{j,t}^{F,H} \sim N\left(0, \sigma_{HF}^2\right) \tag{10}$$

$$v_{j,t}^{F,F} = \varepsilon_{F,t+1} + \epsilon_{j,t}^{F,F} \qquad \epsilon_{j,t}^{F,F} \sim N\left(0, \sigma_{HH}^2\right) \tag{11}$$

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.[8]

Private Information Unrelated to Future Fundamentals

A central ingredient of NRE models is the presence of unobservable noise, which usually takes the form of exogenous "noise" or "liquidity" trade unrelated

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[8] See for example Bae, Stulz and Tan (2007), who document that earnings forecasts are more precise for local than foreign analysts. Leuz, Lins and Warnock (2009) provide evidence that agency problems are better monitored by locals. Ahearne et.al. (2004) find that home bias of U.S. investors relative to other countries is significantly reduced when the stock of foreign countries is traded on centralized exchanges. This reduces information barriers as a result of the regulatory and accounting burden imposed on such foreign firms. Portes and Rey (2005) find that "the geography of information is the main determinant of the pattern of international (financial) transactions", documenting the effect of a variety of informational frictions on cross-border equity flows. Kang and Stulz (1997) document that investors tend to invest in foreign firms for which information barriers are lower (large firms with good accounting performance, low unsystematic risk and low leverage).

to portfolio optimization. In the absence of noise the asset price would fully reveal the aggregate private information about future fundamentals $\varepsilon_{H,t+1}$ and $\varepsilon_{F,t+1}$. While agents have private information about their own liquidity, noise or hedge trades, they do not observe that of others and therefore do not know the aggregate. Some papers have introduced it endogenously in various forms of hedge trade and liquidity trade.[9]

For our purposes the existence of noise is more important than its exact nature. We introduce 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.

Fluctuations around τ include both agent-specific and country-specific components. The average cost faced by Home investors in period t is τ_{Ht}, which is unobserved. We assume $\tau_{H,t} = \tau\left(1 + \varepsilon_t^{\tau}\right)$, where ε_t^{τ} has a $N(0, \theta\sigma_a^2)$ distribution. An individual investor making a portfolio decision at time t knows her own cost $\tau_{Hj,t}$, but not the aggregate cost $\tau_{H,t}$. We assume that the individual cost is an infinitely noisy signal of the average cost. This assumption can be relaxed but simplifies the analysis.[10] 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 fully revealing private information

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

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

about future productivity.

2.3 Consumption and Portfolio Choice

We adopt an overlapping generation structure, which assures a well-defined stationary distribution of wealth across countries. A young Home agent j at time t chooses her consumption and portfolio to maximize

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

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

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

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

The intertemporal consumption Euler equation implies

$$C_{y,t}^{Hj}=\frac{1}{1+\beta}W_{H,t} \tag{14}$$

Consumption is a constant fraction of labor income and so is saving:

$$S_{y,t}^{Hj}=\frac{\beta}{1+\beta}W_{H,t} \tag{15}$$

The portfolio Euler equation is

$$E_t^{Hj}\left(R_{t+1}^{p,Hj}\right)^{-1}\left(R_{H,t+1}-R_{F,t+1}e^{-\tau_{Hj,t}}\right)=0 \tag{16}$$

(16) 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 inversely proportional to the return on the agent's portfolio. A central aspect of our model is that (16) is evaluated with expectations that can differ across individual agents.

Foreign agents face an analogous decision problem with portfolio return

$$R_{t+1}^{p,Fj}=z_{Fj,t}e^{-\tau_{Fj,t}}R_{H,t+1}+(1-z_{Fj,t})R_{F,t+1} \tag{17}$$

The corresponding optimality conditions for a Foreign investor j give:

$$C_{y,t}^{Fj} = \frac{1}{1+\beta} W_{F,t} \tag{18}$$

$$E_t^{Fj} \left(R_{t+1}^{p,Fj} \right)^{-1} \left(R_{H,t+1} e^{-\tau_{Fj,t}} - R_{F,t+1} \right) = 0 \tag{19}$$

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 $z_{F,t} = \int_0^1 z_{Fj,t} dj$.

2.4 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. We denote the financial wealth in country i, which is equal to saving by the young, as $W_{i,t}^F = \beta W_{i,t}/(1+\beta)$. The goods market equilibrium condition is then

$$\begin{aligned} Y_{H,t+1} + Y_{F,t+1} &= Q_{H,t+1} I_{H,t+1} + Q_{F,t+1} I_{F,t+1} + \frac{1}{1+\beta} W_{H,t} + \frac{1}{1+\beta} W_{F,t} \\ &+ W_{H,t}^F \left(z_{H,t} R_{H,t+1} + (1 - z_{H,t}) R_{F,t+1} \right) + W_{F,t}^F \left(z_{F,t} R_{H,t+1} + (1 - z_{F,t}) R_{F,t+1} \right) \end{aligned}$$

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.[11]

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 asset market clearing conditions are then

$$Q_{H,t} K_{H,t+1} = W_{H,t}^F z_{H,t} + W_{F,t}^F z_{F,t} \tag{20}$$

$$Q_{F,t} K_{F,t+1} = W_{F,t}^F (1 - z_{H,t}) + W_{F,t}^F (1 - z_{F,t}) \tag{21}$$

2.5 Solution

The solution method is described in a companion paper, Tille and van Wincoop (2011). The solution combines and extends methods for solving standard NRE models with recently developed local approximation methods for solving DSGE

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

models with portfolio choice (Devereux and Sutherland (2010), Tille and van Wincoop (2009)). A Technical Appendix provides full algebraic detail. While we will not describe details of the solution method here, which would lead to a significant technical detour, a couple of comments are needed in order to interpret the results in the next section.

There are two types of model innovations: productivity shocks and noise shocks. We hold constant the standard deviation of noise shocks relative to technology shocks, $\sqrt{\theta}$, and therefore refer to σ_a as the standard deviation of all model shocks. Any variable x_t can be decomposed into components of all orders. The zero-order component, denoted $x(0)$, is the level of x_t when $\sigma_a \rightarrow 0$. The first-order component $x_t(1)$ is linear in model innovations, or in the standard deviation σ_a of model innovations. The second-order component $x_t(2)$ depends linearly on the product of two model innovations (or the square of a single innovation) or the variance or covariance of innovations. Higher orders are defined analogously. In the next section we focus on first-order solutions for asset prices, portfolio allocation and capital flows. But as we will see, this requires also solving second and third-order components of some other variables.

It is useful to stress a conceptual distinction between σ_a on the one hand and σ_{HH} and σ_{HF} on the other hand. σ_a is a measure of volatility, by which we mean the magnitude of random shocks. σ_{HH} and σ_{HF} by contrast measure uncertainty, which relates to the precision of agents' information about these shocks. As signal errors are not shocks to the model, we assume that σ_{HH} and σ_{HF} are zero-order constants. Notice that this implies that the private signals are weak as the unconditional distribution of the productivity innovations has a variance of σ_a^2 that is much smaller (second-order). We will show that these weak private signals nonetheless have a significant impact on asset prices and capital flows.

Apart from the conceptual distinction, the "weak" private signals are also needed to have a well-defined distribution of optimal portfolio shares across agents. As discussed in Tille and van Wincoop (2011), if we assumed that σ_{HH} and σ_{HF} are first-order, the difference in expected returns across agents would be first-order as well. As optimal portfolios divide expected returns by the variance of the excess return, which is second-order, the difference in portfolio shares across agents would be of order -1, which means that it would explode to plus or minus infinity when $\sigma_a \rightarrow 0$. Intuitively, agents' expectations about returns would be so different as to dominate risk and agents would take infinite long or short positions in assets.

The solution of the model involves mapping of the state variables into all control variables. The difference with standard macro models that are entirely based on public information is that there are now also unobserved state variables. There are 4 observed and 3 unobserved state variables. The observed state variables are:

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

Here a D and A stand for respectively the difference across countries and the average, so that $a_t^D = a_t^H - a_t^F$ and $a_t^A = (a_t^H + a_t^F)/2$. The lower case k stands for the log of the capital stock. The three unobserved state variables are ε_{t+1}^D, ε_{t+1}^A and τ_t^D. Control variables at time t will depend on ε_{t+1}^D and ε_{t+1}^A as agents trade based on private information about future technology innovations. They also depend on τ_t^D, which aggregates private information about financial frictions and generates unobserved portfolio shifts.

