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ON ASYMMETRIC INFORMATION ACROSS COUNTRIES AND THE HOME-BIAS PUZZLE

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On Asymmetric Information across Countries and the Home-Bias Puzzle

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Abstract

This paper investigates the allocation decision of an investor who owns two projects, a domestic and a foreign one. A manager governs the expected return from each project, and the investor has less information on the actions of the foreign manager. The investor's portfolio will be tilted relative to a situation with full information. With asymmetric information, he generally achieves a better risk-return characteristic of his net terminal wealth with an allocation different from full diversification, because a "biased" allocation can be beneficial to the managers' efforts and/or risk properties of the optimal contracts. However, numerical simulations illustrate that, in general, the portfolio bias is small for plausible parameter values, and theoretically it may even be towards the foreign project. This weakens the case for asymmetric information as a prime reason for the observed home-bias in portfolio allocation.

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1. Introduction

The bias towards domestic markets in international asset allocation, documented in e.g. French and Poterba (1991), Cooper and Kaplanis (1994), and Tesar and Werner (1995), has been one of the most extensively researched areas in international finance during the last 10-15 years. This behavior is labeled the "home-bias puzzle" since it is squarely at odds with the predictions of standard international portfolio selection models (e.g. Adler and Dumas, 1983), and the estimated gains in terms of the risk-return trade-off from international diversification risk appear to be substantial (Grauer and Håkansson, 1987).

A number of possible explanations of the home-bias puzzle have been discussed in the literature.[1] Among these is the hypothesis that there is asymmetric information across countries. Gehrig (1993) and Brennan and Cao (1997) explore the implications of investors, on average, being better informed about the risk-return characteristics of domestic stocks, and they show that this leads to home-bias in portfolio holdings. Gordon and Bovenberg (1996) analyze a "lemons" problem where foreigners systematically overpay for domestic firms - from the point of view of the domestic investors – because they cannot observe firm-specific shocks. Foreign investors may still gain from acquiring domestic firms since they face a lower cost of capital in this model, but capital mobility would be lower than with full information.

The present paper adds to this research by investigating a model where domestic investors have less information about the actions of managers in charge of their foreign projects, compared to the information available on domestic managers. The investors may still want to invest in foreign projects, however, because the return on the projects is partly a function of project specific shocks, which are imperfectly correlated. The extent to which they want to invest in foreign projects depends on the effort-level they can generate from foreign managers through optimal contracts.

Our paper differs from those above in that moral hazard creates the information problem, and optimal contracts are at the center stage of the analysis. We argue that hidden actions may be equally plausible as the information distortions analyzed in earlier research on the home-bias puzzle. Obstfeld and Rogoff (1996, p. 416) emphasize the importance of moral

[1] Besides asymmetric information, the most common explanations are the existence of non-traded income risk, non-traded consumption goods, and statistical measurement problems. See Lewis (1999) for a recent survey.

hazard in explaining why friction-free models of international asset trade square so poorly with data, including portfolio allocation across countries.

It could be argued that foreign investors might avoid possible information disadvantages by investing in a diversified portfolio of publicly traded domestic firms. This would not eliminate the disadvantage, however, since only a subset of national firms list their shares on public exchanges and information available to domestic investors might possibly not be fully conveyed through market prices, due to noise in these prices. Another argument against the relevance of asymmetric information across countries is that foreign investors can hire local experts. Since those experts would be better informed than the investor, a serious asymmetric information problem would materialize in this case as well.[2] The model presented here is easiest interpreted as investments in individual firms rather than in diversified portfolios. A large fraction of purchases of foreign assets takes the form of direct investment and thus, studying such investment decisions in the context of the home-bias puzzle also seems relevant.

The model we develop draws on the dynamic principal-agent problems by Holmström and Milgrom (1987), Schättler and Sung (1993), Sung (1995), and Müller (1998). That is, we study a continuous-time model where output follows a Brownian motion and both the principal (the investor) and the agents (the managers) have constant absolute risk aversion. This is a natural point of departure since, unlike the static principal-agent model, the continuous-time version admits a simple closed-form solution: the optimal compensation schemes are linear in output. To this principal-agent problem, we add a portfolio problem on behalf of the principal who can invest his resources in a domestic and a foreign project. The managers control the drift rates of the Brownian motions governing output. It is easier for the investor to observe the actions of the domestic than those of the foreign manager. Specifically, domestic effort will be assumed to be perfectly observable while the effort put in by the foreign manager is unobservable.

