

# INTERNATIONAL CAPITAL FLOWS WHEN INVESTORS HAVE LOCAL INFORMATION\*

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## **International Capital Flows when Investors have Local Information**

While international capital flows have increased dramatically over the past two decades, from a risk-sharing perspective, world capital markets do not appear highly integrated. Investors continue to hold disproportionately large claims to domestic output, fund domestic investment mostly out of domestic savings, and consume at very different rates than agents residing abroad. In this paper, we investigate investment behavior in a model in which agents have superior information regarding domestic returns than those overseas. We show that such a setting, when calibrated to U.S. macroeconomic data, offers a unified explanation for the three risk-sharing puzzles in an environment of active capital flows. Investors' cross-border trading serves to amplify, rather than dampen, cross-border consumption differences and domestic savings-investment correlations.

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# 1 Introduction

The liberalization of world capital markets in the early 1980's, while resulting in large increases in cross-border flows of capital,<sup>1</sup> has not led to a greater degree of global risk-sharing. Three distinct sets of evidence on risk-sharing appear at odds with a world of high capital mobility. Investors continue to hold disproportionately large claims to domestic output, they save at rates that depend mostly on domestic investment opportunities, and they consume quite differently from agents residing overseas. A major challenge to international financial theory is to reconcile these three "anomalies" with a world of large and growing flows of capital.

This paper shows how an international capital market, characterized by information asymmetries, can jointly account for each of the three risk-sharing puzzles while sustaining a high degree of capital mobility. In spite of the well-documented potential gains offered by the international diversification of equity holdings, the average investor's portfolio remains substantially biased in favor of domestic investments.<sup>2</sup> Domestic ownership varies from 98% in Japan and 94% in the US to lower, but nonetheless significant, levels in smaller countries (for example 65% in Switzerland and 56.5% in the Netherlands). Although diversification benefits are difficult to characterize, home bias is still inconsistent with a frictionless capital market, if not unambiguous evidence of low global risk-sharing. Finally, it is worth noting that while investors favor holding domestic equities, recent studies indicate they prefer *trading* foreign equities.<sup>3</sup> Tesar and Werner (1994a) find that US investors trade overseas holdings relatively more frequently than their domestic portfolios, with foreign turnover rates inversely related to the size of foreign positions.

A second puzzle, described by Backus, Kehoe, and Kydland (1992) as one of the most important unexplained puzzles in the international real business cycle literature, is that cross-country consumption growth correlations are extremely low; whereas the theory of complete, integrated markets suggests that they should equal one.<sup>4</sup> In fact, many authors

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<sup>1</sup>The 1994 BIS Annual Report states that gross capital outflows from main industrialized countries have increased from \$100 billion per year in the early 1980's to \$850 billion in 1993. U.S. portfolio outflows increased from \$6.5 billion to \$125.4 billion and inflows expanded from \$29.4 billion to \$103.9 billion over the same period.

<sup>2</sup>See, for example, Grubel (1968), Tobin (1983), Eldor, Pines, and Schwartz (1988), French and Poterba (1991), Cooper and Kaplanis (1994), and Tesar and Werner (1994A, 1994B). Cooper and Kaplanis (1994) estimate that a representative US investor with risk tolerance of 0.4 forgoes up to 2.85% in annual returns.

<sup>3</sup>Hamao and Mei (1995) and Tesar and Werner (1994a, 1994b)

<sup>4</sup>See Grossman and Shiller (1982), Sheinkman (1984), Obstfeld (1986, 1989, 1995), Backus, Kehoe, and Kydland (1992), and Backus and Smith (1993).

find consumption correlations to be even lower than cross-country output correlations, suggesting a complete failure of international consumption insurance.<sup>5</sup> Equally troubling is that growing capital flows may be actually making the puzzle worse, since consumption correlations among most industrial countries are on the decline.<sup>6</sup> Although consumption correlations must be adjusted to control for the tradability and durability of goods, the consensus is that they indicate a low degree of international risk-sharing.

The final risk-sharing anomaly concerns the high degree of correlation between national savings and investment rates. This result, first documented by Feldstein and Horioka (1980), and confirmed by a large body of empirical research, is widely (though not unanimously) interpreted as evidence of low global financial integration.<sup>7</sup> A setting of open and integrated markets would suggest that domestic savings decisions should be made largely independent of domestic investment opportunities. While a number of potential explanations have been put forth, and a benchmark correlation of zero may indeed be inappropriate, most view the correlations between domestic savings and investment rates to be too high to be consistent with a world of substantial risk-sharing.<sup>8</sup>

There are several indications that information asymmetry may explain low international risk-sharing. Recent studies have presented evidence consistent with cross-border, distance-dependent informational divergence.<sup>9</sup> These findings have prompted the development of asymmetric information models to account for the home bias puzzle.<sup>10</sup> In particular, Low (1992), Gehrig (1993), Kang and Stulz (1995), and Brennan and Cao (1995) have all constructed models in which information asymmetry between foreign and domestic investors leads to a home equity preference. Brennan and Cao (1995) demonstrate that information differences can also generate higher turnover rates on overseas than on domes-

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<sup>5</sup>See Baxter and Crucini (1991), Backus, Kehoe, and Kydland (1992), and Devereaux, Gregory, and Smith (1992).

<sup>6</sup>The exception is intra-EC correlations. Obstfeld (1995).

<sup>7</sup>See, for example, Feldstein and Horioka (1980), Feldstein (1983), Murphy (1984), Penati and Dooley (1984), Frankel (1986), Obstfeld (1986), Dooley, Frankel and Mathieson (1987), Tesar (1991) and Baxter and Crucini (1991).

<sup>8</sup>See Fieldeke (1982), Caprio and Howard (1984), Obstfeld (1986), Summers (1988), Cardia (1991), and Ghosh (1995).

<sup>9</sup>Chuhan (1992) reports that foreign and domestic investors often have significantly different forecasts of market returns. Tesar and Werner (1994a) find distance as an important determinant in US investment abroad. Coval and Moskowitz (1998) find that distance plays a significant role in U.S. money managers' domestic portfolios. Kang and Stulz (1995) show that foreign investors overweight large Japanese firms in their portfolios – firms that they would presumably hold at less of an informational disadvantage. Shiller et al. (1995) report that US and Japanese investor held 'stunningly' divergent expectations for the Nikkei during its crash in 1989.

<sup>10</sup>The notion that information asymmetries could account for the home bias puzzle was originally suggested by Lucas (1982).

tic holdings. Unfortunately, these models are not equipped to address the other puzzles, as they rely on single and two-period settings with no characterization of long-term dynamics of consumption growth, savings, or investment rates.<sup>11</sup> Furthermore, Gordon and Bovenberg (1996) analyze foreign direct investment in a setting of asymmetric information, finding results consistent with the savings-investment correlations. Again, studying these patterns in a two-period setting with no portfolio investment or asset pricing dynamics, they are unable to address the savings-investment correlations in conjunction with the portfolio holdings/trading anomalies or the consumption puzzle.

To *jointly* address each of the above phenomena, we develop a heterogeneous information model in a consumption-based, infinite-horizon, general equilibrium setting in which asset prices are solved in the presence of direct investment activity. The merit of a comprehensive approach to the risk-sharing puzzles is argued in Ghosh and Pesenti (1994). When analyzed individually, any of the three anomalies can be easily accounted for within *ad hoc* frameworks, whose partial explanatory success often masks an explicit failure to account for the other puzzles.<sup>12</sup> For example, an information story which merely leads investors to hold disproportionate claims to domestic output is not terribly distinct from other models which characterize the world as a set of financial autarkies.<sup>13</sup> Asymmetric information must be able to jointly account for each of the risk-sharing anomalies in a world that, at least from the flows perspective, is moving *away* from financial autarky. It is here where the comprehensive approach has particular merit. The information-based framework of this paper yields both an investor preference for domestic holdings and larger cross-border capital flows than in a perfect-information setting. To properly test the information story, it is however also necessary to examine the effect these capital flows have on consumption and savings decisions. It is entirely possible for flows of capital to result in consumption and savings rates that are more dependent on worldwide investment opportunities, even if holdings remain biased homewards. If this is the case, the information story fails the comprehensive test. If, on the other hand, capital flows work in conjunction with the holdings bias to deliver low consumption correlations and high savings-investment correlations, then the asymmetric information explanation appears robust – particularly in light of what may

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<sup>11</sup>While Low (1992) considers information asymmetries in an infinite-horizon context, he assumes asset prices to be exogenous and contains no treatment of consumption or investment patterns.

<sup>12</sup>For a discussion of how many popular theories of international capital market equilibrium fail to jointly explain all three anomalies, see Ghosh and Pesenti (1994).

<sup>13</sup>Models which rely on high international transaction costs, differential taxation, or political risks all link low international risk-sharing to financial autarky.

be only modest benefits to international diversification and consumption correlations which have been declining over time.

Using our unified approach, we show that capital flows brought about by active trading of the asymmetrically-informed investors directly bring about the consumption divergence and high savings-investment co-movements. The implication is that when worldwide capital flows increase, international risk-sharing declines. When investors are endowed with superior information regarding their own country's asset returns, they attempt to predict overseas returns from prices and dividend payments. Greater uncertainty in overseas forecasts, and a consumption-hedging benefit offered by the domestic asset, combine to create a preference for domestic holdings. When investors do trade in the overseas market, they face an adverse selection problem. The better-informed foreign investors exploit domestic investor forecast errors – selling when their asset is overpriced and purchasing when undervalued. Nonetheless, when adverse selection is not severe, information heterogeneity serves to increase overall trading. Investors profit sufficiently in their transactions overseas to compensate for the adverse selection. The information-based trades have direct impact on consumption decisions. When overseas investors forecast incorrect domestic returns, their trades prompt domestic investors to adjust how much risk they bear and to substitute between current and future consumption. Information trading leads to divergent consumption paths and declines in consumption correlations. Under certain conditions, trading produces consumption correlations that are even lower than those of output. In addition, cross-border capital flows cause savings decisions to react more directly to changes in home investment opportunities. When overseas investors assess returns incorrectly, they create possibilities for domestic investors to adjust savings rates to exploit their superior forecasts of future domestic investment opportunities. Instead of dampening domestic savings-investment correlations, foreign trading makes the correlations more pronounced.

The paper is organized as follows. Section 2 sets forth a simple two-country world of asymmetric information. In Section 3, we solve for investor expectations and decision rules and then derive an equilibrium pricing function. Section 4 provides numerical results and analyzes some implications of this economy, while Section 5 presents our conclusions.

## 2 The Model

Consider a two-country world where each country is endowed with a single, risky asset and inhabited by a large number of infinitely-lived, identical agents. Agents in both countries have preferences defined over a stream of tradable consumption goods. In each period, each asset provides a dividend payment in the consumption good. This dividend payment contains both a permanent and a transitory component. The permanent component, called the dividend “fundamental,” evolves through time following an AR(1), while the transitory component is white-noise. Agents differ only in their ability to observe the permanent component of the dividend stream. Specifically, the fundamental of a given country’s asset is perfectly observed by agents within that country, while it is only partially observed by agents residing overseas.

This model resembles the asymmetric information models of Hussman (1992), Wang (1993), Asea (1995), and Zhou (1995). However, it offers two main innovations over existing models. First, we assume an information structure that enables an international version of the dynamic consumption-based asymmetric information problem, in which information sets are not perfectly ranked, to be solved.<sup>14</sup> Second, we introduce real investment activity into an asset pricing setting, where both prices and supplies of assets fluctuate as investment opportunities change. These features yield a two-asset, infinite-horizon, consumption-based equilibrium from which implications for holdings, consumption, savings and investment behavior can be jointly derived.

Within our two-country model, assets, agents, and countries are indexed by  $i$  ( $i = 1, 2$ ) and, unless noted, variables are written as  $(2 \times 1)$  vectors. The total world population is normalized to equal 1, with proportion  $k$  of the total population inhabiting country 1. The vector of current dividends is the sum of:

$$D_t = \mu_D + F_t + u_{D,t} , \tag{1}$$

where  $\mu_D$  is a vector of unconditional expected dividend levels,  $F_t$  is a vector of the dividend “fundamentals,” or the persistent component of dividend fluctuations, and  $u_{D,t}$  represents the vector of transitory shocks to dividend payments. Dividend fundamentals,  $F_t$ , follow

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<sup>14</sup>Zhou (1995), using the methods of Sargent (1991), solves an approximating equilibrium to a consumption-based model with information sets which are not perfectly ranked. He and Wang (1995) solve a model with a single asset and non-hierarchical information sets. However, because investors differ only in terms of the noise in their personal signal of the assets’ value, only the average of the signals received by investors influences the equilibrium price.

an AR(1):

$$F_t = \rho_F F_{t-1} + u_{F,t}, \quad (2)$$

where the fundamentals endure according to the  $(2 \times 2)$  diagonal matrix  $\rho_F$ , with diagonals  $0 \leq \rho_{Fi} \leq 1$  and an error term of  $u_F$ . Both permanent and temporary innovations,  $u_D$  and  $u_F$ , are mean-zero, iid bivariate normal, with respective covariance matrices of  $\Sigma_D$  and  $\Sigma_F$ , allowing for cross-country correlations.