3 Asset Prices and Portfolio Allocation

3.1 Asset Prices

Denoting equity prices in logs with a lower case q, the first-order solution for the average asset price and the relative asset price is

$$\begin{aligned} q_t^A(1) &= \frac{\xi}{1+\xi}\left(a_t^A(1) - \omega k_t^A(1)\right) && (23) \\ q_t^D(1) &= \alpha_{1,qD}(0)\, a_t^D + \alpha_{3,qD}(0)\, k_t^D(1) + \alpha_{5,qD}(0)\left(\varepsilon_{t+1}^D + \lambda \tau_t^D(3)/\tau\right) && (24) \end{aligned}$$

Here the coefficients α and λ are zero-order constants. We assume that the average cost τ of investing abroad is a second-order constant (of the same order as σ_a^2).

First consider the global asset price (23). It depends on the average of the two observed state variables, technology and the capital stock. It does not depend on any of the unobserved state variables. Intuitively the global asset price is driven by global asset demand, which in turn depends on global saving. Global saving is proportional to global labor income and therefore does not depend on private information.[12]

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[12] This proportionality follows from our assumption of a log utility of consumption and is therefore not a general feature.

The relative price, on the other hand, is driven by both observed and unobserved state variables. Particularly, the relative price depends positively on

$$h_t = \varepsilon_{t+1}^D + \lambda \tau_t^D(3)/\tau$$

Both the unobserved state variables ε_{t+1}^D and τ_t^D have a first-order impact on the relative asset price.

The first-order impact of ε_{t+1}^D and τ_t^D on the relative price is a result of an amplification effect which reflects the use of the relative price as a source information by investors . If investors were to ignore the relative price, the impact of ε_{t+1}^D and τ_t^D on the relative price would be very small (third-order). Intuitively, ε_{t+1}^D would have little effect as private signals are imprecise and thus get a low weight. $\tau_t^D = 2\tau\epsilon_t^\tau$ would also have little effect because it is third-order, requiring only a third-order change in the expected return differential, and therefore the relative asset price, to clear markets.[13]

But instead the impact of ε_{t+1}^D and τ_t^D on the relative asset price is first-order as the impact of the imprecise private information is amplified through the asset price. While the private information about future technology innovations is weak to start with, the information is aggregated into the price through h_t. As agents observe the asset price, they learn the value of h_t, which gives them a noisy signal about ε_{t+1}^D. Investors put a high weight on this price signal to learn about each other's private information. This significantly amplifies the impact of private information. In terms of order-algebra, the impact increases from third to first-order.

The impact of the noise τ_t^D is also amplified from third to first-order through the price. This happens through a mechanism that Bacchetta and van Wincoop (2006) have called "rational confusion." An increase in τ_t^D leads to a portfolio shift towards Home equity, which marginally raises the relative price of Home equity. The amplification occurs when investors use the Home equity price as a piece of information about future relative productivity. The higher relative price of Home equity then leads to an increase in the expectation of future relative Home productivity, which leads to a further increase in the relative price of Home equity.

Gennotte and Leland (1990) show that such amplification effects can indeed be very large in practice. They provide evidence that during the U.S. stock market crash of October 19, 1987, the impact of non-informational trade (noise) on the

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[13] This is similar to a noisy asset supply shock. It affects the asset price by changing the risk-premium. A change in the risk-premium is something that is of third and higher order.

U.S. stock price was amplified by a factor greater than 100 as a result of the information content of the stock price.

3.2 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, which is a measure of home bias. We consider both their zero and first-order components. We discuss these portfolio shares as a function of intuitive moments that involve expectations of asset returns and their risk. In the next section we relate these moments to observed and unobserved state variables.

The zero-order components are

$$z^A(0) = 0.5 \tag{25}$$

$$z^D(0) = \frac{2\tau}{\left[var_t\left(er_{t+1}\right)\right](2)} \tag{26}$$

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

The zero-order components have also been interpreted as the steady state in the literature (e.g. Devereux and Sutherland, 2010). Since the steady Home equity supply is half of the world equity supply, it is not surprising that the steady state average portfolio share invested in Home equity is also 0.5. (26) depends on the ratio of the second-order average financial friction τ and the second-order component of the variance of the excess return. This reflects a tradeoff between the gain from portfolio diversification and the desire for home bias due to the financial friction. The larger the variance of the excess return, the bigger the gains from diversification and therefore the smaller the home bias.

The first-order components are

$$z_t^A(1) = \frac{\tau_t^D(3)}{2\left[var_t\left(er_{t+1}\right)\right](2)} + \frac{\left[\bar{E}_t^A er_{t+1}\right](3)}{\left[var_t\left(er_{t+1}\right)\right](2)} \tag{27}$$

$$z_t^D(1) = \frac{\left[\bar{E}_t^H er_{t+1}\right](3) - \left[\bar{E}_t^F er_{t+1}\right](3)}{\left[var_t(er_{t+1})\right](2)} - z^D(0)\frac{\left[var_t(er_{t+1})\right](3)}{\left[var_t(er_{t+1})\right](2)} \tag{28}$$

where $\bar{E}_t^A$ denotes the average expectation across agents from both countries and $\bar{E}_t^i$ the average expectations across agents from country i ($i = H, F$). The first-order components are determined by a ratio of third-order components in the numerators and second-order component in the denominators.

The first-order component of z_t^A is driven by two intuitive elements. First, a rise in τ_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 expression (28) 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. As investors in both countries become relatively more optimistic about the expected return on their domestic equity, both Home and Foreign investors reallocate their equity portfolio to the domestic stock market. Second, an increase in the variance of the excess return reduces home bias. This is reflected in the third-order component of the variance of the excess return, which captures time-variation in the variance of the excess return.[14] It relates to the tradeoff discussed above 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.

So far we have only discussed the first-order component of portfolio allocation from the demand side. Obviously asset demand must be equal to asset supply in equilibrium. Imposing the first-order component of the asset market clearing conditions (20)-(21), we get

$$\Delta z_t^A(1) + \frac{1}{4} z^D(0) s_t^D(1) = z_H(0)(1 - z_H(0)) \Delta q_t^D(1) + \frac{1}{4} i_t^D(1) \tag{29}$$

Here s_t^D and i_t^D are Home relative saving and investment, both divided by the zero-order component of financial wealth $W^F(0)$, which is the same for both countries.[15]

The left-hand side of (29) shows the relative demand for Home equity can rise due to either a larger portfolio share z_t^A invested in Home equity or an increase in Home saving relative to Foreign saving. Positive portfolio home bias ($z^D(0) > 0$) implies that an increase in relative Home saving leads to an increase in demand for Home relative to Foreign equity. The supply side is on the right hand side of (29).

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[14] See Tille and van Wincoop (2011) for a further discussion of this.

[15] Also, i_t^D is net investment, equal to the change in the capital stock.

The relative value of Home equity supply can rise either because of an increase in the relative price of Home equity or an increase in the relative Home capital stock due to investment.

Substituting the expression (27) of the average Home portfolio share from the demand perspective into the equilibrium (29) implies that changes in the equilibrium expected excess return are equal to

$$\begin{aligned}\Delta[\bar{E}_t^A er_{t+1}](3) &= -0.5\Delta\tau_t^D(3) + [var_t(er_{t+1})](2) z_H(0)(1 - z_H(0))\Delta q_t^D(1) + \\ & \frac{1}{4}[var_t(er_{t+1})](2)\left[i_t^D(1) - z^D(0)s_t^D(1)\right] \qquad (30)\end{aligned}$$

Three factors drive changes in the expected excess return on Home equity. A higher relative friction of investing in Home equity (decrease in τ_t^D) implies a higher equilibrium expected excess return on Home equity to clear the asset market. A higher relative supply of Home equity due to a higher relative price implies a higher equilibrium expected excess return in order to raise demand for Home equity. Finally, either an increase in Home relative investment or drop in Home relative saving will raise the supply of Home equity relative to the demand, which requires a rise in the expected excess return on Home equity to bring demand in line with supply. We write this last component of changes in the expected excess return as $\Delta\bar{E}_t^A er_{t+1}(3)^{IS}$, where the IS superscript stands for investment and saving.