Compared to a situation with full and symmetric information, the investor's allocation policy will be tilted. The mechanisms behind this can be explained by observing that the argument in the investor's (expected) utility function is $X_1 + X_1^* - (S + S^*)$, where X_1 [X_1^*] is output from his domestic [foreign] project and S [S^*] is the salary paid to the domestic [foreign] manager. Later we will refer to this expression as the investor's net terminal wealth.

[2] See the papers by Gehrig (1993), Gordon and Bovenberg (1996), and Brennan and Cao (1997) for further arguments in favor of the relevance of asymmetric information across countries.

In the first-best situation, the two managers will make the same effort for given invested resources in their respective projects. In the model, this implies that expected value of $W_1 \equiv X_1 + X_1^*$ is independent of the allocation of resources between the two projects. Moreover, both the expected value and standard deviation of total salary costs ($S + S^*$) are independent of the allocation decision with full information. This leaves only the variability of W_1 as relevant for the allocation decision, and this is minimized by what we label 'full diversification'.

With asymmetric information, the domestic manager will make higher effort than the foreign manager for given invested resources. Hence, the expected value of W_1 can be increased by investing more resources at home than abroad. This will unambiguously contribute to a home-bias. However, with asymmetric information, the expected value and variability of salary costs ($S + S^*$) are also affected by the allocation decision. For instance, the size of the constant amounts or what fraction of output the managers are to keep according to the salary contracts is in part determined by how the investor allocates his resources. The consequences for the allocation decision are ambiguous however. That is, it *may* be that allocating more resources to the domestic project make the optimal contracts less attractive as seen from the investor. If so, the effect on ($S + S^*$) will counteract the home-bias induced by asymmetric information on the expected value of W_1. Indeed, it is theoretically possible that the optimal portfolio will be tilted towards the foreign project. But the opposite may also be the case; the effect on ($S + S^*$) can strengthen the home-bias in portfolio allocation. Numerical simulations illustrate that, for plausible parameter values, the portfolio bias is likely to be towards the domestic project, but seems to be small in magnitude.

Section 2 presents the model and the solution to the first-best problem. The case of asymmetric information across countries is analyzed in section 3. In section 4 we present some numerical illustrations, and then conclude and discuss some possible extensions in section 5.

2. The Model and the Full Information Case

We investigate the principal-agent relationship on the time interval [0,1]. At time 0, the principal (the investor) decides how to allocate his initial resources W_0 to two projects, a domestic and a foreign project. The investment decisions are assumed to be irreversible; the allocation is fixed until time 1.[3] The output from the projects is publicly observable and governed by the processes

$$dX_t = u_t X_0 dt + \sigma X_0 dz_t,$$

$$dX_t^* = u_t^* X_0^* dt + \sigma X_0^* dz_t^*,$$

for the domestic and foreign project, respectively. In these equations, X_0 [X_0^*] is the amount invested in the domestic [foreign] project, so that $X_0 + X_0^* = W_0$. Furthermore, σ is the common diffusion parameter, while dz and dz^* are standard wiener processes representing shocks, which are considered as project-specific. The instantaneous correlation coefficient, ρ, of these shocks is obtained from $dzdz^* = \rho dt$, $\rho \in [-1,1)$. The drift variables u_t and u_t^* are controlled by a domestic and foreign agent (manager) respectively, and may or may not be observed by the investor. On basis of these assumptions, the investor's wealth accumulation equation can be written as

$$dW_t = \left[\omega(u_t - u_t^*) + u_t^*\right] W_0 dt + W_0 \mathbf{w}' \mathbf{\Sigma} d\mathbf{B}_t, \tag{1}$$

where

$$\mathbf{\Sigma} = \begin{bmatrix} \sigma & 0 \\ \sigma\rho & \sigma\sqrt{1-\rho^2} \end{bmatrix},$$

ω is the fraction of initial wealth invested in the domestic project, $\mathbf{w}' = [\omega\ (1-\omega)]$, $d\mathbf{B} = [dz\ dh]'$, and dh a standard wiener process independent of dz.

At time 0, the investor and the mangers individually agree on sharing rules specifying payment from the investor to the managers at time 1. The sharing rules specify salaries S and S^* for the domestic and foreign manager, respectively, and are random via dependence on the outcome of the stochastic process for W. The managers' control variables, $u \geq 0$ and $u^* \geq 0$, can be revised continuously during the time interval [0,1] and may depend on the history of W in $[0,t]$, but not on the future $(t,1]$. The managers incur costs for putting effort into the projects. For simplicity, these costs are assumed to be given by $\frac{1}{2}ku_t^2$ and $\frac{1}{2}k(u_t^*)^2$, respectively, where k is a constant. The important thing is that the effort costs are convex. Using the quadratic form makes the model easier to solve.