In our model, after dividend payments have been made, asset shares may be traded at price  $P_t$ . This represents the vector of prices at which all period- $t$  asset trades occur. Each country's economy is endowed with two shares of its asset per inhabitant. This is so that in a perfect-information equilibrium, inhabitants of economies of equivalent size will hold one share of each country's asset. In addition to the fixed supply of assets, there are two variable components to asset supply. First, in order to prevent prices from fully revealing private information, we require the supply of assets to contain a noise component. The noise component is expressed as  $2u_{N,t}$ , where  $u_N$  is mean-zero, iid bivariate normal with a covariance matrix of  $\Sigma_N$ . Supply noise can be thought of as asset demand that arises from unmodeled, non-informational reasons. For example, this form of demand may arise from investor activity to hedge non-tradable endowment risk.<sup>15</sup> Alternatively, the noise component could reflect trades of investors faced with liquidity shocks. No agent can directly observe the supply noise.

Secondly, investors have the opportunity to invest in projects that have dividends equal to those of the existing asset. Since these projects, once operational, will be indistinguishable from existing assets, their shares will be priced identically to those of existing assets and will contribute to fluctuations in overall supply. However, these projects require capital – physical investments in plant and equipment – to become operational. When the investment to make these projects operational is lower than the price at which shares can be sold, arbitrageurs will bring new projects online, thereby increasing the outstanding supply of shares in the market. Likewise, when the price falls below the value that can be recovered by dismantling projects, shares will be purchased and converted back into capital. For simplicity, we assume that the conversion process is entirely symmetric; the investment to bring a new share to the market equals the amount of capital recovered from dismantling a share of the asset.

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<sup>15</sup>As in, for example, Wang (1994).



Furthermore, projects differ in terms of the magnitude of investment needed by each to become operational. Some projects require little investment capital while for others the requirement is considerable.<sup>16</sup> For simplicity, we assume the capital required to make projects operational is distributed uniformly across the population of projects. Since projects are operationalized in order of investment cost, the marginal project at time  $t$  will have an investment cost linear in the outstanding stock of operational projects at time  $t$ . In particular, let the total amount of shares supplied via investment at time  $t$  be denoted as the  $(2 \times 1)$  vector  $M_t$ . The marginal cost of investment can then be expressed as  $BM_t$ , where  $B$  is a  $(2 \times 2)$  diagonal matrix reflecting the conversion cost in each country. In general, the diagonal coefficients of  $B$  will be higher for those countries and industries with fewer inexpensive projects.<sup>17</sup> For simplicity, we assume the diagonal elements of  $B$  to be proportional to the respective populations, so that projects are equally expensive in both countries. Arbitrageurs can risklessly produce additional shares of the asset at cost  $BM_t$  and then sell them in the market at price  $P_t$ . Thus, the stock of physical investment will be set each period at the level where marginal cost equals marginal return:  $M_t = B^{-1}P_t$ . Hence, the total supply of assets in a given period can be written as:

$$N_t = 2K \left( l + u_{N,t} + B^{-1}P_t \right),^{18} \quad (3)$$

where  $l$  is a  $(2 \times 1)$  vector of ones and  $K$  is a  $(2 \times 2)$  diagonal matrix with  $k$  and  $1 - k$  on the diagonal. Since prices are entirely observable in both countries and conversion costs are fixed, investment levels can be perfectly inferred by inhabitants of either country.

Furthermore, in our model, agents have access to a risk-free asset available in limitless supply with a return of  $r$ . The agents have preferences over current consumption exhibiting

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<sup>16</sup>This assumption is required so that the amount of investment varies continuously with changes in project returns – or the price at which shares in the operational project can be sold. Otherwise there would exist a threshold price above which all projects would be operational and below which all would be dismantled. The assumption also reflects the fact, in reality, few projects have identical investment costs. For example, certain oil reserves require greater outlays than others to be developed. Certain retail locations require more extensive storefronts than others to attract customers.

<sup>17</sup>Such costs could depend, for example, on the infrastructure of a given country or regulatory barriers to entry in a particular industry.

<sup>18</sup>Our assumption of normally distributed supply shocks is required to maintain the linearity of the model. With this comes the possibility that the supply of assets facing investors may be negative. Although investment activity mitigates this potential to some extent, there is little that can be done in the current setting to guarantee information traders always face positive supplies of assets. On the other hand, a situation of negative asset supply can be thought of as one in which liquidity shocks or non-tradable endowment shocks turn up so large that non-informational trading raises prices to the point where information traders find it worthwhile to short the asset. In the numerical analysis that follows, the supply noise and investment parameters we use result in information traders actually short assets less than 1% of the time.

constant absolute risk aversion (CARA):

$$u(c_t) = -\exp(-\gamma c_t)/\gamma, \quad (4)$$

where  $c_t$  is an agent's period- $t$  consumption and  $\gamma$  is the risk aversion coefficient. We allow utility to be time-separable, with future utility discounted at a rate  $\beta$ . For simplicity, we assume that risk-free return on wealth is perfectly offset by the discount rate, namely  $\beta = \frac{1}{1+r}$ . Note that relaxing this assumption does not change our findings.<sup>19</sup>

The final element of the model's structure has to do with the distribution of information. Whereas all current and past prices and dividend payments are observed by each agent, we allow the current fundamentals to be only observed asymmetrically. For a given asset  $i$ , agents in country  $i$  can precisely observe the current fundamental level, while agents overseas must recover the fundamental from a noisy signal. The vector of signals, observable by agents in both countries, can be written as:

$$S_t = (I - \omega)F_t + \omega u_{s,t}, \quad (5)$$

where  $\omega$  is a (2x2) diagonal weighting matrix and  $u_{s,t}$  is mean-zero, iid bivariate normal with a covariance matrix,  $\Sigma_s$ . When the diagonals of  $\omega$  are zero, information is entirely symmetric, as signals perfectly reveal fundamentals to overseas investors. When the diagonals of  $\omega$  are unity, the signals are pure noise, and investors must rely entirely on prices and dividends for information about the overseas fundamental. After a lag of  $j$  periods, fundamentals are fully revealed to agents residing overseas. This assumption is required in order to avoid an "infinite regress" problem, which will arise when information sets are not perfectly ranked.<sup>20</sup> We define the relevant information set of an investor inhabiting country  $i$  accordingly:

$$\mathcal{I}_{i,t} = \{P_\tau, D_\tau, F_{i,\tau}, F_{-i,\tau-j}, S_\tau : \tau \leq t\}.$$

We assume consumption levels are sufficiently noisy or delayed so that they are of little use in returns forecasts, and therefore are not part of the country  $i$  investor's relevant information set. This is done so that investors use only prices, dividends and signals to forecast overseas

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<sup>19</sup>If we allow the risk-free rate to be determined endogenously, the effect of information differences may be somewhat amplified. For example, when uninformed investors erroneously purchase too much of a given asset (and therefore reduce savings in the risk-free asset), in raising the risky asset price and raising the risk-free rate of return, their activity will make it doubly attractive for informed investors to do the opposite.

<sup>20</sup>See Sargent (1991) or Zhou (1995) for an alternative approach of dealing with the infinite regress problem, which allows for the solving of an approximating equilibrium of infinite informational lags.

returns and are unable to infer the overseas investor's perceptions of returns from overseas consumption behavior.

In the above-defined economy,  $n = 8j + 2$  state variables capture all current and future investment opportunities. We can express the  $n \times 1$  vector of state variables as:

$$z_t = \left[ F'_{t-j} \quad u'_{F,t-j+1} \cdots u'_{F,t} \quad u'_{S,t-j+1} \cdots u'_{S,t} \quad u'_{D,t-j+1} \cdots u'_{D,t} \quad u'_{N,t-j+1} \cdots u'_{N,t} \right]',$$

where  $z_t$  evolves according to:

$$z_t = gz_{t-1} + u_t, \tag{6}$$

with  $g$  and  $u_t$  defined according to (1) and (2), and with  $\Sigma_u \equiv E[u_t u_t']$ .

### 3 The Equilibrium

With our economy fully specified, we now will proceed to solve for an equilibrium. We initially conjecture a pricing rule. Based on this, we solve for investor expectations and decision rules. Market clearing is then imposed in order to validate the proposed pricing rule. We begin with the following proposition:

**Proposition 1** *For the world economy defined above, under appropriately-defined parameters, there exists an equilibrium asset pricing rule with the following linear form:*

$$P_t = p^* + Az_t, \tag{7}$$

where  $p^*$  is a  $(2 \times 1)$  constant vector and  $A$  is a  $(2 \times n)$  matrix of coefficients.

Since  $z_t$  is the vector of underlying economic variables, each period agents will use price and dividend observations to form expectations of  $z_t$ 's actual value.  $X_{i,t}$  is the  $z$ -vector perceived from the standpoint of agent  $i$ :

$$X_{i,t} \equiv E[z_t | \mathcal{I}_{i,t}].$$

With the linear pricing rule proposed above and multivariate normality,  $X_{i,t}$  will be a linear projection of  $z_t$  on  $\mathcal{I}_{i,t}$ . We next define matrices  $d_L$ ,  $d_{Fi}$ ,  $d_S$ , and  $d_D$  such that  $d_L$  extracts the  $t - j$ -period fundamentals from the  $z$ -vector;  $d_{Fi}$  forms the  $(j \times 1)$  vector of the last  $j$  domestic fundamentals observed by agent  $i$ ;  $d_S$  produces the vector of the last  $j$  signals; and  $d_D$  extracts the error component from the last  $j$  dividend payments:

$$d_L z_t = F_{t-j}, \quad d_{Fi} z_t = [F_{i,t-j+1} \cdots F_{i,t}]', \quad d_S z_t = [S'_{t-j+1} \cdots S'_t]', \quad \mu_D + d_D z_t = [D'_{t-j+1} \cdots D'_t]'$$

Using these matrices, we write the vector of agent  $i$ 's period- $t$  observation of prices, fundamentals, signals, and dividend errors as:  $\phi_i z_t$ , where  $\phi_i \equiv [A' \ d_L' \ d_{Fi}' \ d_S' \ d_D']'$ . Then expectations of  $z_t$  will be constructed from a projection of  $z_t$  onto  $\phi_i z_t$ . Agent  $i$ 's expected value of the  $z$ -vector will therefore be:

$$X_{i,t} = \Phi_i z_t, \text{ with } \Phi_i = \left( [\phi_i \Sigma_u \phi_i']^{-1} \phi_i \Sigma_u \right)' \phi_i. \quad (8)$$

Notice that an agent's perception of the  $z$ -vector is perfectly linear in the actual vector. This feature is critical to the analysis that follows, as it maintains linearity in agent investment rules.

Turning to the investment opportunities presented by the assets in our economy, we write the period  $t + 1$  vector of excess returns as:

$$R_{t+1} = P_{t+1} + D_{t+1} - (1 + r)P_t, \quad (9)$$

where,  $R_{i,t+1}$  is the return received from borrowing enough to purchase one share of asset  $i$  at time  $t$  and repaying from dividend and the share sale proceeds at time  $t + 1$ . Dropping agent subscripts, applying (6), (8), and the conjectured pricing rule, we decompose excess returns into those anticipated and unanticipated by a given agent:

$$R_{t+1} = e_{R,t} + u_{R,t+1}, \quad (10)$$

$$\text{where } e_{R,t} = -rp^* + \mu_D + eX_t, \quad u_{R,t+1} = e(I - \Phi)u_t + (A + d_D)u_{t+1},$$

and the matrix  $e \equiv A(g - (1 + r)I) + d_D g$  captures the translation of current perceptions of the  $z$ -vector into forecasts of excess returns. Furthermore, our unanticipated returns,  $u_{R,t+1}$ , contain two components. The first reflects the impact of today's error in recovering the current  $z$ -vector. The second is the effect of the innovation in the  $z$ -vector on returns. The perceived  $z$ -vector,  $X_{t+1}$ , is:

$$X_{t+1} = e_{X,t} + u_{X,t+1}, \quad (11)$$

$$\text{where } e_{X,t} = gX_t \text{ and } u_{X,t+1} = \Phi g(I - \Phi)u_t + \Phi u_{t+1}.$$

Having fully characterized the rules which govern state motion and agents' formation of state expectations, we are now in a position to solve for the equilibrium consumption and investment decision rules. With the specified utility function, (4), we can write a given

agent's value function as:

$$\begin{aligned} J(W_t, X_t) &= \max_{c_t, Q_t} \mathbb{E} \left\{ \sum_{s=t}^{\infty} -\beta^{s-t} \exp(-\gamma c_s) / \gamma | X_t \right\} \\ \text{s.t. } W_{t+1} &= (1+r)(W_t - c_t) + Q_t' e_{R,t} + Q_t' u_{R,t+1}, \end{aligned} \quad (12)$$

where  $W_t$  is a measure of total traded-good wealth available for consumption at time  $t$ ,  $Q_t$  is the number of shares invested by the agent in each risky asset, and  $c_t$  is the agent's current consumption level. The solution is provided in the following theorem:

**Theorem 1** *Equation (12) has a solution of the following form:*

$$J(W_t, X_t) = -\frac{1+r}{r} \exp \left( -\gamma \left( \frac{r}{1+r} W_t + \lambda_0 + \Upsilon' X_t + \frac{1}{2} X_t' \Lambda X_t \right) \right) / \gamma, \quad (13)$$

where  $\lambda_0$  is a constant and  $\Upsilon$  and  $\Lambda$  are a  $(nx1)$  vector and a  $(n \times n)$  matrix of coefficients, respectively. Optimal consumption levels and risky asset demands are given respectively by:

$$c_t = \frac{r}{1+r} W_t + \lambda_0 + \Upsilon' X_t + \frac{1}{2} X_t' \Lambda X_t, \quad (14)$$

$$Q_t = \frac{1+r}{r} \Sigma_R^{-1} [e_{R,t} / \gamma - \Sigma_{RX} (\Upsilon + \Lambda X_t)], \quad (15)$$

where  $\Sigma_R = E(u_R u_R')$  and  $\Sigma_{RX} = E(u_R u_X')$ .