Substituting (30) back into (27) we have

$$\Delta z_t^A(1) - \Delta z_t^p(1) = \frac{\Delta\bar{E}_t^A er_{t+1}(3)^{IS}}{[var_t(er_{t+1})](2)} \qquad (31)$$

where $z_t^p(1) = z_H(0)(1 - z_H(0))q_t^D(1)$ is a passive portfolio share. It captures changes in the share invested in Home equity (by both Home and Foreign investors) due to equity price changes alone, without any asset trade. An increase in the deviation from this passive portfolio share, $\Delta z_t^A(1) - \Delta z_t^p(1)$, measures active reallocation towards Home equity that takes place by selling Foreign equity and buying Home equity. (31) shows that this depends on just one component of changes in the expected excess return on Home equity, the component related to changes in relative Home investment and saving.

4 Impact of Dispersed Information on International Capital Flows

We are now in a position to discuss the drivers of international capital flows and the impact of dispersed information. We first derive an expression of capital inflows and outflows as a function of various intuitive components that relate to changes in financial wealth and the allocation of the wealth across the assets. After that we relate these components to observed and unobserved state variables in order to discuss the various mechanisms through which dispersed information affects capital flows.

4.1 Capital Inflows and Outflows

From straightforward balance of payment accounting, the first-order components of capital flows can be written as

$$outflows_t(1) = (1 - z_H(0))s_t^H(1) - [\Delta z_t^A(1) - \Delta z_t^p(1)] - 0.5\Delta z_t^D(1) \quad (32)$$

$$inflows_t(1) = (1 - z_H(0))s_t^F(1) + [\Delta z_t^A(1) - \Delta z_t^p(1)] - 0.5\Delta z_t^D(1) \quad (33)$$

Just like saving and investment, capital flows are divided here by the zero-order component $W^F(0)$ of financial wealth. Outflows are purchases of Foreign stock by Home investors and inflows are purchases of Home stock by Foreign investors.

Capital flows are driven by portfolio growth and portfolio reallocation. Portfolio growth measures capital flows due to changes in financial wealth resulting from saving, holding portfolio shares themselves at their steady state levels. It corresponds to the first term on the right hand side of (32)-(33). For example, capital outflows depend on Home saving, $s_t^H(1)$ times the steady state share invested abroad by Home investors, $1 - z_H(0)$.

Portfolio reallocation measures capital flows due to changes in portfolio allocation, holding financial wealth constant, and is captured by the last two terms on the right hand side of (32)-(33). The second term, which is discussed in section 3.2, measures average reallocation towards Home equity. This raises capital inflows and lowers capital outflows. The last term in (32)-(33) captures changes in portfolio home bias. An increase in home bias z_t^D corresponds to a retrenchment towards domestic equity, which reduces both capital inflows and outflows.

Substituting the expressions (31) and (28) for $\Delta z_t^A(1) - \Delta z_t^p(1)$ and $z_t^D(1)$, (32)-(33) become

$$\begin{aligned} outflows_t(1) &= (1 - z_H(0))\, s_t^H(1) + \frac{z^D(0)}{2} \frac{\Delta\left[var_t\left(er_{t+1}\right)\right](3)}{[var_t(er_{t+1})](2)} \\ &\quad - \frac{\Delta \bar{E}_t^A er_{t+1}(3)^{IS}}{[var_t(er_{t+1})](2)} - \frac{1}{2} \frac{\Delta\left[\bar{E}_t^H er_{t+1}\right](3) - \Delta\left[\bar{E}_t^F er_{t+1}\right](3)}{[var_t(er_{t+1})](2)} \end{aligned} \tag{34}$$

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

The terms on the right hand side are related to saving, time-varying expected returns and risk. We now discuss each of these terms and how they are affected by dispersed information.

4.2 Impact of Dispersed Information on Capital Flows

Figure 2 illustrates the impact of dispersed information on capital flows. It shows results for both gross flows (capital inflows plus outflows) and net flows (capital outflows-inflows). The impact of dispersed information takes place through the 3 unobserved state variables in the model, which aggregate different types of private information. We will now discuss how these unobserved state variables affect the four terms in (34)-(35) and how this is graphically illustrated in Figure 2.

Portfolio Growth

The first term on the right hand side of (34)-(35) 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

$$s_t^H(1) = s_t^A(1) + 0.5 s_t^D(1) \tag{36}$$

$$s_t^F(1) = s_t^A(1) - 0.5 s_t^D(1) \tag{37}$$

Average world saving only depends on observed state variables. It is equal to

$$s_t^A(1) = \Delta a_t^A(1) + (1 - \omega)\Delta k_t^A(1) - \Delta q_t^A(1) \tag{38}$$

The observed state variables a_t^A and k_t^A affect average wages and therefore world saving by the young. These same variables one period ago affect dissaving by the current old generation. In addition the saving by the old generation is affected by the average equity price. A higher equity price implies higher wealth. This positive wealth effect raises consumption and therefore lowers saving. But as we have seen in section 3.1, the average asset price is determined by the same public information variables a_t^A and k_t^A.

Relative saving is equal to

$$s_t^D(1) = \Delta a_t^D(1) + (1-\omega)\Delta k_t^D(1) - z^D(0)\Delta q_t^D(1) \tag{39}$$

It depends on the observed state variables a_t^D and k_t^D, which affect relative wages. But is also depends on the relative equity price q_t^D. This again operates through a wealth effect. As long is there is positive portfolio home bias ($z^D(0) > 0$), an increase in the relative price of Home equity raises the wealth of the old generation in the Home country relative to that in the Foreign country. This wealth effect raises relative consumption in the Home country and lowers relative saving.

These results imply that the unobserved fundamentals ε_{t+1}^D and τ_t^D impact capital flows through the relative equity price, which affects saving through a wealth effect. In particular, an increase in either ε_{t+1}^D or τ_t^D raises the relative price of Home equity, which lowers Home saving and raises Foreign saving. This leads to lower capital outflows through portfolio growth and an increase in capital inflows. Net capital outflows (outflows minus inflows) drop. Gross capital flows (outflows plus inflows) do not change as the drop in outflows is equal to the increase in inflows. This effect is illustrated in Figure 2 through the relative equity price-saving-portfolio growth channel.

Time-Varying Risk

The other three terms driving capital inflows and outflows in (34)-(35) 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, captured by its third-order component. 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. The third-order component of the variance of the excess return is equal to

$$[var_t(er_{t+1})](3) = \delta_1 \sigma_a^2 S_t(1) \tag{40}$$

where δ_1 is a 1 by 4 vector and S_t is the vector of observed state variables. The variance of the excess return therefore only depends on publicly observed state variables.[16]

Average Expected Excess Return

The third term on the right hand side of (34)-(35) represents capital flows due to changes in the average expected excess return that is associated with changes in relative saving and investment. It is equal to

$$\frac{\Delta\bar{E}_t^A er_{t+1}(3)^{IS}}{[var_t(er_{t+1})](2)} = \frac{1}{4}\left[i_t^D(1) - z^D(0)s_t^D(1)\right] \tag{41}$$

The expression for relative saving is in (39). The first-order component of relative investment depends on the relative equity price through a standard Tobin's Q expression:

$$i_t^D(1) = \frac{1}{\xi}q_t^D(1) \tag{42}$$

These results imply that the unobserved fundamentals ε_{t+1}^D and τ_t^D impact capital flows again through the relative equity price. An increase in either ε_{t+1}^D or τ_t^D raises the relative equity price, which lowers relative Home saving and raises relative Home investment. Both lead to an excess relative supply of Home equity. In order to equilibriate equity markets the expected excess return on Home equity will need to rise. This leads to a portfolio shift to Home equity. Capital outflows will drop and capital inflows will rise. Net capital outflows will go down. Gross capital flows remain unchanged. This effect is illustrated in Figure 1 through the relative equity price-saving/investment-expected return channel.

Differences in Expected Returns across Countries

The last term driving capital outflows and inflows in (34) and (35) 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 drop. This difference in the expected excess return between Home and Foreign investors is equal to

$$[\bar{E}_{H,t}er_{t+1}](3) - [\bar{E}_{F,t}er_{t+1}](3) = \delta_2\sigma_a^2\left[\frac{1}{\sigma_{HH}^2} - \frac{1}{\sigma_{HF}^2}\right]\varepsilon_{t+1}^A \tag{43}$$

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[16] Only the second and fourth elements of δ_1 are non-zero. These elements multiply a_t^A and k_t^A, hence only global state variables affect the variance of the excess return.

where δ_2 is positive zero-order constant.