[3] This assumption is imposed to obtain tractability, since allowing for continuous reallocation would introduce time-dependent drifts in the processes for X and X^*. Schättler and Sung (1997) show that introducing time-dependent drifts of the Brownian motions would destroy the result that sharing rules are linear in output, and thus also the tractability of the model.

Finally, both the investor and the managers have exponential time separable utility. The investor's constant coefficient of absolute risk aversion is R while the two managers are equally risk averse with a CARA-coefficient r.

For the sake of later comparison, let us first characterize the optimal sharing rules, effort levels, and resource allocation in the first-best setting; that is, when the managers' controls are observable and can be enforced at no cost. At time 0, the investor's first-best problem is

$$\max_{\{u,u^*\},S,S^*,\omega} E\left[-\exp\left\{-R\left(W_1 - S - S^*\right)\right\}\right], \tag{2}$$

subject to (1) and subject to the managers' participation constraints:

$$E\left\{-\exp\left[-r\left(S - \tfrac{1}{2}k\int_0^1 u_t^2 dt\right)\right]\right\} \geq -\exp\{-rU_0\}, \tag{3}$$

$$E\left\{-\exp\left[-r\left(S^* - \tfrac{1}{2}k\int_0^1 (u_t^*)^2 dt\right)\right]\right\} \geq -\exp\{-rU_0\}, \tag{4}$$

where U_0 is the managers' certainty equivalent at time 0, assumed to be identical for the domestic and the foreign manager. The solution to this problem is summed up in the first result.

<u>Proposition 1:</u> *Under full information, the salaries of the domestic and the foreign manager are equal, linear in combined output and given by*

$$S = S^* = K + \frac{R}{r+2R}W_1, \tag{5}$$

where $K \equiv (r+2R)^{-1}\left[\ln(\lambda r / R) - RW_0 + \tfrac{1}{2}rk\int_0^1 u^2 dt\right]$ *is a constant. Moreover, the effort levels are constant, equal across countries, and determined by the equality of marginal productivity of invested resources and marginal cost of effort*

$$\frac{\omega}{k}W_0 = u = u^* = \frac{(1-\omega)}{k}W_0\,. \tag{6}$$

Finally, the investor allocates equal amounts to the domestic and the foreign project,

$$\omega = \frac{u - u^*}{2W_0\sigma^2(1-\rho)R}\frac{(r+2R)}{r} + \frac{1}{2} = \frac{1}{2}. \tag{7}$$

The proof is in the appendix.

The optimal sharing rule given in (5) is very similar to the corresponding rule in the one-agent model of Müller (1998). One difference is that the coefficient before W_1 gives more weight to the principal's risk aversion, since he now shares the final output with two agents. It also worth noting that the first-best sharing rules imply full risk sharing between the domestic and the foreign manager. They receive a fixed share of total output, independent of the relative output from the project of which they are in charge.

Constancy of u and u^* over time follows from the fact that ω is constant and that W_0 is given. Equal effort levels across countries follow by combing $ku = \omega W_0$ and $ku^* = (1-\omega)W_0$ with the expression on the right hand-side of the first equality in (7). In turn, this yields the result that the investor allocates equal amounts to the two projects.

The demand function on the right hand-side of the first equality in (7) warrants a comment. The first term here represents demand arising from potentially higher return on one of the projects. Relative to a standard CAPM (e.g. Adler and Dumas, 1983), this demand is adjusted by a factor $(r + 2R)/r$. The first term is 0 under full information because the optimal contract ensures equal effort levels across countries. The second term on the right hand-side of the first equality in (7) is the portfolio share that minimizes the variance of time 1 wealth. This is always equal to ½ in our case, because the instantaneous standard deviation σ is equal for the two projects. To sum up, with full information the investor chooses an allocation minimizing his wealth variance because the optimal contracts ensure equal expected returns for the two projects.

3. Moral Hazard in the Foreign Project

We now turn to the case where the investor cannot observe the actions of the foreign manager. Then, the investor faces an additional constraint in his problem:

$$u^* \in \arg\max_{u^*} E\left[-\exp\left\{ -r\left(S^* - \tfrac{1}{2} k \int_0^1 (u_t^*)^2 \, dt \right) \right\} \right].$$

This is the familiar incentive compatibility constraint, that is, the foreign manager chooses the u^* that is in his best interest. We follow Schättler and Sung (1993), and use the so-called first-order approach to solve the investor's problem. In this approach, the incentive compatibility constraint in the principal's problem is relaxed to the first-order necessary condition for optimality in the agent's problem.