*Proof.* See Appendix A. ■

Note that because of the exponential utility specification, an agent's demand for risky assets does not depend on her level of wealth. Two components comprise the optimal risky asset portfolio. The first term depends only on the agent's view of the current investment opportunities. Holdings are selected to optimally trade off perceived risks and returns. The second term acts as the hedging portion of the portfolio. It captures the covariance of the current state, through investment returns, with future investment opportunities. Agents select portfolio holdings that are linear with respect to these two concerns.

Recalling the expression for asset supply in equation (3), the condition for asset market clearing is simply:

$$2K (l + u_{N,t} + B^{-1} P_t) = k Q_{1,t} + (1-k) Q_{2,t}.$$

Substituting equilibrium investment demands, we identify the linear pricing rule that clears the market. Solving for  $p^*$ , we get:

$$p^* = \frac{\mu_D}{r} - \frac{\gamma}{r} \left( k \Sigma_{R1}^{-1} + (1-k) \Sigma_{R2}^{-1} \right)^{-1} \left( \frac{r}{1+r} 2Kl + k \Sigma_{R1}^{-1} \Sigma_{RX1} \Upsilon_1 + (1-k) \Sigma_{R2}^{-1} \Sigma_{RX2} \Upsilon_2 \right). \quad (16)$$

The first term in the above expression reflects the value of the riskless component of the assets – the stream of perpetual dividends payments equal to  $\mu_D$ . The second term captures the unconditional risk premium imbedded in asset prices. Since risky assets are in positive net supply and their dividend payments contain risk, their prices must be discounted sufficiently to induce agents to hold them in favor of the risk-free asset. The  $z$ -vector coefficients in the pricing rule,  $A$ , are solved from the following set of non-linear equations, which require supply noise to be cleared by the market:

$$\frac{r}{1+r}2K(d_N + B^{-1}A) = k\Sigma_{R1}^{-1}e\Phi_1/\gamma + (1-k)\Sigma_{R2}^{-1}e\Phi_2/\gamma - k\Sigma_{R1}^{-1}\Sigma_{RX1}\Lambda_1\Phi_1 - (1-k)\Sigma_{R2}^{-1}\Sigma_{RX2}\Lambda_2\Phi_2, \quad (17)$$

with  $d_N$  defined such that  $d_N z_t = u_{N,t}$ . Solutions to (16) and (17) entirely determine the pricing function and complete our proof of Proposition 1.<sup>21</sup>

In general, the equilibria derived above will not be unique. The numerically-derived solutions of the following section indicate that there exist, in fact, two sets of equilibria – one exhibiting greater pricing variability than the other. This is in line with the findings of Grundy and McNichols (1989), and especially Hirshleifer, Subrahmanyam, and Titman (1994) and Spiegel (1997) – who also identify high and a low-volatility equilibria. The point is made quite apparent upon inspection of the perfect-information sub-case. Consider a setting where signals are perfect ( $\omega = 0$ ) and, for simplicity, asset fundamentals are uncorrelated, investment does not take place, investors have risk-aversion ( $\gamma$ ) equal to 1, and the information lag is one-period. In this situation, we drop agent and asset subscripts to describe the linear equilibria in the following theorem:

**Theorem 2** *When information is perfect, assets are uncorrelated across countries, no investment takes place, and a single-period information lag exists, linear equilibrium pricing rules for each asset will obey:*

$$P_t = p^* + A_F F_t + A_N u_{N,t}. \quad (18)$$

Here,  $A_F = \frac{\rho_F}{1+r-\rho_F}$  and  $A_N$  solves the following quadratic equation:<sup>22</sup>

$$\frac{r}{1+r}\Sigma_N A_N^2 + (1+r + \Sigma_N \Lambda_N)A_N + \frac{r}{1+r}(\Sigma_D + (1+A_F)^2\Sigma_F) = 0, \quad (19)$$

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<sup>21</sup>We do not have an analytical form of the solution to equation (17). The results provided in the following section are derived using numerical solutions.

<sup>22</sup>Note that a real solution to equation (19) exists only when the discriminant is positive; namely when  $\Sigma_D + (1+A_F)^2\Sigma_F$  is not too large relative to  $\Sigma_N$ .

where  $\Lambda_N$  corresponds to one of the final two diagonal entries in  $\Lambda$  (the only non-zero entries). Each solves a second quadratic equation:

$$A_N^2 \Sigma_N^2 \Lambda_N^2 + (1+r)(A_F^2 \Sigma_F + A_N^2 \Sigma_N) \Lambda_N - (1+r)^2 A_N^2 = 0. \quad (20)$$

Joint solutions to (19) and (20) with  $\Lambda_N > 0$  and  $A_N < 0$  entirely determine the perfect-information equilibria.<sup>23</sup>

Note that the sign on the discriminant of equation (20) must be positive for  $\Lambda_N$  to be positive. On the other hand,  $A_N$  will be negative regardless of discriminant sign. Hence, there are two different equilibria for which  $\Lambda > 0$  and  $A_N < 0$ . When the discriminant of equation (19) is negative, the equilibrium resembles “ $T^+$ ” in Hirshleifer, Subrahmanyam, and Titman (1994). That is, prices respond in greater magnitude to supply shocks, and agents receive greater value through their responses to these shocks.

The intuition for multiple equilibria in a perfect-information setting is as follows. Consider the case where investors conjecture a highly volatile pricing rule where prices respond drastically to supply shocks. In this case, although investors have incentives to purchase the asset when supply is high and prices low, these incentives are severely mitigated by the high risk associated with the asset’s returns. As a result, there exists a market-clearing price rule where the attractiveness of expanding holdings at low prices when supply is high is offset by the highly risky returns associated with such trading. Appendix B shows that there exist imperfect-information equilibria which are local to the perfect-information equilibria with negative and positive signs on the equation (19) discriminant.<sup>24</sup> We call these sets “high-volatility” and “low-volatility” equilibria, respectively.

## 4 Numerical Results and Implications

The following section first solves for equilibrium consumption, investment, and pricing rules under various parameterizations, and then investigates the economy’s implications for international risk-sharing puzzles. As a benchmark, we calibrate the model to U.S. macroeconomic data. The interest rate is set to 5% per year, roughly the rate of return on capital over the past century. Following the literature, the risk aversion coefficient is set to 2.5.<sup>25</sup>

<sup>23</sup>In general, there will be four solutions to (19) and (20). We restrict our attention to the two ‘non-perverse’ equilibria where agents benefit from supply shocks with prices falling when supply is excessive.

<sup>24</sup>The uniqueness of these equilibria, particularly with respect to non-linear possibilities, is not addressed.

<sup>25</sup>See Sundaresan (1989), Leland (1992), and Hirshleifer, Subrahmanyam, and Titman (1994).

Table 1: Benchmark Parameter Values

Preferences	$\beta=0.95, \gamma=2.5$
Technology	$\rho_F = 0.764, B = \begin{bmatrix} 156 & 0 \\ 0 & 156 \end{bmatrix}, \mu_D = \begin{bmatrix} 1.75 \\ 1.75 \end{bmatrix}$
Technology shocks	$\Sigma_F = \Sigma_D = \Sigma_S = \begin{bmatrix} 0.529 & 0.077 \\ 0.077 & 0.529 \end{bmatrix}, \Sigma_N = \begin{bmatrix} 0.367 & 0 \\ 0 & 0.367 \end{bmatrix}$

Fundamental persistence,  $\rho_F$ , is set to 0.764 for both countries, following Dejong and Whiteman's (1991) the estimate persistence in the value-weighted NYSE earnings between 1926 and 1986. The investment cost is set so that the standard deviation of investment, as a fraction of the total capital stock, equals the 1.25% figure for the postwar U.S. economy.<sup>26</sup> Unconditional dividend levels and variances of persistent and transitory dividend shocks are calibrated to the average return (20.2%) and variance (408%) of the S&P500 from 1926-1994.<sup>27</sup> Cross-country correlations are set to 0.145, the correlation of U.S. and Japanese annual postwar output growth. This figure is consistent with estimates of Backus, Kehoe, and Kydland (1991). In the results that follow, supply noise is set to account for 0 to 50% of price variability. Signal quality ( $\omega$ ) and population distribution ( $k$ ) are allowed to vary over their entire ranges - from 0 to 1. When held constant, supply noise is set so that it accounts for 25% of price variability and the population distribution is set to 0.5. Wherever results are sensitive to the selected parameters, the sensitivity is addressed in the figures and discussion that follow. For simplicity, we focus on the single-period information lag. In the final subsection, we compare the results to those obtained in a setting with two- and three-period information lags.

#### 4.1 Perfect Information

We first examine the perfect-information case where  $\omega$  equals zero for both countries. Solving, we get the following low-volatility equilibrium pricing rule:

$$p^* = \begin{bmatrix} 14.93 \\ 14.93 \end{bmatrix} \quad A = \begin{bmatrix} 2.00 & -0.01 & 2.61 & -0.01 & 0 & 0 & 0 & 0 & -0.89 & -0.13 \\ -0.01 & 2.00 & -0.01 & 2.61 & 0 & 0 & 0 & 0 & -0.13 & -0.89 \end{bmatrix}.$$

<sup>26</sup>In our economy, the investment variance-covariance matrix, as a fraction of asset supplies, is equal to  $B^{-1}AK^{-1}\Sigma_uK^{-1}A'B^{-1}/4$ . The standard deviation of U.S. investment, as a fraction of U.S. stock market capitalization, is estimated to be 1.25% over the 1948-1997 period. Source: International Monetary Fund, *International Financial Statistics*.

<sup>27</sup>Source: Ibbotsen Associates, Inc., *1995 Yearbook*.



The high-volatility pricing rule solves as the following:

$$p^* = \begin{bmatrix} 142.76 \\ 142.76 \end{bmatrix} \quad A = \begin{bmatrix} 1.91 & 0.01 & 2.51 & 0.01 & 0 & 0 & 0 & 0 & -31.68 & 1.57 \\ 0.01 & 1.91 & 0.01 & 2.51 & 0 & 0 & 0 & 0 & 1.57 & -31.68 \end{bmatrix}.$$

Notice that without investment, the coefficients on  $u_{F,t}$  would equal 2.67 instead of 2.61 and 2.51 in the low- and high-volatility equilibria, respectively. With investment a unit increase in fundamentals does not translate into a full 2.67 point increase in price. Since additional capacity is brought online when fundamentals improve, some of the price rise is mitigated by increased share supply. Coefficients on  $u_{S,t}$  and  $u_{D,t}$  are zero, as neither has an impact on future dividends or expectations thereof. The supply coefficients are negative so that the market can clear supply shocks. In the high-volatility equilibrium, the coefficients are more negative as prices respond more drastically to these shocks.