To understand (43), assume that $\sigma^2_{HH} < \sigma^2_{HF}$, 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.

In this case the impact of information dispersion on capital flows operates through ε^A_{t+1}. As ε^A_{t+1} increases, investors from both countries believe that their own relative productivity will rise as they have better information on that. This leads to a retrenchment towards domestic assets. Both capital inflows and outflows drop, by an equal amount. Net capital flows remain unchanged in this case, while gross capital flows go down. This channel is represented on the right hand side of the chart in Figure 2.

Through each of these channels the unobserved state variables ε^D_{t+1}, ε^A_{t+1} and τ^D_t affect international capital flows and therefore disconnect these flows from publicly observed information. Moreover, the impact of ε^D_{t+1} on net capital flows and ε^A_{t+1} on gross capital flows imply that capital flows contain information about future fundamentals. Net capital flows contain information about future relative productivity or profit rates while gross capital flows contain information about future world productivity or profit rates.

We have not used this information content of capital flows as a source of information of investors when computing expectations of ε^D_{t+1} and ε^A_{t+1}. In practice the difficulty is that capital flows are observed both with substantial delay and with noise, which limits the use to investors. We could allow investors in our model to observe capital flows with noise. This makes no difference for net capital flows as the relative asset price contains the same information. For gross capital flows it allows investors to obtain another piece of information about ε^A_{t+1}. But as long as the information is noisy, it does not reveal ε^A_{t+1} and therefore does not qualitatively change our results for gross flows either.

4.3 Amplified Role of Public Information Due to Dispersed Information

So far we have discussed only one aspect of the role of dispersed information. Capital flows are at least partially affected by unobserved state variables. This ‘ by itself increases the volatility of capital flows if we hold constant the impact of public information. But dispersed information has the additional effect of also changing the impact of public information on capital flows, leading to a further increase in the volatility of capital flows.

In order to understand this, first consider gross capital flows. In the absence of private information gross capital flows depend positively on ε_t^A. An increase in ε_t^A raises Home and Foreign saving, leading to an increase in both capital inflows and outflows through portfolio growth.[17] A rise in ε_t^A leads to an additional increase in capital flows under dispersed information through the expected return differential. Using (34)-(35) and (43), the component of capital flows that depends on the expected return differential between Home and Foreign investors depends positively on $\varepsilon_t^A - \varepsilon_{t+1}^A$. Intuitively, a rise in ε_t^A at first leads to a retrenchment towards domestic markets at $t-1$ as investors anticipate a higher expected return on their domestic equity due to better local information. This will be reversed at time t, leading to larger capital inflows and outflows. This amplification channel through the expected return differential is entirely a result of dispersed information.

Next consider net capital flows. In the absence of private information net capital flows depend positively on ε_t^D. An increase in ε_t^D raises relative Home wages and therefore saving. This in turn leads to net capital outflows both through the portfolio growth and average expected return channels.[18] A rise in ε_t^D leads to an additional increase in net capital outflows under dispersed information. To see this, first consider the impact of a rise in ε_t^D at time $t-1$. It raises the relative asset price at $t-1$ through the aggregation of private information. This lowers relative Home saving and raises relative Home investment at $t-1$, which

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[17] There is a slight offsetting effect as a rise in ε_{t+1}^A lowers the variance of the excess return, which reduces inflows and outflows. But we find this effect to be very small, independent of the parameterization.

[18] There is an offsetting effect through the relative asset price, which depends positively on ε_t^D. A higher relative price lowers relative Home saving and raises relative Home investment. But we find that only for extreme parameter assumptions does this offset the effect through relative wages.

reduces net capital outflows through the portfolio growth and average expected return channels. At time t this is then reversed, raising net capital outflows. The amplified impact of ε_t^D on net capital outflows at time t therefore operates through dispersed information that impacts the relative asset price.

4.4 Other Channels though which Dispersed Information Impacts Capital Flows

We have kept the model relatively simple in order to achieve analytic tractability and transparency of the results. It is not difficult to generalize the model, at the cost of further complexity, and obtain additional channels through which dispersed information impacts capital flows. While in principle this can be done in many ways, we discuss a couple of such possibilities here.

One assumption we made is that agents have log utility. We could relax this and allow the rate intertemporal substitution to differ from 1. When it is larger than 1, an increase in the future expected portfolio return will raise saving by the young. Now assume that ε_{t+1}^A rises. Agents have private information about this, which will increase the expected portfolio return and raise world saving. This in turn will raise the average asset price q_t^A. In order to prevent the average asset price from completely revealing ε_{t+1}^A one would then need to introduce another type of noise that affects the world asset supply or demand and therefore q_t^A. This can for example come from private information about the time discount rate that cannot be observed in the aggregate and affects world saving.

In such a setup an increase in ε_{t+1}^A, as well as the noise that impacts global saving, will raise both Home and Foreign saving, which leads to increased capital inflows and outflows. An increase in ε_{t+1}^D in this setup will raise relative Home saving as the relative portfolio return in the Home country is expected to rise due to portfolio home bias. This in turn impacts capital flows through the portfolio growth channel as well as through the expected return channel. Note that in this case the impact of ε_{t+1}^D on capital flows does not just operate through the relative asset price as in Figure 2.

Another extension is to assume that agents work both periods of their life and have private information about their income when old. This provides an alternative channel through which future productivity innovations can impact saving today. The implications for capital flows should be similar to those discussed above for the case where the intertemporal elasticity of substitution differs from 1.

One could also consider shifts in risk-aversion that are unobserved. Only individual agents know their own risk aversion. If average risk-aversion increases in both countries, investors like to become more diversified. Both capital inflows and outflows then increase. Gross capital flows are then driven by an unobserved current fundamental as opposed to the future fundamental ε_{t+1}^{A}.

Agents may also have private information about fundamentals further into the future. In that case ε_{t+s}^{D} and ε_{t+s}^{A} for values of s from 1 to T affect capital flows, with T possibly quite large. As shown by Bacchetta and van Wincoop (2006) in the context of exchange rates, this implies that the disconnect from observed fundamentals can be very persistent.

The extensions discussed above only scratch the surface of additional avenues of research. We have kept things simple in the model, but naturally there are a large number of other ways that dispersed information can affect capital flows. They all have in common that they disconnect capital flows from observed fundamentals and imply that capital flows contain information about future fundamentals beyond what can be learned from public information alone.

5 Model Calibration

For illustrative purposes, and to show that the impact of dispersed information can be quantitatively large, we now turn to a calibration and simulation of the model. The goal is not to match a wide range of data moments. We have made too many simplifying assumptions, especially the OLG structure, to make that a worthwhile exercise. Rather, we focus on the volatility of capital flows and the correlation between capital inflows and outflows. We show that for a reasonable calibration of the model, these basic capital flow moments in the model are close to those in the data. We use annual data from 1977 to 2006 for 6 industrialized countries (the G7 minus Italy). We then report results on the impact of the dispersed information on capital flows in the context of the calibrated model. We compare this to the case where there is only public information in order to evaluate the role of dispersed information.

5.1 Calibration

As is standard in the literature for calibration with annual data, we set the rate of depreciation at $\delta = 0.1$, the time discount rate at $\beta = 0.95$ and the labor share at $\omega = 0.7$. We set $\rho = 0.99$ as it is hard to distinguish between ρ close to 1 and exactly 1 and the unit root case cannot be rejected by the data (e.g. Baxter and Crucini, 1996). We set $\sigma_a = 0.017$ so that the standard deviation of output growth in the model is equal to the average standard deviation of annual real GDP growth for the 6 countries, which is 1.7%. We compute all model moments based on a simulation over 100,000 periods.

We set the adjustment cost parameter $\xi = 2.5$ 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.

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.[19]

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. For this purpose we use data 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 in the United States and Japan. We provide a description of these data and the calibration exercise in the Appendix. We set $(\sigma_{HH} + \sigma_{HF})/2 = 0.21$. This generates a standard deviation

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[19] 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 (26) 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.

of the cross-sectional distribution of next period's equity prices, scaled by the unconditional variance of equity price changes, which closely matches data for both the United States and Japan.