We also make the simplifying assumption that the optimal salary of the foreign manager is contingent on his own output only. By introducing this assumption some generality is lost, but the model's tractability and its illustrative ability are preserved.[4]

Given these assumptions, the problem of the foreign manager is

$$\max_{u^*} E\left[-\exp\left\{-r\left(S^* - \tfrac{1}{2}k\int_0^1 (u_t^*)^2\,dt\right)\right\}\right],$$

subject to

$$dX_t^* = u_t^*(1-\omega)W_0\,dt + W_0\mathbf{w}^{*}{}'\boldsymbol{\Sigma}d\mathbf{B}_t,$$

where $\mathbf{w}^{*'} = [0\ (1-\omega)]$. Schättler and Sung (1993) show that the solution to this problem implies the optimal sharing rule to be of the following form (using our notation):

$$S^* = U_0 + \tfrac{1}{2}k\int_0^1 (u_t^*)^2\,dt + k\int_0^1 u_t^*(1-\omega)^{-1}\mathbf{w}^{*}{}'\boldsymbol{\Sigma}d\mathbf{B}_t + \tfrac{1}{2}r\int_0^1 \left[ku_t^*(1-\omega)^{-1}\right]^2 \mathbf{w}^{*}{}'\boldsymbol{\Sigma}\boldsymbol{\Sigma}'\mathbf{w}^*dt. \quad (8)$$

The first two terms in (8) provides the foreign manager with his certainty equivalent plus the compensation for the cost he actually incurs. The next term is the compensation error, arising because the investor's compensation is based on realized outcome rather than the manager's actual effort. Finally, to compensate the foreign manager for the risk he carries, a risk premium is paid, given by the last term in (8).[5]

The investor's relaxed problem can then be written as

$$\max_{u,u^*,S,\omega} E\left[-\exp\left\{-R\left(W_1 - S - S^*\right)\right\}\right],$$

subject to (1), (3) and (8). The solution to this problem is summarized in the second result.

<u>Proposition 2:</u> *Suppose that the foreign manager's effort level cannot be observed and that his salary depends on his own output only. The salary of the foreign manager is linear in his own output and is given by*

$$S^* = \kappa^* + \frac{ku^*}{(1-\omega)W_0}X_1^*, \quad (9)$$

where $\kappa^* \equiv U_0 - ku^* - \tfrac{1}{2}ku^{*2} + \tfrac{1}{2}rk^2\sigma^2u^{*2}$ *is a constant. The salary of the domestic manager depends on combined output:*

$$S = \kappa + \frac{R}{r+R}X_1 + \frac{R}{r+R}\left(1 - \frac{ku^*}{(1-\omega)W_0}\right)X_1^*, \quad (10)$$

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[4] Actually, the model is solvable if S^* is made a function of W_1 in this section also, but the central asset demand equation turns out to be a polynomial of degree 4, giving very little economic insight.

[5] See Holmström and Milgrom (1987) or Schättler and Sung (1993) for further discussion of the optimal sharing rule under asymmetric information.

where $\kappa \equiv (r + R)^{-1}[\ln(\lambda r/R) - RW_0 + ½rku^2 - R\kappa^*]$ *is another constant. The optimal effort level for both the domestic and the foreign manager is constant over time and given by*

$$u = \frac{\omega}{k} W_0 \tag{11}$$

$$u^* = \frac{(1-\omega)}{k} W_0 \frac{r + R + rR\sigma^2}{r + R + (r^2 + 2rR)\sigma^2} + \frac{\omega}{k} W_0 \frac{rR\sigma^2\rho}{r + R + (r^2 + 2rR)\sigma^2}, \tag{12}$$

respectively. Finally, the investor allocates a fraction

$$\omega = \frac{u - u^*}{2W_0\sigma^2(1-\rho)R} \frac{r + R}{r} - \frac{ku^*}{2W_0} + \frac{1}{2} \tag{13}$$

of initial wealth to the domestic project.

The proof is in the appendix.

From equation (9), we notice that the investor's share of foreign final output depends on the choices of u^* and ω, while with full information, it is determined solely by the parameters r and R. For a given portfolio allocation, equation (12) implies that the effort level is lower than in the first-best situation (confer equation (6)). Finally, for given effort levels, the asset demand function (13) differs from the first-best by the second term on the right hand-side, which is the foreign manager's marginal cost of effort (divided by $2W_0$). The higher is the marginal cost, the more resources are allocated to the foreign project (given u and u^*), because a high marginal cost discourages effort, but the investor can counteract this by investing more resources in the foreign project, as can be seen from (12).