The excess return covariance matrices are:

$$\text{low: } \Sigma_R = \begin{bmatrix} 8.41 & 1.27 \\ 1.27 & 8.41 \end{bmatrix} \quad \text{high: } \Sigma_R = \begin{bmatrix} 442.85 & -25.60 \\ -25.60 & 442.85 \end{bmatrix}.$$

Although returns are equally variable across assets, they are considerably more variable in the high-volatility equilibrium. The value function's parameters,  $\lambda_0$ , the final two entries of  $\Upsilon$ , and the final four entries of  $\Lambda$ , turn out to be:

$$\begin{aligned} \text{low: } \quad \lambda_0 &= 1.61 & \Upsilon_N &= \begin{bmatrix} 0.05 & 0.05 \end{bmatrix}' & \Lambda_N &= \begin{bmatrix} 0.04 & 0.01 \\ 0.01 & 0.04 \end{bmatrix} \\ \text{high: } \quad \lambda_0 &= 14.27 & \Upsilon_N &= \begin{bmatrix} 1.43 & 1.43 \end{bmatrix}' & \Lambda_N &= \begin{bmatrix} 0.64 & 0 \\ 0 & 0.64 \end{bmatrix} \end{aligned}$$

Note that the unconditional consumption levels,  $\lambda_0$ , are positive, reflecting that, unconditionally, there are positive returns to be earned in this economy and positive risks to be borne. Additionally, the final two terms of  $\Upsilon$  and four terms of  $\Lambda$  are positive, while other terms are zero. When supply is excessive, prices are low and can be expected to rise. Part of this expected increase is transferred to current consumption, and this takes place through the final two coefficients in  $\Upsilon$ . In addition, risky asset holdings are optimally adjusted. As equation (15) shows, asset holdings depend conditionally on the state vector through  $\Lambda$ . Since  $Q_t$  can be adjusted to profit from the noise trade (through selling at an inflated price or buying at a depressed price), the agent receives additional current consumption from changes in asset supply. In the high-volatility equilibrium, prices respond more drastically to supply shocks. Thus current consumption, through  $\Upsilon$  and  $\Lambda$ , is more sensitive to current supply levels, as their effect on future wealth is more exaggerated.

We now proceed to examine the behavior of our economy as the distribution of information becomes asymmetric. As many of the results are qualitatively similar for the two equilibria, we focus primarily on the low-volatility equilibrium, pointing out where distinctions between the two emerge.

## 4.2 Home Bias

When fundamentals are signaled perfectly to overseas investors, assets appear identical from a risk-return standpoint. Agents have no incentive to bias holdings domestically. However, as  $\omega$  increases, and fundamentals are signaled abroad with increasing noise, investors begin to favor domestic assets. This takes place through two distinct avenues. From equation (15), we can express unconditional asset holdings as:

$$E[Q] = \frac{1+r}{r} \Sigma_R^{-1} (-rp^* + \mu_D) / \gamma - \frac{1+r}{r} \Sigma_R^{-1} \Sigma_{RX} \Upsilon. \quad (21)$$

When less of the overseas fundamental is observed, the agent forecasts returns with less precision. Greater supply ( $\Sigma_N$ ) or signal noise ( $\Sigma_S$ ) further inhibits the recovery of overseas fundamentals from prices and signals. As a result,  $\Sigma_R^{-1}$  discounts the overseas unconditional risk premium more severely, shifting investment domestically. For the benchmark economy, when signals are purely noise,  $\Sigma_R$  tilts clearly in favor of domestic holdings:

$$\Sigma_R = \begin{bmatrix} 7.57 & 1.14 \\ 1.14 & 8.26 \end{bmatrix}.$$

In addition to avoiding the higher variability of overseas returns forecasts, domestic assets provide a superior hedge against consumption risk. This advantage is reflected in the covariance of asset returns, through next period's perceived state, with consumption (the second term of (21)). To illustrate this relationship, we consider the impact of a temporary negative shock to domestic dividends. An uninformed foreign investor, worried that the dividend decline might reflect a fall in the home fundamental, will sell holdings, thus depressing the domestic asset price. In addition, as a result of the perceived poor state, the overseas investor will reduce consumption. On the other hand, the domestic agent, aware that the low dividend is temporary, will increase holdings at the reduced price and, forecasting a price increase, will expand consumption. As a result, domestic assets act as more effective hedges against consumption risk. When  $\omega = I$ , the domestic asset offers a definitive hedging advantage:

$$-\Sigma_{RX} \Upsilon = \begin{bmatrix} 0.019 \\ 0.017 \end{bmatrix}.$$

\*\*\*\*\*

[Insert Figure 1 about here.]

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Figure 1 illustrates the effect of information on portfolio composition. As signals of overseas fundamentals become increasingly noisy, agents exhibit a strong preference for domestic assets. Supply noise hides information contained in the prices and thus reinforces these tendencies. Smaller countries, relative to the fraction of their portfolio invested domestically in the perfect information case, tilt their portfolios aggressively homewards. In a frictionless world, the fraction of an investor's portfolio allocated to domestic securities should be identical to the domestic market's share of the world market portfolio. For example, inhabitants of Switzerland invest less domestically than U.S. investors simply because their market is a smaller fraction of the world market. To account for this, in the second panel of Figure 1 we express home bias as the extent to which the fraction of an investor's portfolio allocated to domestic investments differs from the domestic market's share of the world market portfolio. Not surprisingly, large countries with already most of their holdings at home have little room to bias portfolios. Yet, when countries are very small, the degree of home bias caused by information advantages is also low. This is because their asset, whose return has a low correlation with the rest of the world market, becomes exceedingly scarce. Hence, uninformed foreign investors are eager to hold the asset in spite of their information disadvantage.

### 4.3 Capital Flows

The lack of precision of overseas return forecasts, coupled with home bias, suggests that little overseas trading occurs. However, while agents favor holding domestic assets, they actively transact in the overseas market. As information becomes asymmetric, trading volumes grow. Under certain conditions, agents actually prefer transacting in the foreign markets, trading relatively larger portions of their overseas portfolio. This behavior is documented in recent studies that have found that foreign investors, although generally holding a small portion of a given market, can often have important influences on the market itself.<sup>28</sup>

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[Insert Figure 2 about here.]

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<sup>28</sup>See Tesar and Werner (1994a, 1994b) and Hamao and Mei (1995)

\*\*\*\*\*

Defining total trading volume as the weighted sum of standard deviations in investor asset holdings as a percentage of market size, we plot its response to increasing information asymmetry in Figure 2. The graphs of Figure 2 show that informational differences result in definitive increases the volume of trade. Under perfect information conditions, the only trades that take place under perfect information are those to absorb supply shocks. However, when information sets diverge, information-based trades increase. As differences of opinion increase, so do the number of “horse races.” As long as the adverse selection cost of trading with better-informed overseas investors does not become prohibitive, volumes will increase uniformly. Only as  $\omega$  nears unity, and adverse selection is severe, do trading volumes trail off slightly. Less obvious, is the fact that smaller countries experience relatively larger increases in volume. Smaller countries with fewer assets, find the relative risk-reward value of those assets to the average portfolio is greater (insofar as they are subject to country-specific shocks). As a result, overseas agents willingly incur large adverse selection costs to hold the scarce asset of the small country, trading frequently with the better-informed domestic agents.

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[Insert Figure 3 about here.]

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An examination of portfolio turnover rates further illustrates the role of information in investor behavior. Although investors will always tilt their holdings towards domestic securities, under certain conditions, they choose to trade a greater portion of their overseas portfolio. In this setting, the two equilibria differ importantly. Figure 3 plots the ratio of overseas to domestic portfolio turnover for both the low- and high-volatility equilibria. In the low-volatility equilibrium, supply shocks are absorbed primarily by domestic investors. In this equilibrium, informed agents can expand positions with relatively low increases in portfolio variability. As a result, foreign investors face a more severe adverse selection problem. In the high-volatility equilibrium, when asset returns are considerably more variable, foreign investors bear a large share of the supply shock absorption. Domestic agents, already facing substantial unconditional risks, are not willing to assume positions on the order of those in the low-volatility equilibrium. As a consequence, foreign agents face less adverse

selection, and transact more willingly in the domestic market. In this equilibrium, agents trade a greater portion of their overseas than home portfolio. Although unconditional holdings are similar in the two equilibria, a comparison of the final four terms of  $\Lambda$  confirms that investors are considerably more willing to absorb overseas supply shocks in the high-versus low-volatility equilibrium:

$$\text{low: } \Lambda_N = \begin{bmatrix} 0.101 & -0.006 \\ -0.006 & 0.092 \end{bmatrix} \quad \text{high: } \Lambda_N = \begin{bmatrix} 0.659 & -0.013 \\ -0.013 & 0.645 \end{bmatrix}.$$

Notice that in the low-volatility case,  $\Lambda_N$  is more tilted towards the domestic security, indicating that a higher fraction of domestic supply shocks will be absorbed. Conversely, in the high-volatility equilibrium,  $\Lambda_N$  is nearly identical for the domestic and overseas supply shocks, reflecting indifference in trading foreign versus domestic securities. Finally, as supply noise nears zero and home bias disappears, the turnover ratio returns to unity.

#### 4.4 Consumption Patterns

As information asymmetries are introduced, consumption patterns across countries differ. Clearly, as investors tilt holdings toward domestic assets, and income streams diverge, domestic consumption levels depend more heavily on domestic asset returns. Equally important, however, in terms of its impact on domestic consumption, is the trading behavior of overseas investors in domestic markets.

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[Insert Figure 4 about here.]

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Figure 4 depicts domestic and overseas consumption responses to temporary and permanent increases in dividends. If overseas agents correctly perceived the given shock, consumption would follow the dotted line. A comparison of these to the actual paths reveals that, in both cases, the shifts in consumption occur primarily because of information asymmetry, and not because investors hold domestically-biased portfolios. With a shock to the fundamental, both overseas and domestic agents' consumption rise. The domestic agent, with holdings tilted homeward, sees the greater increase. The overseas agent, not fully informed of the surge in the fundamental, sells some domestic holdings. This sell-off further shifts consumption from the overseas to the domestic agent. However, domestic consumption does not fully realize this increase until the uncertainty is resolved at time  $t + 2$ . To

take advantage of the overseas information, the domestic agent must increase her share of the world portfolio, thereby incurring a high amount of risk. To equate expected marginal utility in periods  $t + 1$  and  $t + 2$ , she must delay a portion of her increased consumption.

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[Insert Figure 5 about here.]

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The temporary domestic dividend shock can also generate long-run consumption shifts. Although the domestic agent holds a greater share of the asset experiencing the high dividends, the information structure results in a greater share of consumption going to the overseas agent. Under some conditions, a temporary shock, and its ensuing capital inflows, can leave the domestic agent with less consumption than if no shock had occurred.

Nonetheless, the domestic agent fares better in this situation than the overseas investor when risk is considered. In fact, she fares even better than she would have in a perfect information setting. That is, the overseas agent perceives the high dividend as an increased fundamental and buys up the domestic asset. The domestic agent, although substituting partially into the foreign asset, bears less risk from periods  $t + 1$  to  $t + 2$ . As a result, she requires less consumption from period  $t + 2$  onward. By contrast, the overseas agent, having borne an excessive share of world risk, is only partially compensated with a greater consumption level.

When investors trade on the basis of differential information, their activities directly alter overseas short-term and long-term consumption patterns, as the consumption responses to temporary dividend shocks in Figure 4 illustrate. Although the temporary shocks have no long-term dividend implications, the fact that the agents perceive and react to them differently (in particular, the overseas agent reacts overly optimistically) creates long-term divergence in their respective consumption behavior. Figures 5 and 6, plot consumption correlations in relation to information asymmetries, supply noise, and country size.

As can be seen in the left-hand side panels, increased information asymmetry causes consumption correlations to fall uniformly. These results reflect more than portfolio divergence, however. Hence it is worth abstracting from the segmentation in holdings to identify the effect of differential information trading on the consumption correlations. To do so, we compare the current specification to a perfect-information case with an equivalent bias in investor portfolios and where investors trade supply shocks in each security in proportion

to their holdings. Such a specification will identify how much consumption correlations are being lowered due to imperfect risk-sharing rather than to trading on differential information. A perfect information setting in which investors bias portfolios domestically and trade supply shocks in proportion to their holdings can be captured by altering the variance-covariance matrix so that it tilts towards domestic investments from the perspective of each investor. Specifically, if investors in country 1 (2) view  $\Sigma_u$  to be  $H\Sigma_uH$ , where  $H$  is a diagonal matrix with odd (even) row entries equal to  $0 < h < 1$  and even (odd) row entries equal to  $1/h$ , investors will bias portfolios domestically, and will trade supply shocks in each security in proportion to their holdings. In this scenario, solving for the  $h$  that delivers holdings bias equivalent to the asymmetric information case, we can measure how much decline in consumption correlation comes about solely because of investors' placement of a disproportionate share of their portfolio in the domestic security. The second panel of Figures 5 and 6 display consumption correlations when this component is removed.

\*\*\*\*\*  
 [Insert Figure 6 about here.]  
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As we can see, differential information plays an important role in altering consumption behavior, while the holding of divergent portfolios plays only a secondary role. The second panels show what the advantage of information asymmetry over other explanations of international capital market segmentation. With differing information, the information trading of overseas investors directly alters domestic consumption patterns. It is this activity which reconciles evidence of low and declining cross-country consumption correlations with a setting where barriers to international investment are falling and incentives to diversify holdings internationally are mild. When permanent and temporary dividend shocks are highly correlated across countries, consumption correlations may end up even lower than those of dividends.<sup>29</sup> Because diversification benefits are low, the trading activity can amplify consumption differences beyond those of output.

#### 4.5 Savings-Investment Correlations

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<sup>29</sup>For example, in the benchmark model, when permanent dividend shock covariance is 0.7 and that of temporary shocks is 0.9, output growth correlation is 0.83 while consumption growth correlation is 0.81.

[Insert Figure 7 about here.]