The remaining two parameters, σ_{HF}/σ_{HH} and θ, also relate to the extent of information dispersion. As these are hard to calibrate, we vary them over a wide range. We will do the same for $(\sigma_{HH} + \sigma_{HF})/2$ as well. Under the benchmark we set $\theta = 100$ and $\sigma_{HF}/\sigma_{HH} = 1.5$.

5.2 Model Simulation

We simulate the model over 100,000 periods in order to produce some basic moments for capital flows reported in Table 1. These moments are compared to the data. In the data we use aggregate capital inflows and outflows, divided by GDP and HP(10) filtered. The reported moments are for the average of the United States, Japan, Canada, United Kingdom, Germany and France. In the model we use the first-order components of capital inflows and outflows as a fraction of GDP, also HP(10) filtered.

We report results both for the benchmark parameterization with dispersed information and the case with only public information. In the public information case we set $(\sigma_{HH} + \sigma_{HF})/2$ extremely large, so that private signals carry no information. The impact of the noise τ_t^D then also vanishes to zero, so that capital flows are only driven by public information about a_t^H and a_t^F.[20] Other than setting $(\sigma_{HH} + \sigma_{HF})/2$ very large, we keep the parameterization under public information the same as under dispersed information.

It is important to emphasize that our calibration is not based on any capital flow data. Nonetheless, as can be seen in the top half of Table 1, the model with dispersed information generates a volatility of capital flows and correlation between inflows and outflows that is broadly consistent with that in the data. The standard deviation of capital inflows and outflows is about 3% in both the model and the data. Gross capital flows have a standard deviation just below 6% in both the model and the data.

For net capital flows we report data results based both on capital flows and the current account. These should be exactly the same, but measurement error

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[20] Formally, the impact of the noise τ_t^D on the relative asset price and capital flows will be of third-order. It therefore vanishes from our first-order approximation.

in capital flow data tends to overstate the volatility of net capital flows a bit. The current account numbers are therefore probably more reliable. The standard deviation is 0.7% in the data versus 0.5% in the model.

The correlation between capital inflows and outflows is very high in both the data and the model. It is just a bit higher in the model (0.99 versus 0.89 in the data), but measurement error is likely to understate the correlation in the data somewhat.

The last column reports the same moments in the model with public information. The volatility of capital flows now becomes very small, only 0.05% for capital inflows and outflows. The volatility of gross flows is only 0.02%. The correlation between capital inflows and outflows is now -0.85. This clearly demonstrates that introducing dispersed information substantially brings the model in line with basic capital flow moments.

As discussed in section 4.3, the increase in the volatility of capital flows due to dispersed information has two sources. First, capital flows are now driven by unobserved state variables as well. Second, the impact of public information variables ε_t^A and ε_t^D on capital flows at time t is amplified because it operates through a mechanism whose presence is a direct result of dispersed information.[21]

The correlation between capital inflows and outflows is very high in the model with dispersed information, similar to what we see in the data, while the correlation is -0.85 in the public information model. This relates to the criticism by Broner et.al. (2010) on public information models of capital flows. The very negative correlation between capital inflows and outflows under public information is mainly a result of time-varying expected returns. This by itself causes capital inflows and outflows to be perfectly negatively correlated. An increase in the expected excess return on Home stock raises capital inflows and reduces capital outflows by the same amount.

The key factor in generating a very positive correlation between capital inflows and outflows under dispersed information is time-variation in the difference in

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[21] The very low volatility of capital flows under public information in our model should not be considered as a general criticism of public information models. By changing the structure of the model, for example by dropping the OLG assumption and introducing other shocks, one can get substantially more volatility of capital flows in a public information model. Our focus here is on the contribution of dispersed information. We have shown that it contributes to increasing the volatility of capital flows relative to a model with only public information.

the expected excess return between Home and Foreign investors, which depends on ε^A_{t+1}. When agents have different information, they take opposite sides of a transaction. For example, an increase in ε^A_{t+1} causes Home agents to sell Foreign equity and Foreign agents to buy it. Similarly, Home agents will buy Home equity while Foreign investors sell it. In this case capital inflows and outflows both drop.

The bottom half of Table 1 reports on the extent of disconnect of capital flows from observed macro fundamentals and the ability of capital flows to predict future fundamentals.[22] It shows that in the dispersed information model about 50% of the variance of both gross capital flows, and 40% of the variance of net capital flows, can be explained by unobserved fundamentals that aggregate the private information.

Two of these unobserved fundamentals, ε^A_{t+1} and ε^D_{t+1}, imply that capital flows contain information about future fundamentals. This information content of capital flows is documented in the last two rows of Table 1. The R^2 of a regression of ε^A_{t+1} on gross flows at time t is 0.5. The R^2 of a regression of ε^D_{t+1} on net flows at time t is 0.34. Therefore both gross and net capital flows contain considerable information about future fundamentals.

5.3 Sensitivity to Dispersed Information Parameters

We now consider the sensitivity of these results to the three parameters related to the extent of dispersed information, namely information dispersion $(\sigma_{HH}+\sigma_{HF})/2$ (Figure 3), information asymmetry σ_{HF}/σ_{HH} (Figure 4) and noise θ (Figure 5). We vary the information dispersion $(\sigma_{HH}+\sigma_{HF})/2$ from 0 to 2, the information asymmetry σ_{HF}/σ_{HH} from 1 to 2, and the noise θ from 1 to 1000. Each figure displays the standard deviation of gross capital flows (panel A), the standard deviation of net capital flows (panel B), the correlation between capital inflows and outflows (panel C), the extent of disconnect in capital flows, measured by the share of the variance of flows that is explained by unobserved fundamentals (panel D), and the predictive content of capital flows, measured by the R^2 in a regression of ε^D_{t+1} and ε^A_{t+1} on net and gross capital flows, respectively (panel E).

Information dispersion

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[22] For this purpose we use the first-order components of gross and net capital flows as a share of GDP. We do not apply an HP filter, which mixes up current, past and future capital flows.

Private signals carry little information when their average dispersion $(\sigma_{HH} + \sigma_{HF})/2$ becomes very high. This significantly reduces the volatility of both gross and net capital flows (Figure 3, panels A and B). As discussed in section 4.3, this happens both because the three state variables associated with dispersed information disappear and because less private information implies a smaller impact of public information. The correlation between capital inflows and outflows goes down as the private information becomes weaker (panel C). But even when $(\sigma_{HH}+\sigma_{HF})/2$ is equal to 2, which is ten times as high as estimated, the correlation remains positive at 0.33.

The extent of disconnect of gross capital flows (panel D) and their predictive power for future average innovations ε^A_{t+1} (panel E) are not very sensitive to the average precision of the private signals. As the private signals become weaker, the impact of observed and unobserved state variables weaken in tandem, so that the extent of disconnect does not change much. By contrast, the predictive content of net capital flows for the relative innovation ε^D_{t+1} quickly deteriorates as private signals become weaker. When private signals are weak, net capital flows are dominated by public information and therefore carry little information about ε^D_{t+1}.

International Information Asymmetry

The extent of asymmetric information across countries σ_{HF}/σ_{HH} has no little impact on net capital flows (Figure 4). We therefore focus our discussion on gross capital flows. It is through this information asymmetry that ε^A_{t+1} affects gross capital flows in our model. Not surprising therefore, the volatility of gross capital flows depends critically on the extent of this information asymmetry (panel A). Information asymmetry also matters for the correlation between capital inflows and outflows (panel C). As a result of the information asymmetry capital inflows and outflows both drop when ε^A_{t+1} rises, as agents retrench towards domestic assets about which they have more information and are therefore more optimistic. We only need a small amount of information asymmetry to generate a high correlation between capital inflows and outflows, with the correlation reaching 0.8 even if we set σ_{HF}/σ_{HH} as low as 1.1 (rather than the 1.5 in the benchmark).

The extent of information asymmetry has very little effect on the extent of disconnect (panel D) and the predictive content of gross capital flows (panel E). A lower value of σ_{HF}/σ_{HH}, implying less information asymmetry across countries, reduces the impact of both ε_{t+1}^A and ε_t^A on gross capital flows. It proportionally reduces the impact of both observed and unobserved state variables.