Equations (11)-(13) can solely be expressed in terms of the parameters of the model, R, r, k, σ, and ρ, and these solutions will be presented below. However, some interesting implications are apparent already at this stage.

Suppose for instance that, as under full information, the parameters imply that the investor chooses the same allocation as under full information, $\omega = ½$. If so, equations (11) and (12) imply

$$\frac{u^*}{u} = \frac{r + R + (1+\rho)rR\sigma^2}{r + R + 2rR\sigma^2 + r^2\sigma^2} < 1.$$

With full diversification, the foreign manager puts in a lower effort than his domestic counterpart. As a second example, suppose that the parameters are such that the domestic and the foreign manager make the same effort. With $u = u^*$, equations (11) and (13) imply that

$\omega = 1/3$. Hence, to generate the same effort level from the two managers, the investor has to invest twice as much in the foreign project as in the domestic one.[6]

These examples illustrate that the investor can increase expected output by investing more in the domestic project than in the foreign one. More formally; from (11) we find that $\partial u/\partial\omega = W_0/k$, while $|\partial u^*/\partial\omega| < W_0/k$ from (12). Hence, by reallocating resources from the foreign to the domestic project, the effort made by the domestic manager increases more than the corresponding decrease in the foreign manager's effort. This clearly contributes to a home-bias under asymmetric information. However, the investor does not care about final output only, but also about how much of it he has to pay the managers according to the optimal contracts. Now, since these contracts are influenced by the allocation of resources, we must take this into account when the optimal allocation policy is derived.

Solving equations (11)-(13) for u, u^*, and ω, we obtain

$$u = (kN)^{-1}\left[(r+R)^2 + rR\sigma^2\left((r+R)(1-k\sigma^2(1-\rho))\right)\right]W_0 \quad (14)$$

$$u^* = (kN)^{-1}\left[(r+R)^2 - kR^2\sigma^2(1-\rho) + rR\sigma^2\left((r+R) - k(1-\rho) - kR\sigma^2(1-\rho^2)\right)\right]W_0 \quad (15)$$

$$\omega = (kN)^{-1}\left[(r+R)^2 + rR\sigma^2\left((r+R)(1-k\sigma^2(1-\rho))\right)\right], \quad (16)$$

where

$$N = rR\sigma^2\left[r(4-\rho) + R(3-\rho) - k(1-\rho) - 2kR\sigma^2\left(\tfrac{3}{2} - \rho - \tfrac{1}{2}\rho^2\right) - 2kr\sigma^2(1-\rho)\right] + 2(r+R)^2 + r^3\sigma^2 - kR^2\sigma^2(1-\rho).$$

The third result follows immediately.

Proposition 3: *If* $r^3\sigma^2 - kR^2\sigma^2(1-\rho) < rR\sigma^2[kR\sigma^2(1-\rho^2) - r(2-\rho) - R(1-\rho)]$, *the allocation under asymmetric information is tilted towards the domestic project relative to the first-best allocation*.

Proof: Follows immediately by imposing $\omega > ½$ in (16) and simplifying.

Interestingly, this result implies that we cannot rule out a "foreign-bias" where $\omega > ½$. But in general, the condition in proposition 3 is too complex to give any general statements on when a home-bias is most likely to occur in the model. The reason for this ambiguity is that, as

[6] There are two exceptions to these statements. If either σ or r approaches 0, the foreign effort level u^* will approach its first-best, see equation (12). In these cases we would have $u = u^*$ and $\omega = ½$ even with asymmetric information. See also the numerical examples presented in the next section.

opposed to a standard portfolio selection model, the optimal allocation decision is the result of interactions with the optimal actions of the managers and the optimal compensation schemes. To get a hinge on these interactions and what conditions are most likely to create a home-bias, we next provide some numerical simulations.

4. Numerical Examples

4.1 A Baseline Example

The intuition in the following numerical illustrations is somewhat simplified by considering the case where the return shocks to the projects are uncorrelated, $\rho = 0$. Notice in particular that from (12), the optimal sharing rules under asymmetric information can be expressed as

$$S = \kappa + AX_1 + BX_1^*, \tag{17}$$

$$S^* = \kappa^* + CX_1^*. \tag{18}$$

where $A \equiv R/(r+R)$, $B \equiv rR\sigma^2/[r+R+(r^2+2rR)\sigma^2]$, and $C \equiv (r+R+rR\sigma^2)/[r+R+(r^2+2rR)\sigma^2]$ are all constants. Hence, a fraction $1 - A = r/(r+R)$ of domestic final output and a fraction $1 - B - C = r^2\sigma^2/[r+R+(r^2+2rR)\sigma^2]$ of foreign final output are retained by the investor.