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As mentioned earlier, one of the more puzzling aspects of international capital market segmentation is how capital mobility differs from the stock than from the flow perspective. From the standpoint of the Feldstein-Horioka Paradox, the distinction is particularly acute. As Martin Feldstein puts it, “Although there are large daily flows of capital around the world, when the dust settles most of the saving done in each country remains in that country.”<sup>30</sup> Hence, a major challenge in understanding the nature of international capital market segmentation is to reconcile these two seemingly contradictory aspects of capital mobility. Information asymmetry offers some key insights towards resolving this puzzle. Under informational differences, portfolios tilt domestically but agents trade actively overseas. A natural conclusion might be that these transactions break the co-movement between national savings and investment rates. However, information trading has the opposite effect.

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[Insert Figure 8 about here.]

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In Figures 7 and 8, we plot correlations of national savings and investment rates relative to information asymmetry, supply noise, and country size.<sup>31</sup> As these figures show, when the dust settles, savings rates move moving more closely with investment under information asymmetry than under perfect information. Certainly, part of the correlation comes simply from the fact that because portfolios begin to tilt domestically, domestic wealth changes are increasingly determined by changes in domestic returns, which in turn determine the incentives to bring new investment on line or dismantle existing investment. This aspect is captured in the overall effect of information asymmetry depicted in the first panels. More importantly, information differences are the mechanism that allows domestic agents to *profit* from changes in domestic investment opportunities. When the domestic fundamental increases, but the price does not reflect this fact, the domestic agent profits. In particular, aware that domestic returns are favorable, the domestic agent expands holdings (i.e., her savings rate), earning returns from the ensuing improvement in the domestic investment

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<sup>30</sup>The Economist, June 24, 1995, p.73

<sup>31</sup>Following Backus, Kehoe, and Kydland (1992), we use changes in national wealth as the measure of national savings.



climate. In fact, as we see in Figure 8, it is in the smaller countries, with relatively large amounts of information trading taking place, where the presence of information asymmetries results in the greatest increases in savings-investment correlations. Indeed, domestic savings and investment rates can move closely together even in a setting with substantial cross-border financial transactions.

## 4.6 Assessment

The success of information asymmetry in explaining international capital market segmentation is mixed. On the one hand, information asymmetries affect portfolios, consumption correlations, and savings-investment correlations in the proper directions; portfolios tilt homeward, consumption correlations fall, and savings-investment correlations rise. Indeed, as Gosh and Pesenti (1994) discuss, few models of the international capital market can jointly address these empirical regularities. Moreover, the correlations largely reflect increased trading due to informational divergence rather than homeward-biasing of portfolio holdings. On the other hand, the calibrations of the data to real-world magnitudes indicate that information asymmetries alone, as modeled here, are not sufficient to account for the observed magnitudes of home bias, low consumption correlations, and high savings-investment correlations.

With the benchmark parameters, investors hold only 52.7% of their wealth in domestic assets in the low-volatility equilibrium and 57.5% in the high volatility equilibrium. While these figures are above the 50% of the perfect information case, they reflect far less bias than that exhibited by U.S. investors, who place an average of over 90% of their holdings in domestic securities. One possible reason for this might be that the single-period information lag understates the disadvantage investors face selecting overseas securities. Indeed, Brennan and Cao (1997) demonstrate that marginal and cumulative (multi-period) information advantages can have substantially different impacts on investor trading strategies. To investigate this possibility, in Figure 9, we graph the increase in local bias brought about by extending the information lag from one to two and from two to three periods.

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[Insert Figure 9 about here.]

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As can be seen, when supply noise accounts for a modest fraction of price variability

(around 20%), a two-period information lag can increase home bias an additional 2.5%. At low and high fractions, the cumulative information advantage has less of an effect. When the lag is extended to three periods, there is little further increase in home bias. Hence, we must conclude that the current model, like many other potential explanations,<sup>32</sup> delivers a degree of local bias that is not large relative to magnitudes observed in the real world.

There are several potential reasons for this finding. First, the present model may overstate the benefits of international diversification. With error terms normally distributed and fundamentals only correlated by only 14.5%, considerable incentives exist to diversify across borders. Empirically, returns appear to have more kurtosis than a normal or a log-normal specification, and cross-country correlations are high over these extreme values (particularly when returns are negative).<sup>33</sup> In reality, the ability of an internationally-diversified portfolio to mitigate large negative returns is likely much lower. A second explanation for the low home bias of the model is that the form of information asymmetry considered here is fairly straightforward. Using observations of dividends and prices to recover a single unknown variable each period, foreign investors simply do not forecast returns with far greater inaccuracy than domestic investors. On the other hand, the ability of investors to observe and hold overseas market indices cautions against constructing overly complicated characterizations of information asymmetry. In the concluding section, we discuss some alternative possibilities for amplifying the degree of home bias delivered by an asymmetric information setup.

In explaining consumption correlations, the model fares better. For the benchmark parameters, consumption correlations fall from 100% to nearly 80%. The bulk of this shift comes from the information component. Considering that U.S. consumption correlations with Japan are 30%, while those with Europe are 46% (Backus, Kehoe, and Kydland (1992)), this lowering of consumption correlations is non-trivial and compares favorably to that explained by other models.<sup>34</sup> Moreover, because the present model produces reduced consumption correlations which result largely from expanded information-based capital flows, it offers something that other models do not: an explanation for why cross-border consumption correlations have declined while capital flows have increased.<sup>35</sup> Unfortunately,

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<sup>32</sup>See, for example, Adler and Dumas (1983), Ghosh and Pesenti (1994), and Baxter and Jermann (1997).

<sup>33</sup>See Lin, Engle, and Ito (1994).

<sup>34</sup>Backus, Kehoe, and Kydland (1992) simulate a two-country benchmark economy where consumption correlations are 88% between foreign and domestic consumption, and offer alternative specifications which deliver consumption correlations of similar magnitude.

<sup>35</sup>See Devereaux, Gregory, and Smith (1992) and Obstfeld (1995).

increasing the information lag does not significantly lower consumption correlations further.

It is worth noting that the information-based capital flows generated in this model have properties which are consistent with other empirical and theoretical findings. In the benchmark high-volatility equilibrium, the turnover of overseas holdings is 34% higher than that of the domestic portfolio. This figure is comparable to measurements of Tesar and Werner (1994b), who estimate the 1989 U.S. investor turnover rate to be twice as high abroad as at home.<sup>36</sup> Additionally, the capital flows in this paper exhibit patterns consistent with those identified in Brennan and Cao (1997), with the foreign investor shares increasing when the returns in a particular market are high. This was alluded to in our discussion of consumption responses in Section 4.4. That is, when a market experiences a rise in the dividend fundamental, local investors, aware that the dividend increase is permanent, expand their holdings by purchasing shares from foreigners. When foreigners finally become aware that the dividend increase is permanent, they repurchase shares from locals, bidding up prices. As a result, their purchases are positively associated with the local returns. Likewise, when the dividend increase is temporary, foreigners purchase shares from locals, thus inflating share prices. When the dividend increase is revealed as temporary, foreigners sell back their shares, resulting in declining prices to accompany their withdrawal from the market.

Finally, the model provides promising savings-investment correlations. In absolute levels, the model delivers savings-investment correlations of 70-85%. These levels equal or exceed those reported by Backus, Kehoe, and Kydland (1992) for the U.S. (68%), Germany (42%), and Japan (50%). On the other hand, while information trading increases the correlations, its role in overall magnitude is more modest. At most, information-based trades can add 3 percentage points to the benchmark correlations and up to 6% for smaller countries. Extending the information lag to multiple periods does not increase the correlations significantly. Hence, although information asymmetries appear to increase a country's savings-investment correlation, the high overall savings-investment rates of our model likely have more to do with how explicitly the rate of investment has been tied to the current level of asset prices. A more general investment technology, incorporating a time-to-build structure<sup>37</sup> or investment return uncertainty, would weaken this link, producing significantly

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<sup>36</sup>Tesar and Werner (1994b) estimated the domestic turnover rate at 1.16 and the foreign turnover rate to be 2.5. Tesar and Werner (1994a) found that, between 1982 and 1990, foreigners turned over US holdings 25% more frequently than the US average.

<sup>37</sup>See Kydland and Prescott (1982).

lower correlations and a potentially larger role for information asymmetry.

## 5 Conclusion

This paper outlines the importance of cross-country informational differences in reconciling evidence of low global risk-sharing with a world of growing cross-border capital flows. The information-based approach in this paper relies on a simple information structure, where inference rules are linear projections, and hidden variables are fully revealed over time. Nonetheless, the model provides a unified explanation for the three major risk-sharing puzzles of the international economy: home bias in equity holdings, low cross-country consumption correlations, and high domestic savings-investment correlations. The model establishes an environment where investors transact actively in foreign markets - under some conditions trading a larger portion of foreign than domestic holdings - which, in turn, strengthens the savings-investment correlations and weakens the cross-border consumption correlations.

Despite its promise, the model in this paper has difficulty delivering magnitudes – particularly levels of home bias – which are consistent with the data.<sup>38</sup> Two related lines of research are likely to remedy this weakness of the asymmetric information approach. The first focuses on agency issues surrounding delegated portfolio management. In particular, relative performance considerations, associated with portfolio managers attempting to signal ability to clients, may compel managers to further bias portfolios domestically. Managers may signal relative ability more clearly by selecting investments from the pool in which their competitors invest, even if this pool consists largely of domestic opportunities.<sup>39</sup> A related possibility is that of relative utility. If investors are concerned with their level of utility relative to their neighbor, then their risk-free portfolio is that of their neighbor – even if it is undiversified internationally. Under some conditions, investors may find it optimal to select their investments from this portfolio, and not to deviate towards one which is more diversified internationally. If the above considerations hold up under general equilibrium conditions, small informational advantages in evaluating domestic investments can compound into a large home bias in portfolios.

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<sup>38</sup>This is a problem with information-based explanations of the home bias phenomenon, in general.

<sup>39</sup>See Maug and Naik (1996) for a similar argument in a domestic context.

## Appendix A. Solution to Investors' Optimization Problem

$$\begin{aligned}
J(W_t, X_t) &= \max_{c_t, Q_t} \mathbf{E} \left\{ \sum_{t=s}^{\infty} -\beta^{t-s} \exp(-\gamma c_t) / \gamma | X_t \right\} \\
s.t. \quad W_{t+1} &= (1+r)(W_t - c_t) + Q'_t e_{R,t} + Q'_t u_{R,t+1}. \quad (12)
\end{aligned}$$

Using (10) and (11) we can write the covariance matrix of the value function's state variables as:

$$\Sigma_{t+1} = \begin{bmatrix} Q'_t \Sigma_R Q_t & Q'_t \Sigma_{RX} \\ \Sigma_{XR} Q_t & \Sigma_X \end{bmatrix}, \text{ where}$$

$$\Sigma_R = e(I - \Phi) \Sigma_u (I - \Phi)' e' + (A + d_D) \Sigma_u (A + d_D)',$$

$$\Sigma_X = \Phi g (I - \Phi) \Sigma_u (I - \Phi)' g' \Phi' + \Phi \Sigma_u \Phi', \text{ and}$$

$$\Sigma_{RX} = \Sigma'_{XR} = e(I - \Phi) \Sigma_u (I - \Phi)' g' \Phi' + (A + d_D) \Sigma_u \Phi'.$$

Defining  $s_t \equiv \begin{bmatrix} W_t & X'_t \end{bmatrix}'$ , we can rewrite the value function as:

$$(1 - \beta) J(s_t) = \max_{c_t, Q_t} \{ -\exp(-\gamma c_t) / \gamma + \beta \mathbf{E} \Delta J(s_{t+1}) \}.$$

Using a discrete time approximation of Ito's lemma<sup>40</sup> and eliminating higher-order terms, this becomes:

$$(1 - \beta) J(s_t) = \max_{c_t, Q_t} \left\{ -\exp(-\gamma c_t) / \gamma + \beta \mathbf{E} \left[ \Delta s_{t+1} \frac{\partial J}{\partial s_t} + \frac{1}{2} \text{tr} \left( \frac{\partial^2 J}{\partial s_t \partial s'_t} \cdot \Sigma \right) \right] \right\}.$$

Differentiating with respect to  $c_t$  and  $Q_t$  we get the following first-order conditions:

$$0 = \exp(-\gamma c_t) + \beta \left[ \frac{\partial \mathbf{E} \Delta s'_{t+1}}{\partial c_t} \cdot \frac{\partial J}{\partial s_t} + \frac{1}{2} \frac{\partial \text{tr} \left( \frac{\partial^2 J}{\partial s_t \partial s'_t} \cdot \Sigma \right)}{\partial c_t} \right], \quad (22)$$

$$0 = \beta \left[ \frac{\partial \mathbf{E} \Delta s'_{t+1}}{\partial Q_t} \cdot \frac{\partial J}{\partial s_t} + \frac{1}{2} \frac{\partial \text{tr} \left( \frac{\partial^2 J}{\partial s_t \partial s'_t} \cdot \Sigma \right)}{\partial Q_t} \right]. \quad (23)$$