Noise

A lower level of noise θ reduces the information asymmetry across countries as the relative equity price then contains more information about relative future productivity. This in turn reduces the impact of ε_{t+1}^A on gross capital flows and therefore its volatility (Figure 5, panel A). The volatility of net flows by contrast is insensitive to the noise (panel B). There are two offsetting effects. On the one hand more noise implies that the relative asset price is more affected by the noise. On the other hand, the noise reduces the information content of the relative price, which limits the extent to which private information about ε_{t+1}^D is aggregated into the relative price. So, while one unobserved state variable (τ_t^D) generates more volatility of the relative asset price and net capital flows when θ rises, another unobserved state variable (ε_{t+1}^D) does the opposite.

The correlation between inflows and outflows is insensitive to the noise (panel C). The noise also has little impact on the extent of disconnect in gross and net capital flows (panel D). While the noise has little impact on the predictive content of gross capital flows (panel E), it affects the predictive content of net flows. Specifically, more noise implies a larger role for τ_t^D relative to ε_{t+1}^D, and thus lowers the predictive content of net capital flows.

6 Conclusion

We investigate the impact of dispersed private information on international capital flows within the context of a DSGE two-country model with dispersed private information within countries as well as information asymmetries across countries. We show that dispersed information increases the volatility of both gross and net capital flows, generates a large positive correlation between capital inflows and outflows as seen in the data, leads to a disconnect between capital flows and observed macro fundamentals, and makes capital flows a relevant source of information about future macro fundamentals. Our calibration exercise shows that all of these effects can be quantitatively large. In addition, we show that dispersed private information can also increase the impact of observed macro fundamentals on capital flows.

While we illustrate that the impact of dispersed information on international capital flows can be potentially large, we have not begun to address how large exactly this effect is empirically. This will be an important topic for future work. We can see a number of possible ways to approach this. A first approach is to evaluate the extent of disconnect by regressing capital flows on observed (current and past) macro fundamentals, either as a single equation or a VAR. Similarly, one can conduct Granger causality tests to evaluate the predictive content of capital flows, controlling for current and past macro fundamentals.[23] An important drawback of this approach though is that it is hard to distinguish between private information and public information that is omitted by the econometrician.

An alternative approach is to use relatively high frequency capital flow data, such as weekly data from State Street Corporation, and consider the relationship between these capital flows and cumulative order flow in equity and FX markets. Order flow specifically aggregates all kinds of private information.

A final approach is to consider a more extensive calibration exercise. In this paper we have made several simplifying assumptions for the sake of tractability and transparency. Many extensions would connect the model to a much broader set of moments. These include relaxing the OLG assumption, introducing other assets, such as bonds and money, allowing agents to have private information about fundamentals further into the future and different types of private information. Ultimately this should lead to better insight into the quantitative role that private information plays in accounting for various aspects of gross and net capital flow data.

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[23] In a previous draft of this paper we took a very preliminary shot at this approach, finding evidence of substantial disconnect for both gross and net capital flows and predictive content of particularly gross capital flows for the future world profit rate.

Appendix: Calibrating Information Dispersion

In this Appendix we provide some details regarding the calibration of dispersed information regarding future fundamentals. 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.

For this purpose we use 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.[24] 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 parameterization focusing on the 1-year ahead forecasts.

For each country the survey is based on about 400 financial institutions. 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 ”.

The survey starts in 1989 with six-month interval surveys until 1998, after which monthly surveys are conducted.[25] 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. Moreover, we eliminate days were there were fewer than 5 responses.

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 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

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

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

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 this scaled measures of dispersion of expected stock price changes is the standard deviation of $E_t^{Hj} q_{t+1}^H$ across investors, divided by the unconditional variance of Δq_t^H. We set $(\sigma_{HH} + \sigma_{HF})/2 = 0.21$, which leads to a scaled measure of dispersion of expected stock price changes of 5.0, close to that for both the U.S. and Japan.

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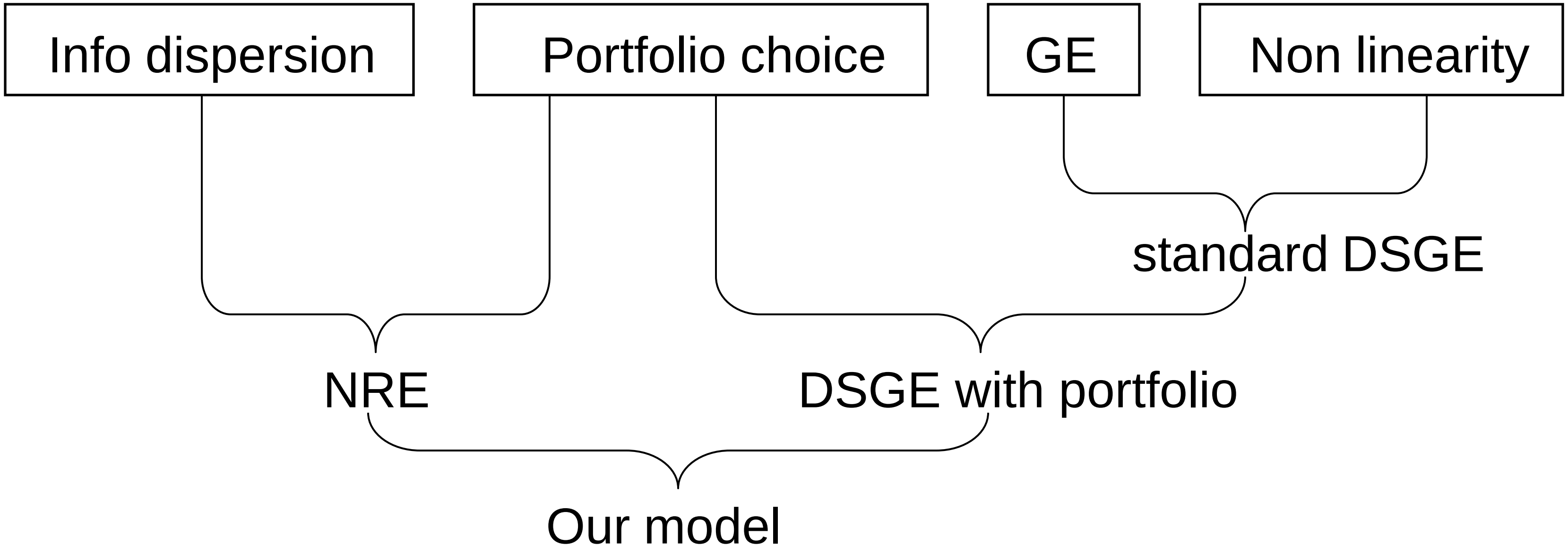
Table 1: Capital Flow Moments

	Data	Model with Dispersed Information	Model with Public Information
	Standard Deviations		
capital outflows	2.89	2.99	0.05
capital inflows	2.99	2.99	0.05
gross capital flows	5.78	5.96	0.03
net capital flows	0.96	0.46	0.10
current account	0.70	0.46	0.10
	Correlation		
capital inflows and outflows	0.89	0.99	-0.85
	Share of Variance Explained by Dispersed Information		
capital outflows	-	0.50	0
capital inflows	-	0.50	0
gross capital flows	-	0.50	0
net capital flows	-	0.40	0
	Information Content Capital Flows		
R^2 of regression of ϵ^A_{t+1} on gross flows	-	0.50	0
R^2 of regression of ϵ^D_{t+1} on net flows	-	0.34	0

Note: In the first column the table shows basic moments involving capital flows. Gross capital flows are defined as capital outflows plus capital inflows. Net capital flows are capital outflows minus capital inflows. All capital flow data are from the IMF International Financial Statistics (IFS). They are multiplied by the exchange rate to convert to the local currency and then divided by GDP (also from the IFS). These scaled capital flows are HP(10) filtered. The corresponding moments in the model in columns 2 and 3 are based on the first-order component of capital flows divided by GDP. They are HP(10) filtered just as in the data. The moments reported only for the model in the lower half of the table are based on the raw first-order components of capital flows without applying a filter. The model with dispersed information is based on the benchmark parameterization. The public information model is the same except that σ_{HH} and σ_{HF} are set extremely large, so that the private signals carry no information.