Let us think of the [0,1] time interval as one year. Then, σ gives the annual standard deviation of returns of the two projects. $\sigma = 0.25$ is used as the baseline value. To obtain sensible annual expected returns, we furthermore set $k = 5$. In principal-agent problems, the agents are commonly assumed to be more risk-averse than the principal. In this baseline experiment, we stick to this assumption, using $r = 4$ and $R = 2$ for the coefficients of absolute risk-aversion. Finally, we assume a zero certainty equivalent ($U_0 = 0$) on behalf of the managers and that the investor enters the year with wealth $W_0 = 1$.

By proposition 1, the first-best situation in the baseline experiment is characterized by $u = u^* = 0.1$, and $\omega = 0.5$. Both managers receive $R/(r+2R) = 25\%$ of final total output plus/minus the constant amount $K = \ln\lambda/8 - 0.15$. The investor thus keeps half of the final output from the projects in addition to the constant amount $2K = 0.30 - \ln\lambda/4$. In turn, this implies the investor's expected net terminal wealth to be $E[W_1 - S - S^*] = 1.33 - \ln\lambda/4$, with a standard deviation of $SD[W_1 - S - S^*] = 0.118$.

When the foreign manager's effort level is unobservable, equations (14)-(18) can be used to characterize the solution. Table 1 reports the results.

Table 1: Characteristics of the baseline example under asymmetric information

u	u^*	ω	κ	κ^*	A	B	C	$E[W_1 - S - S^*]$	$SD[W_1 - S - S^*]$
0.111	0.071	0.557	$\ln\lambda/6 - 0.08$	-0.35	1/3	0.066	0.801	$0.92 - \ln\lambda/6$	0.094

Note: Calculations are based on the parameter values: $r = 4$, $R = 2$, $k = 5$, $\sigma = 0.25$, $\rho = 0$.

The foreign manager's second-best effort level implies that the expected return in his project drops to 7.1%. Together with an increase in expected return from the domestic project to 11.1%, this creates a home-bias. The domestic manager's effort level is higher than in the first-best situation, even though the investor can observe his actions. This is due to the fact that the marginal productivity of invested resources in the domestic project, which is linear in the amount invested, is higher than in the first-best and thus, the marginal cost of effort should be higher, implying increased effort.

The foreign manager's salary is $S^* = -0.35 + 0.801X_1^*$ while the compensation to the domestic manager is $S = \ln\lambda/6 - 0.08 + 1/3X_1 + 0.066X_1^*$. Thus, the investor acquires only 12.3 % of the output from the foreign project, while he retains 2/3 of domestic output. In addition, the investor pays a constant amount $\kappa + \kappa^* = \ln\lambda/6 - 0.49$ to the managers. (Notice that the constant amount may very well be negative. That is, the managers may pay the investor to get a share of the final output). Compared to the first-best situation, the standard deviation of expected net terminal wealth falls, which contributes to explain why the investor diversifies less than with full information: Optimal contracts contribute to lower wealth variance, and his need for diversifying the asset portfolio is thus smaller.

4.2 Sensitivity Analysis

In this baseline experiment, asymmetric information across countries generates a small home-bias in portfolio allocation. How sensitive is this result to our parameter assumptions? In this subsection, we try to answer this question by performing some simple sensitivity analyses.

We start by considering changes in the underlying uncertainty of the projects, σ. If the effort levels were given, equation (13) shows that an increase in σ would mitigate the importance of the expected difference in return for the portfolio allocation decision. However, in our model, the expected difference in return itself is affected by a shift in σ. Moreover, the optimal salary contracts will also be affected, giving further bearings on the asset allocation decision. Table 2 reports the characteristics of the asymmetric information solution for different values of σ.

Table 2: Sensitivity of the asymmetric information solution for changes in σ.

σ	u	u^*	ω	κ	κ^*	A	B	C	$E[W_1-S-S^*]$	$SD[W_1-S-S^*]$
→0	0.1	0.1	0.5	lnλ/6–0.03	–0.53	1/3	0	1	0.92–lnλ/6	0
0.1	0.101	0.095	0.507	lnλ/6–0.04	–0.49	1/3	0.01	0.96	0.92–lnλ/6	0.034
0.25	0.111	0.071	0.557	lnλ/6–0.08	–0.35	1/3	0.07	0.80	0.92–lnλ/6	0.094
0.35	0.143	0.040	0.716	lnλ/6–0.12	–0.19	1/3	0.10	0.70	0.91–lnλ/6	0.168

Note: Other parameters than σ have the same values as in table 1.