Next, assume that the value function has the following form:

$$J(W_t, X_t) = -\frac{1+r}{\gamma r} \exp \left( -\gamma \left( \frac{r}{1+r} W_t + \lambda_0 + \Upsilon' X_t + \frac{1}{2} X'_t \Lambda X_t \right) \right),$$

where  $\lambda_0$  is a constant,  $\Upsilon$  and  $\Lambda$  are an  $(n \times 1)$  vector and an  $(n \times n)$  matrix of coefficients, respectively. From the first-order conditions, we get the following rules for consumption,

<sup>40</sup>See Asea (1995) and Zhou (1995) for detailed discussion of the use of a discrete-time approximation to Ito's Lemma in asset pricing.

expected returns, and investment:

$$\begin{aligned} c_t &= \frac{r}{1+r} W_t + \lambda_0 + \Upsilon' X_t + \frac{1}{2} X_t' \Lambda X_t, \\ e_{R,t} &= \gamma \frac{r}{1+r} \Sigma_R Q_t + \gamma \Sigma_{RX} (\Upsilon + \Lambda X_t), \Leftrightarrow \\ Q_t &= \frac{1+r}{r} \Sigma_R^{-1} [e_{R,t}/\gamma - \Sigma_{RX} (\Upsilon + \Lambda X_t)]. \end{aligned}$$

Substituting the decision rules back into the value function, and using (10) and (11), we can solve for  $\lambda_0$ ,  $\Upsilon$ , and  $\Lambda$ :

$$\begin{aligned} \lambda_0 &= \frac{1}{2r} \{ (rp^* - \mu_D)' \Sigma_R^{-1} (rp^* - \mu_D)' / \gamma + 2(rp^* - \mu_D) \Sigma_R^{-1} \Sigma_{RX} \Upsilon \\ &\quad + \gamma \Upsilon' \Sigma_{RX}' \Sigma_R^{-1} \Sigma_{RX} \Upsilon + \text{tr} [(\Lambda - \Upsilon \Upsilon') \Sigma_X] \}, \end{aligned} \quad (24)$$

$$\Upsilon' = rp^* \Sigma_R^{-1} (\Sigma_{RX} \Lambda g - e/\gamma) \left[ (1+r)I - g + \gamma \Sigma_X \Lambda g + \Sigma_{RX}' \Sigma_R^{-1} e - \gamma \Sigma_{RX}' \Sigma_R^{-1} \Sigma_{RX} \Lambda g \right]^{-1} \quad (25)$$

and  $\Lambda$  is derived from the following set of quadratic equations:

$$0 = (1+r)\Lambda - g' \Lambda g + \gamma g' \Lambda \Sigma_X \Lambda' g - e' \Sigma_R^{-1} e / \gamma + \gamma \Lambda' \Sigma_{RX}' \Sigma_R^{-1} \Sigma_{RX} \Lambda - \gamma \Lambda' \Sigma_{RX}' \Sigma_R^{-1} \Sigma_{RX} \Lambda g + 2e \Sigma_R^{-1} \Sigma_{RX} \Lambda g \blacksquare \quad (26)$$

## Appendix B. Proof of Local Existence

An equilibrium is defined by  $A$ ,  $\Lambda_1$ , and  $\Lambda_2$  which joint satisfy (17) and (26) for each agent.

Define  $\Omega \equiv \begin{bmatrix} \Lambda_1 \\ \Lambda_2 \\ A \end{bmatrix}$  and matrices  $i_i$ ,  $i_A$ ,  $I_i$ , and  $I_A$  such that:

$$i_i \Omega = \Lambda_i \quad i_A \Omega = A \quad I_1 \Lambda_1 = \begin{bmatrix} \Lambda_1 \\ 0 \\ 0 \end{bmatrix} \quad I_2 \Lambda_2 = \begin{bmatrix} 0 \\ \Lambda_2 \\ 0 \end{bmatrix} \quad I_A A = \begin{bmatrix} 0 \\ 0 \\ A \end{bmatrix}.$$

Let  $\mathcal{M}_1$  and  $\mathcal{M}_2$  be vector spaces of equal dimension to  $\omega$  and  $\Omega$ , respectively. Let  $\mathcal{W} \subset \mathcal{M}_1 \times \mathcal{M}_2$  be an open set in the Cartesian product of the two vector spaces. Define  $F : \mathcal{W} \rightarrow \mathcal{M}_2$  as a continuous map such that:

$$\begin{aligned} F(\omega, \Omega) &= \frac{2r}{1+r} I_A \left( K \left( d_N + B^{-1} A \right) \right) + \sum_{i=1}^2 [I_i (1+r)(i_i \Omega) - I_i g'(i_i \Omega) g \\ &\quad + \gamma I_i g' \Sigma_{Xi} (i_A \Omega) (i_i \Omega)' g - I_i e' \Sigma_{Ri}^{-1} e / \gamma - I_i (i_i \Omega) \Sigma_{RXi}' \Sigma_{Ri}^{-1} \Sigma_{RXi} (i_i \Omega) (I - g) \gamma \\ &\quad - (k + (i-1)(1-2k)) I_A \Sigma_{Ri}^{-1} e \Phi_i / \gamma + (k + (i-1)(1-2k)) \Sigma_{Ri}^{-1} \Sigma_{RXi} (i_i \Omega) \Phi_i \\ &\quad + 2I_i e \Sigma_{Ri}^{-1} \Sigma_{RXi} (i_i \Omega) g]. \end{aligned} \quad (27)$$

Denote the perfect-information solution as  $(0, \Omega^*) \in \mathcal{W}$ . Define the linear operator:

$$\frac{\partial F}{\partial \Omega}(0, \Omega^*) : \mathcal{M}_2 \rightarrow \mathcal{M}_2$$

such that:

$$\begin{aligned} \frac{\partial F}{\partial \Omega}(0, \Omega^*) = & \frac{2r}{1+r} I_A K + \sum_{i=1}^2 \{ I_i (1+r) i_i - I_i g' i_i g + \gamma I_i g' \frac{\partial \Sigma_{Xi}}{\partial \Omega}(i_i \Omega) g + \gamma I_i g' \Sigma_{Xi} i_i g \\ & - 2 I_i \frac{\partial e'}{\partial \Omega} \Sigma_{Ri}^{-1} e / \gamma - I_i e' \frac{\partial \Sigma_{Ri}^{-1}}{\partial \Omega} e \gamma - 2 I_i i_i \Sigma_{RXi}' \Sigma_{Ri}^{-1} \Sigma_{RXi}(i_i \Omega) (I-g) \gamma \\ & - 2 I_i (i_i \Omega)' \frac{\partial \Sigma_{RXi}'}{\partial \Omega} \Sigma_{Ri}^{-1} \Sigma_{RXi}(i_i \Omega) (I-g) \gamma - I_i (i_i \Omega)' \Sigma_{RXi}' \frac{\partial \Sigma_{Ri}^{-1}}{\partial \Omega} \Sigma_{RXi}(i_i \Omega) (I-g) \gamma \\ & - (k + (i-1)(1-2k)) I_A \left[ \frac{\partial \Sigma_{Ri}^{-1}}{\partial \Omega} e \Phi_i / \gamma - \Sigma_{Ri}^{-1} \frac{\partial e}{\partial \Omega} \Phi_i / \gamma - \Sigma_{Ri}^{-1} e \frac{\partial \Phi_i}{\partial \Omega} / \gamma \right. \\ & \left. + \frac{\partial \Sigma_{Ri}^{-1}}{\partial \Omega} \Sigma_{RXi} \Lambda_i \Phi_i + \Sigma_{Ri}^{-1} \frac{\partial \Sigma_{RXi}}{\partial \Omega} \Lambda_i \Phi_i + \Sigma_{Ri}^{-1} \Sigma_{RXi} \frac{\partial \Lambda_i}{\partial \Omega} \Phi_i + \Sigma_{Ri}^{-1} \Sigma_{RXi} \Lambda_i \frac{\partial \Phi_i}{\partial \Omega} \right] \}, \end{aligned}$$

where,

$$\begin{aligned} \frac{\partial \Sigma_{Xi}}{\partial \Omega} &= -2g \frac{\partial \Phi_i}{\partial \Omega} \Sigma_u (I - \Phi_i)' g' + 2 \frac{\partial \Phi_i}{\partial \Omega} \Sigma_u \Phi_i' \\ \frac{\partial \Sigma_{RXi}}{\partial \Omega} &= \frac{\partial e}{\partial \Omega} (I - \Phi_i) \Sigma_u (I - \Phi_i)' g' \Phi_i' - 2e \frac{\partial \Phi_i}{\partial \Omega} \Sigma_u (I - \Phi_i)' g' \Phi_i' + i_A \Sigma_u \Phi_i' \\ &+ (i_A \Omega + d_D) \Sigma_u \frac{\partial \Phi_i'}{\partial \Omega} + \frac{\partial \Phi_i}{\partial \Omega} g (I - \Phi_i) \Sigma_u (I - \Phi_i)' e' \\ \frac{\partial \Sigma_{Ri}^{-1}}{\partial \Omega} &= 2 \Sigma_{Ri}^{-1} \left[ -e \frac{\partial \Phi_i}{\partial \Omega} \Sigma_u (I - \Phi_i)' e' + \frac{\partial e}{\partial \Omega} (I - \Phi_i) \Sigma_u (I - \Phi_i)' e' + i_A \Sigma_u (i_A \Omega + d_D)' \right] \Sigma_{Ri}^{-1} \\ \frac{\partial \Phi_i}{\partial \Omega} &= \left( [\phi_i \Sigma_u \phi_i']^{-1} \phi_i \Sigma_u \right)' \frac{\partial \phi_i}{\partial \Omega} + \left( [\phi_i \Sigma_u \phi_i']^{-1} \frac{\partial \phi_i}{\partial \Omega} \Sigma_u \left( -2\phi_i' [\phi_i \Sigma_u \phi_i']^{-1} + 1 \right) \right)' \phi_i \\ \frac{\partial e}{\partial \Omega} &= i_A (g - (1+r)I), \end{aligned}$$

and where  $\frac{\partial \phi_i}{\partial \Omega}$  is  $i_A$  in the first two rows and zeros elsewhere.

If  $\frac{\partial F}{\partial \Omega}(0, \Omega^*)$  is invertible<sup>41</sup>, following Hirsch and Smale (1974) we know from the implicit function theorem that there must exist open sets  $\mathcal{U} \subset \mathcal{M}_1, \mathcal{V} \subset \mathcal{M}_2$  with

$$(0, \Omega^*) \in \mathcal{U} \times \mathcal{V} \subset \mathcal{W}$$

and a unique continuous map  $q$

$$q : \mathcal{U} \rightarrow \mathcal{V}$$

such that

$$F(\omega, q(\omega)) = 0$$

for all  $\omega \in \mathcal{U}$ . ■

<sup>41</sup>We verify nonsingularity for all parameters used in our numerical results.