Figure 1 Modeling Contribution



Info dispersion

Portfolio choice

GE

Non linearity

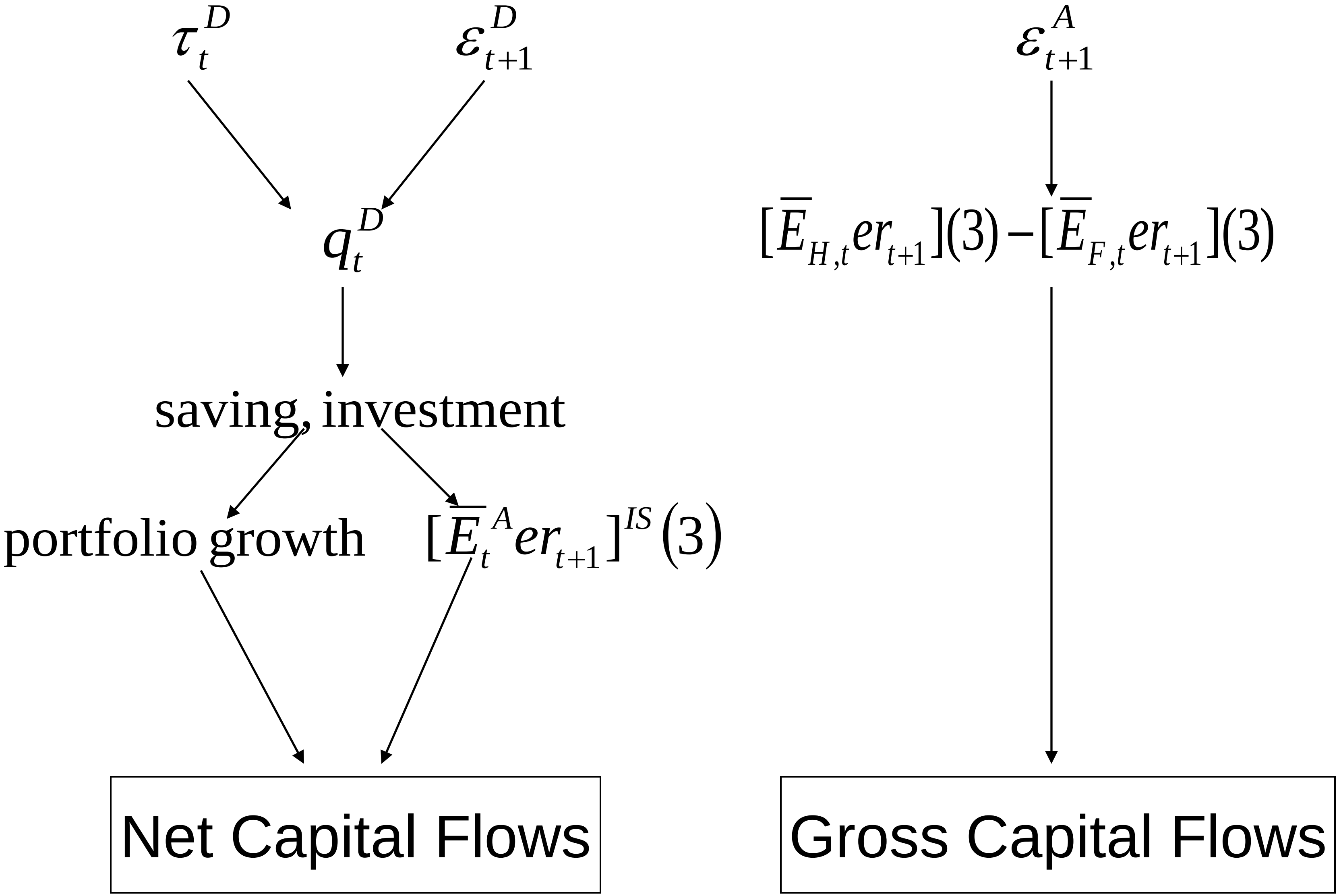
standard DSGE

NRE

DSGE with portfolio

Our model

Figure 2 Role of Information Dispersion



τ_t^D

ε_{t+1}^D

ε_{t+1}^A

q_t^D

$[\overline{E}_{H,t} er_{t+1}](3) - [\overline{E}_{F,t} er_{t+1}](3)$

saving, investment

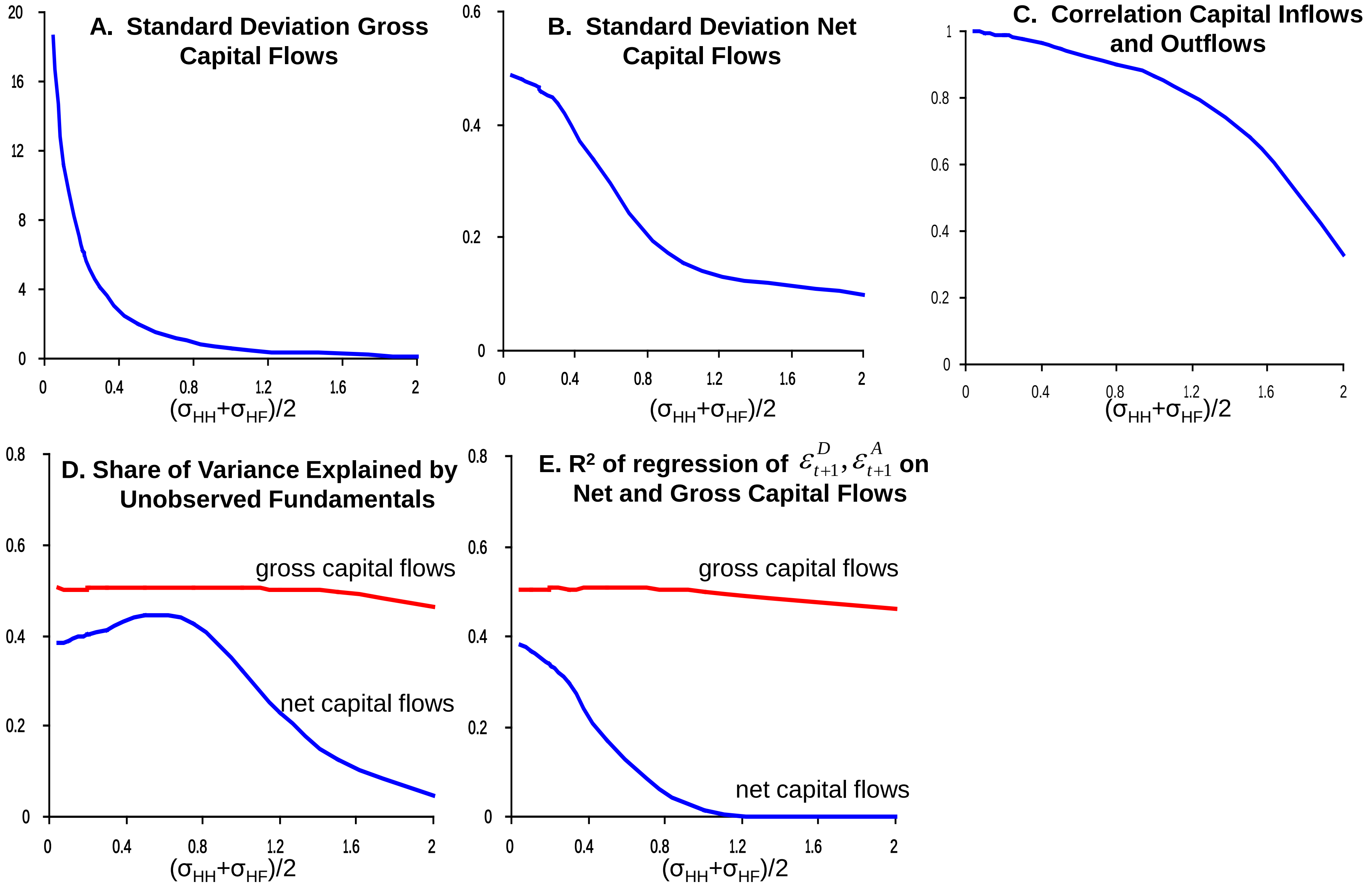
portfolio growth

$[\overline{E}_t^A er_{t+1}]^{IS}(3)$

Net Capital Flows

Gross Capital Flows

Figure 3 Model Simulation: Information Dispersion



A. Standard Deviation Gross Capital Flows

B. Standard Deviation Net Capital Flows

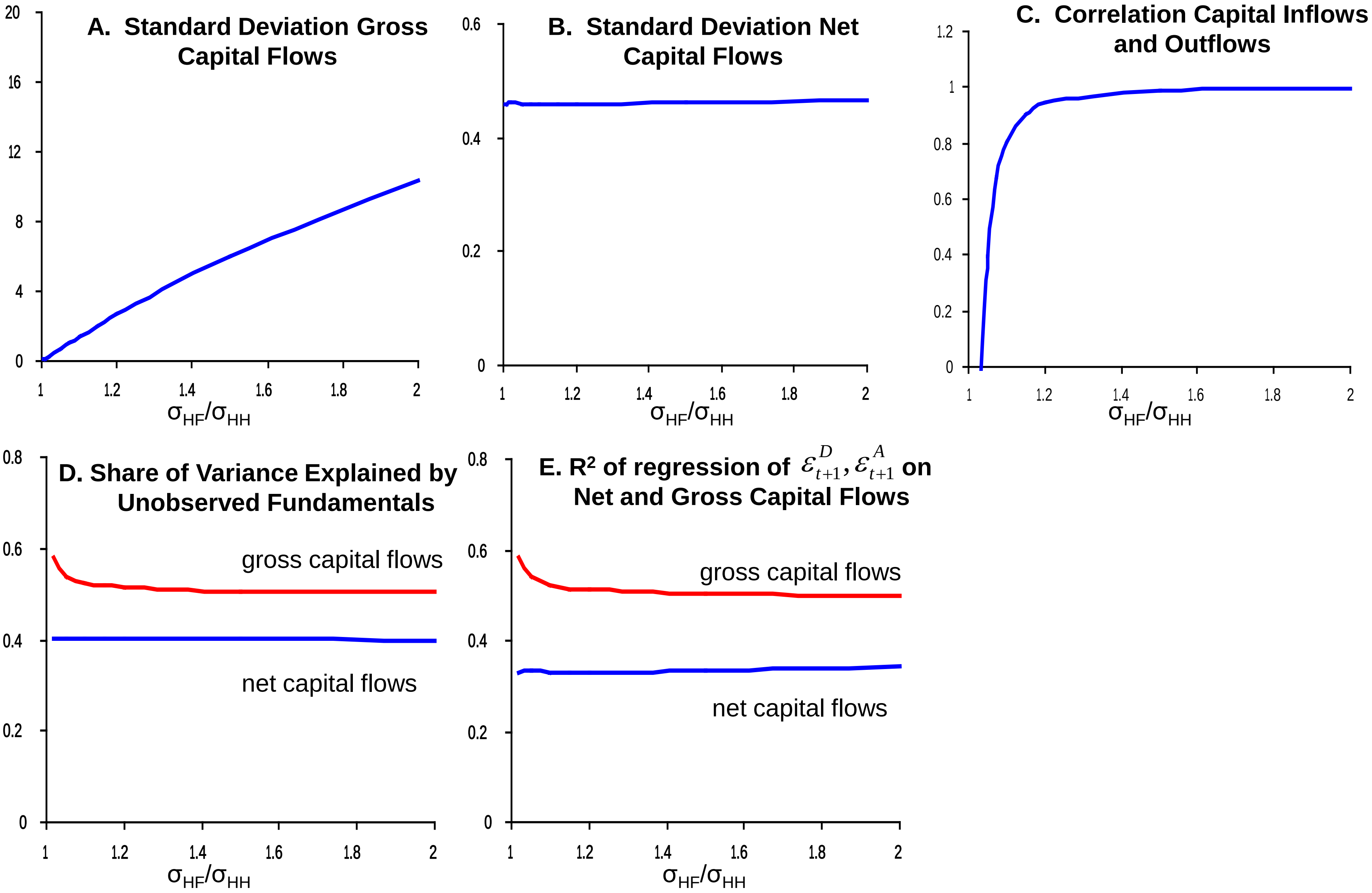
C. Correlation Capital Inflows and Outflows

D. Share of Variance Explained by Unobserved Fundamentals