As intuition suggests, the solutions for u, u^* and ω approach first-best as σ goes to 0. For large values of σ, the expected difference in return, $u - u^*$, is indeed substantial, thereby leading to a significant home-bias. Notice also that the investor's fraction of foreign output ($1 - B - C$) increases with σ, while the constant amount he receives from the foreign manager, κ^*, decreases. Together with less diversification and the increase in σ itself, this contributes to increase the standard deviation of net terminal wealth.

Table 3: Sensitivity of the asymmetric information solution for changes in *r*.

r	u	u^*	ω	κ	κ^*	A	B	C	$E[W_1-S-S^*]$	$SD[W_1-S-S^*]$
0.01	0.1	0.1	0.5	lnλ/2.01–3.1	–0.53	≈1	≈0	≈1	3.5–lnλ/2.01	≈0
0.5	0.105	0.092	0.525	lnλ/2.5–0.97	–0.48	0.8	0.03	0.97	1.57–lnλ/2.5	0.026
1	0.108	0.087	0.541	lnλ/3–0.59	–0.45	2/3	0.03	0.95	1.27–lnλ/3	0.045
4	0.111	0.071	0.557	lnλ/6–0.08	–0.35	1/3	0.07	0.80	0.92–lnλ/6	0.094
6	0.108	0.068	0.541	lnλ/8–0.07	–0.33	1/4	0.06	0.74	0.95–lnλ/8	0.104
10	0.097	0.066	0.484	lnλ/12–0.04	–0.31	1/6	0.06	0.64	0.96–lnλ/12	0.108

Note: Other parameters than *r* have the same values as in table 1.

Table 3 reports on the solution with asymmetric information for different values of the managers' risk-aversion, *r*. In the same manner as in table 2, a small *r* gives solutions for u, u^* and ω close to the first-best. Moreover, the optimal contracts are such that managers carry the entire output risk, giving a certain terminal net wealth to the investor. For moderate values of *r*, the investor chooses to allocate more to his domestic project. This effect is reversed for larger values of *r*, and from table 3, it appears that $r = 10$ implies foreign bias in portfolio allocation. One of the mechanisms behind this is apparent from table 3. The fraction of foreign output the domestic manager obtains, increases with r for low values of this parameter. As r increases, this fraction starts falling, however, making the foreign project more attractive for the investor. The standard deviation of the investor's net terminal wealth increases with r, as he must accept a larger part of the output-risk, the more risk-averse are the managers.

Table 4 reports the solution of the model for different values of R. The foreign manager's optimal effort level decreases with R as does the fraction of foreign output retained by the investor $(1 - B - C)$. Both effects make the foreign project less attractive. Thus, even though increasing risk-aversion should strengthen the case for diversification, the portfolio allocation implies a considerable home-bias for large values of R. We also notice that despite less diversification, the standard deviation of the net terminal wealth decreases with R, since the optimal contracts imply that the managers take more and the investor less output-risk, the higher is the investor's risk-aversion.

Table 4: Sensitivity of the asymmetric information solution for changes in *R*.

R	U	u^*	ω	κ	κ^*	A	B	C	$E[W_1-S-S^*]$	$SD[W_1-S-S^*]$
0.01	0.089	0.088	0.445	$\ln\lambda/4.01+1.5$	–0.44	≈0	≈0	0.79	$-0.47-\ln\lambda/4$	0.115
0.5	0.095	0.085	0.474	$\ln\lambda/4.5+0.42$	–0.42	1/9	0.02	0.80	$0.56-\ln\lambda/4.5$	0.108
1	0.101	0.080	0.503	$\ln\lambda/5+0.18$	–0.40	0.2	0.04	0.81	$0.75-\ln\lambda/5$	0.102
2	0.111	0.071	0.557	$\ln\lambda/6-0.08$	–0.35	1/3	0.06	0.81	$0.91-\ln\lambda/6$	0.094
10	0.172	0.023	0.862	$\ln\lambda/14-0.68$	–0.11	0.71	0.12	0.83	$1.09-\ln\lambda/14$	0.062

Note: Other parameters than *R* have the same values as in table 1.

5. Discussion and Concluding Comments

We have studied the allocation decision of an investor with a foreign and a domestic project. If he can observe the actions of the manager in charge of the domestic project, but not those of the foreign manager, his allocation will be tilted relative to the full information situation. In the model, the investor's allocation decision affects the managers' effort levels, and the form of the contracts. These effects are generally different under asymmetric information as compared to the first-best situation, and generally imply that the investor achieves a better risk-return characteristic of his net terminal wealth with an allocation different from full diversification.