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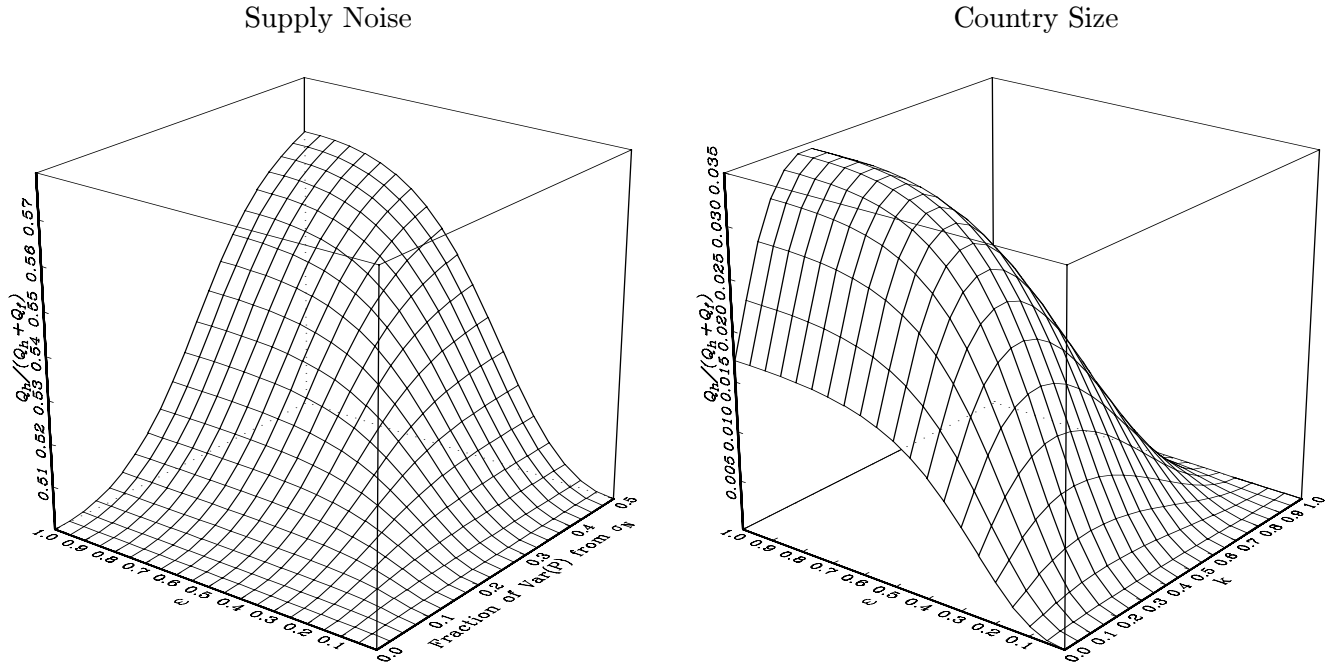
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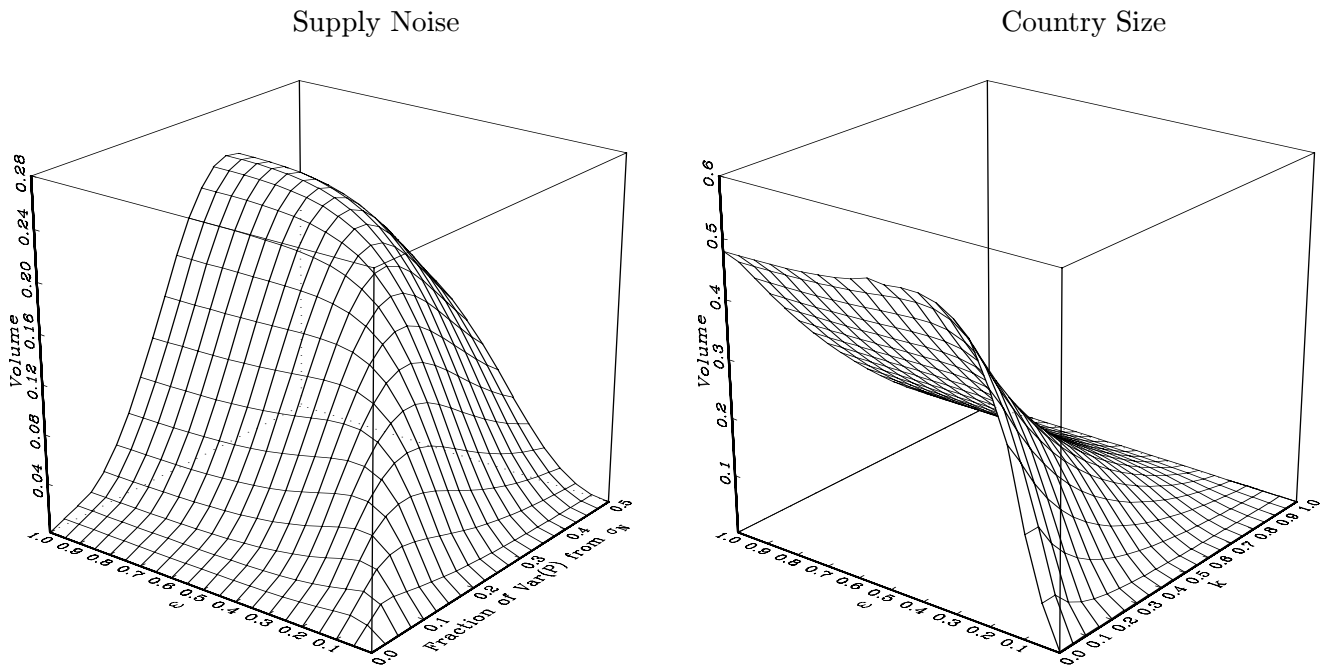
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Figure 1: Home Bias - relative to:



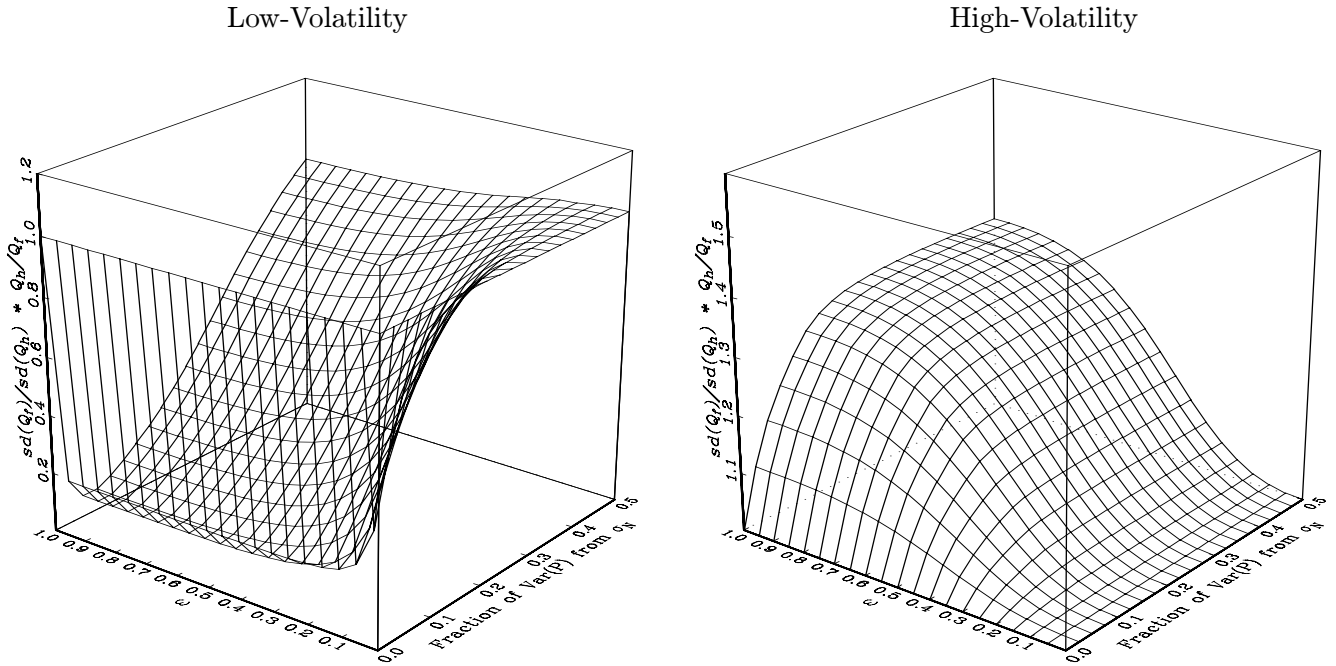
The degree of information asymmetry is reflected on the y-axis as  $\omega$ . The fraction of price variability accounted for by supply noise is shown on the x-axis of the first figure. Country size, denoted by  $k$ , is shown on the x-axis of the second figure. In the second panel, home bias is expressed relative to the perfect information case.

Figure 2: Trading Volume - relative to:



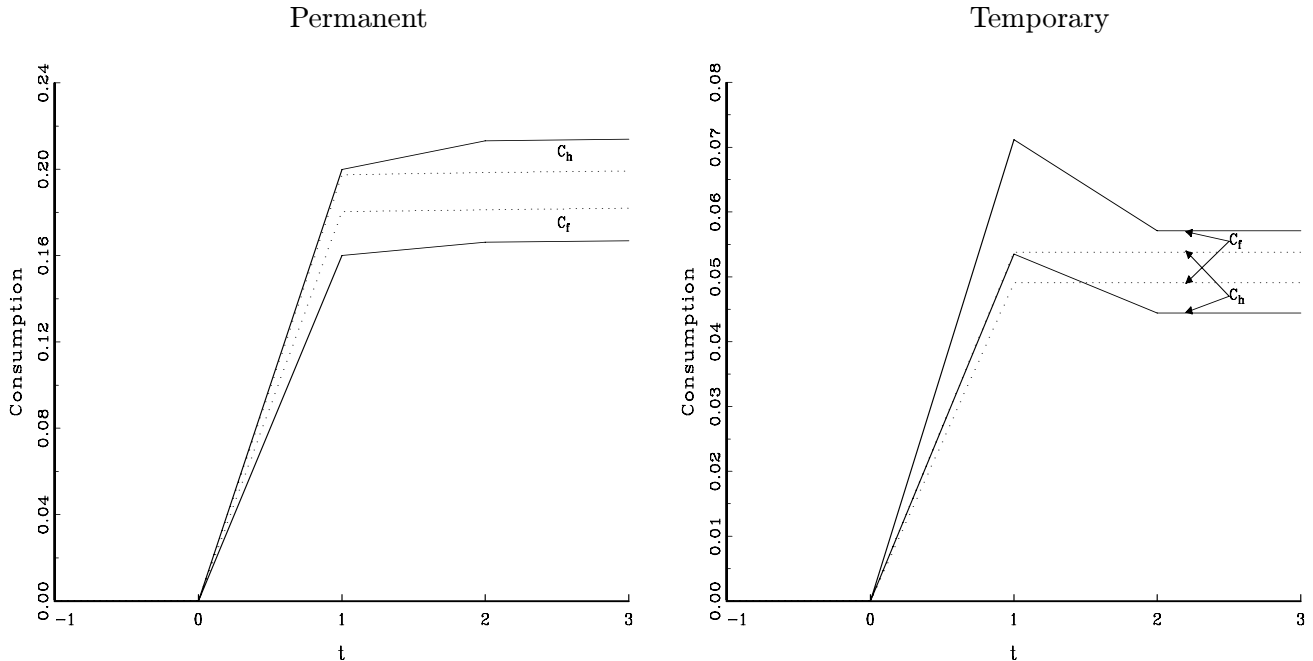
The degree of information asymmetry is reflected on the y-axis as  $\omega$ . The fraction of price variability accounted for by supply noise is shown on the x-axis of the first figure. Country size, denoted by  $k$ , is shown on the x-axis of the second figure. Trading volume is defined as the weighted sum of standard deviations in investor asset holdings as a percentage of market size:  $(kStd(Q_1) + (1 - k)Std(Q_2))/k$  and is graphed relative to the perfect-information case.

Figure 3: Overseas-to-Domestic Turnover Ratio



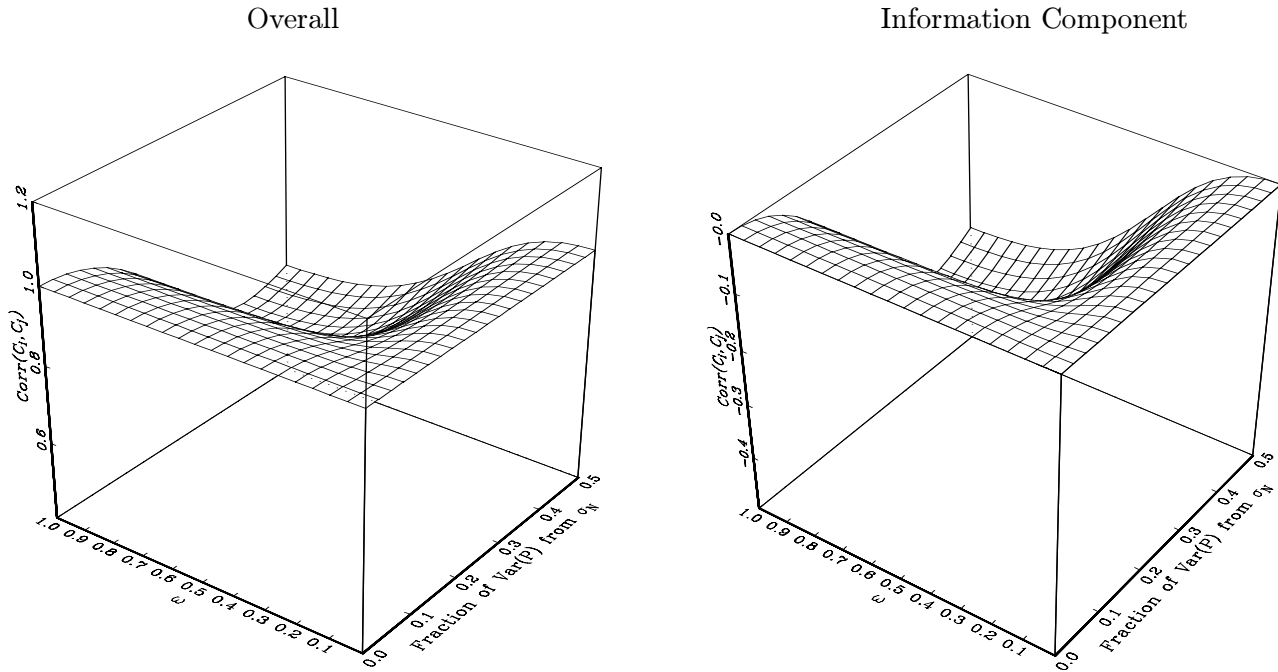
The degree of information asymmetry is reflected on the y-axis as  $\omega$ . The x-axis reflects the fraction of price variability which is due to supply noise. Turnover is defined as the standard deviation of foreign holdings as a fraction of total foreign holdings divided by the standard deviation of domestic holdings as a fraction of total domestic holdings:  $(std(Q_f)/Q_f)/(std(Q_h)/Q_h)$ .