E. R^2 of regression of $\varepsilon^{D}_{t+1}, \varepsilon^{A}_{t+1}$ on Net and Gross Capital Flows

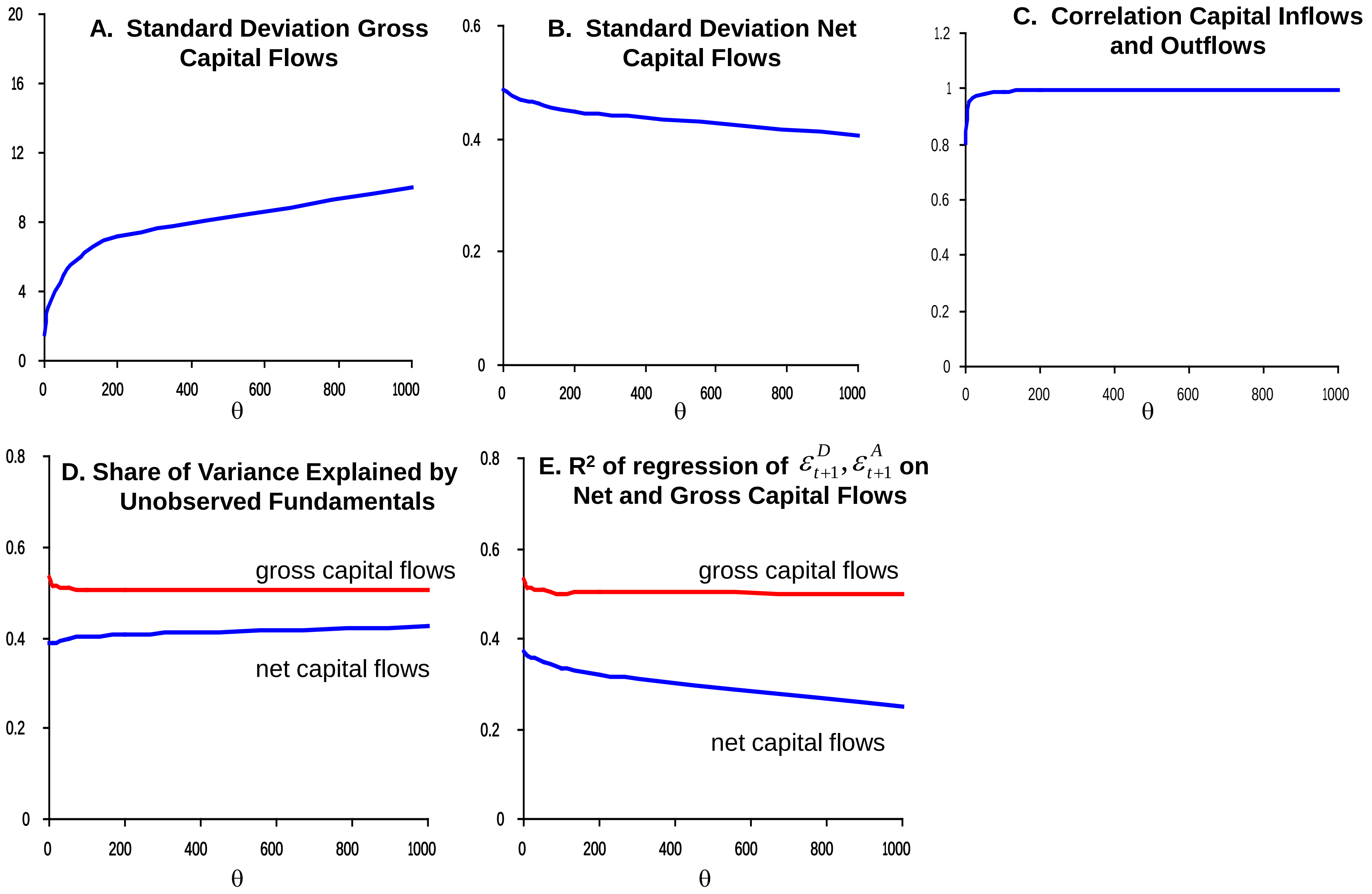
Gross Capital flows=capital outflows+capital infows; Net capital flows=capital outflows-capital inflows. Results are based on a simulation of the model over 100,000 periods.

Figure 4 Model Simulation: Information Asymmetry



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.

Figure 5 Model Simulation: Noise



A. Standard Deviation Gross Capital Flows

B. Standard Deviation Net Capital Flows

C. Correlation Capital Inflows and Outflows

D. Share of Variance Explained by Unobserved Fundamentals

E. R^2 of regression of $\varepsilon_{t+1}^{D}, \varepsilon_{t+1}^{A}$ on Net and Gross Capital Flows

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.