Figure 4: Consumption Responses to Dividend Shocks



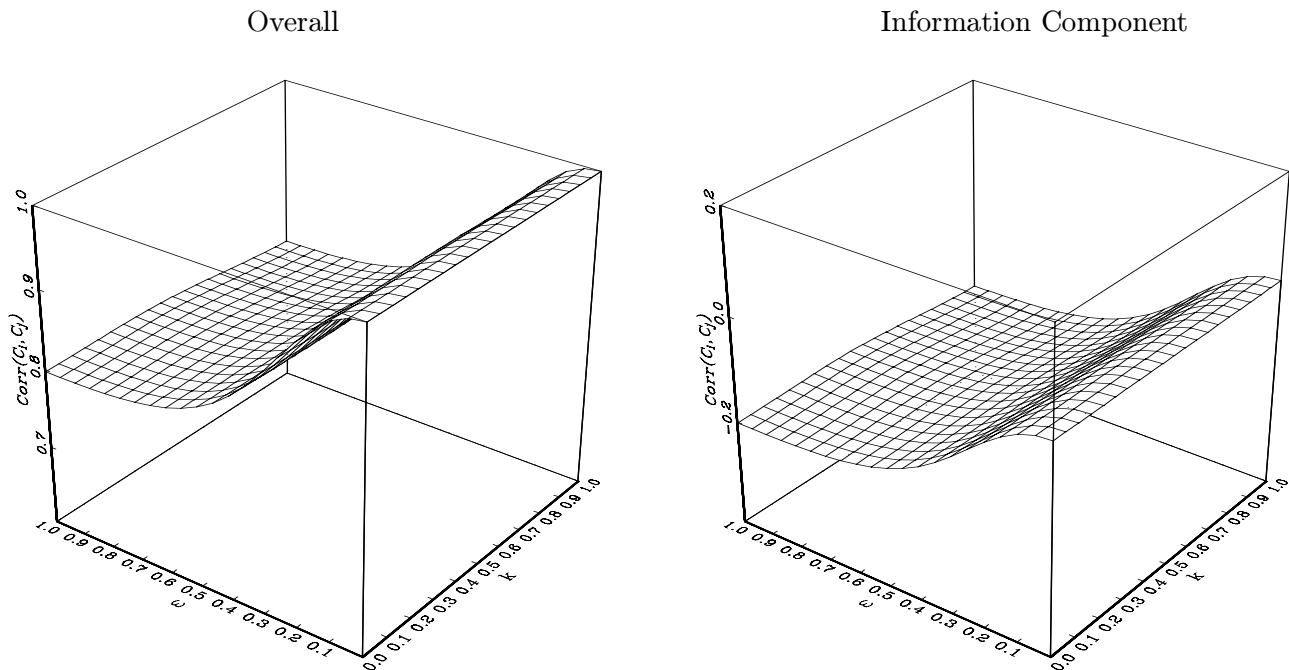
These figures depict the consumption responses to unit standard deviation shocks to permanent and temporary dividends. The dashed lines indicate the perfect-information response ( $\omega = 0$ ) with biased portfolios and the solid lines indicate the asymmetric information response ( $\omega = 1$ ).

Figure 5: Consumption Correlations and Supply Noise



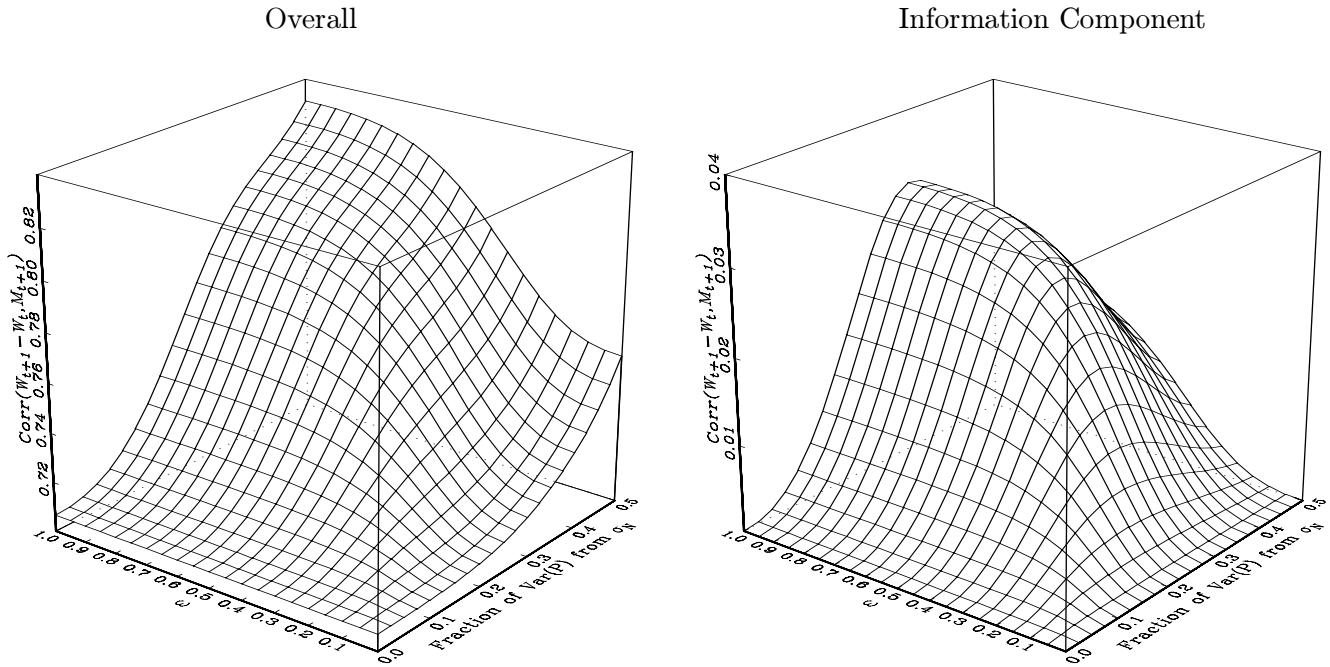
The degree of information asymmetry is reflected on the y-axis as  $\omega$ . The x-axis reflects the fraction of price variability which is due to supply noise. The information component is calculated by subtracting consumption correlations in a symmetric information case with biased holdings from overall consumption correlation.

Figure 6: Consumption Correlations and Country Size



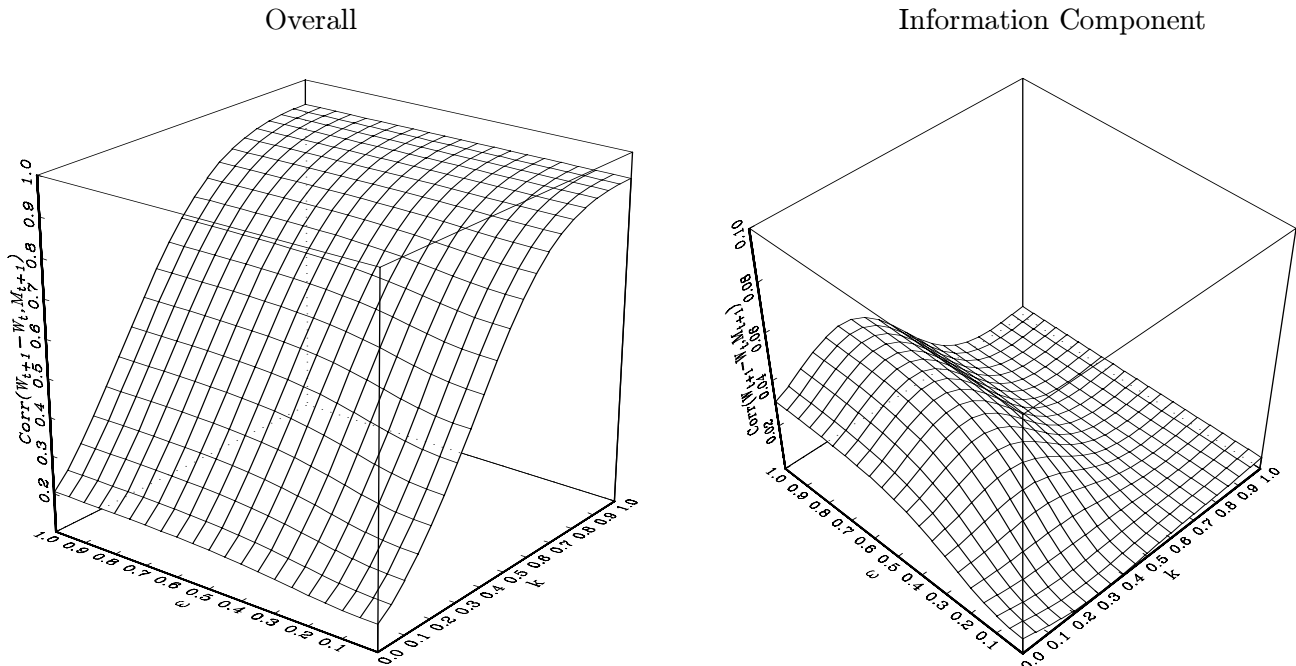
The degree of information asymmetry is reflected on the y-axis as  $\omega$ . Country size as a fraction of the world is shown on the x-axis and is denoted by  $k$ . The information component is calculated by subtracting consumption correlation in a symmetric information case with biased holdings from overall consumption correlation.

Figure 7: Savings-Investment Correlations and Supply Noise



The degree of information asymmetry is reflected on the y-axis as  $\omega$ . The x-axis reflects the fraction of price variability which is due to supply noise. The information component is calculated by subtracting consumption variability in a symmetric information case with biased holdings from overall consumption variability.

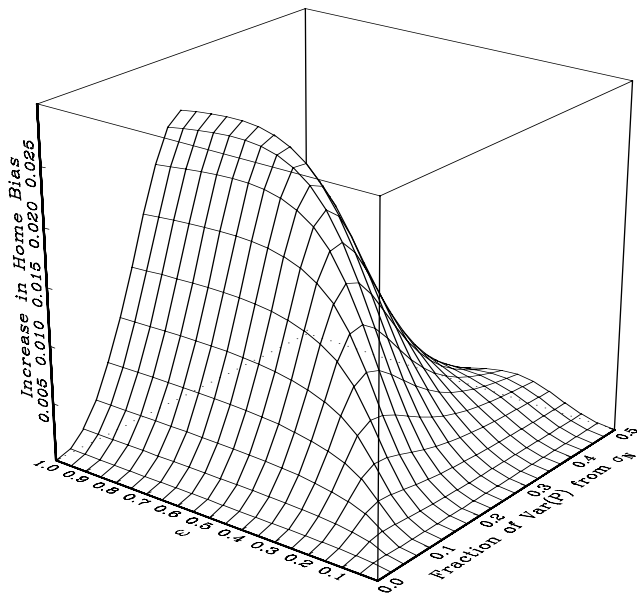
Figure 8: Savings-Investment Correlations and Country Size



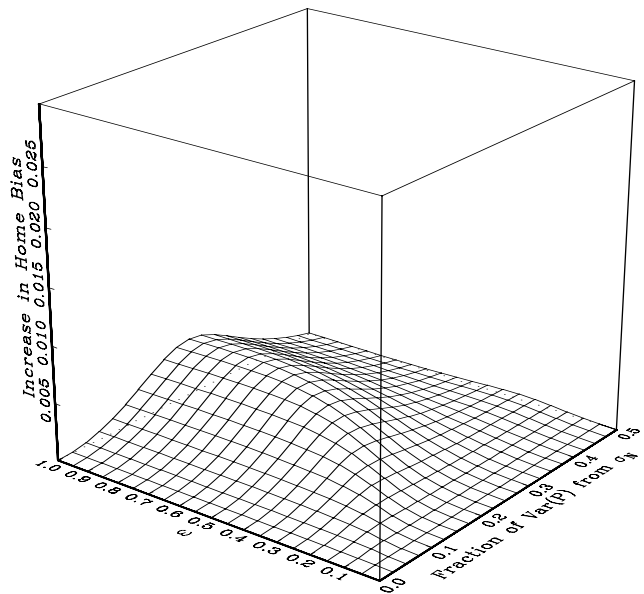
The degree of information asymmetry is reflected on the y-axis as  $\omega$ . Country size as a fraction of the world is shown on the x-axis and is denoted by  $k$ . The information component is calculated by subtracting consumption variability in a symmetric information case with biased holdings from overall consumption variability.

Figure 9: Multiple-Period Information Lags

Two-Period



Three-Period



The degree of information asymmetry is reflected on the y-axis as  $\omega$ . The x-axis reflects the fraction of price variability which is due to supply noise. The figures reflect the additional share of portfolios allocated to the domestic asset when the information lag is increased from 1 to 2 and from 2 to 3 periods.