Four different effects determines the desirability of a given allocation decision:

1. The effect on expected final output. This effect is due to the impact the allocation decision has on optimal effort levels from the two managers.
2. The effect on the standard deviation of final output. This is a direct effect of the portfolio allocation decision.
3. The effect on the fraction of final output retained by the investor. This is due both to the portfolio decision itself and to the indirect effect on the effort level of the foreign manager (see equation (9)).
4. The effect on the constant amounts that the investor receives from/pays to the managers. This effect is due to induced changes in optimal effort levels.

Under full information, effect 3 is irrelevant since the fraction of final output that investor retains is determined solely by the parameters r and R. Moreover, effects 1 and 4 are zero because $du^*/du = -1$ with full information (see equation (6)). That is, a certain reallocation of the portfolio from, e.g., the foreign to the domestic project decreases the optimal effort level of the foreign manager by exactly the same amount as the increase in the domestic manager's effort level. Then, expected final output will be independent of portfolio allocation, as will be the *total* constant amount that the investor pays/receives. This leaves only effect 2 as the relevant under full information. The standard deviation of final output is minimized by full diversification, which the investor accordingly chooses.

The story is a different one under asymmetric information, when all effects above come into play. Investing solely in the domestic project maximizes expected final output (effect 1). This can be seen from equations (11) and (12) which imply that $du^*/du < -1$. I.e., when the investor increases investment in the domestic project, the higher expected return from the domestic project more than outweighs the corresponding fall in expected returns from the foreign project. Effect 1 thus pull in the direction of a home-bias under asymmetric information. Effect 2 counteracts this, but can not offset it. The effect on the fraction of foreign output that is retained by the investor is ambiguously affected by the allocation decision, as is the effect on the total constant amount received/paid by the investor. Hence effects 3 and 4 may or may not counteract the home-bias induced by effect 1. In certain cases, the combined effect may be such that the investor tilts his portfolio towards the foreign project.

Although there is a theoretical possibility that asymmetric information may imply 'foreign-bias' in the model, the numerical illustrations presented in section 4 generate a home-bias more often than the opposite. However, the home-bias is often small in magnitude, leading us to conclude that the information structure investigated in this model is unlikely to explain the bias towards domestic markets observed in the data.

This model is, in effect, a static portfolio allocation model where the investor can influence the expected returns from the assets through his allocation decisions. It would be interesting to explore whether our result of an ambiguous effect from introducing asymmetric information was to survive a more general setup. A first extension would be to allow for continuous reallocation on behalf of the investor. What would then be the effect on the optimal allocation decisions under asymmetric information? A second, and perhaps more interesting, extension is to consider a situation with one investor in each country owning a (divisible) domestic project. With imperfectly correlated shocks, what would be the resulting equilibrium prices and allocation when the investors meet to trade, given that they know less about the actions of foreign managers? What about managerial compensation and expected output compared to a situation where the domestic project has a domestic owner only? These and other questions are left open to future research.

Appendix

A.1 Proof of Proposition 1

We start by deriving the optimal sharing rules in terms of the optimal controls u and u^*, following Müller (1998). Define net compensation to the domestic and foreign manager as $y = S - \tfrac{1}{2}k\int_0^1 u_t^2 dt$ and $y^* = S^* - \tfrac{1}{2}k\int_0^1 (u_t^*)^2 dt$, respectively. Then, integrating (1) and inserting the result in (2) imply that the investor's problem can be expressed as

$$\max_{u,u^*,y,y^*,\omega} E\left[-\exp\left\{-R\begin{pmatrix} W_0 + W_0\mathbf{w}'\mathbf{\Sigma}(\mathbf{B}_1 - \mathbf{B}_0) - y - y^* \\ +\int_0^1 \left[\omega W_0 u_t - \tfrac{1}{2}ku_t^2 + (1-\omega)W_0 - \tfrac{1}{2}k(u_t^*)^2\right]dt \end{pmatrix}\right\}\right],$$

subject to (3) and (4). Pointwise maximization with respect to y and y^* gives the first-order conditions

$$y = \frac{1}{r+R}\ln\left(\frac{\lambda r}{R}\right) + \frac{R}{r+R}\left[W_1 - W_0 - \tfrac{1}{2}k\int_0^1 \left(u_t^2 + (u_t^*)^2\right)dt\right] - \frac{R}{r+R}y^*$$

$$y^* = \frac{1}{r+R}\ln\left(\frac{\lambda^* r}{R}\right) + \frac{R}{r+R}\left[W_1 - W_0 - \tfrac{1}{2}k\int_0^1 \left(u_t^2 + (u_t^*)^2\right)dt\right] - \frac{R}{r+R}y,$$

where λ and λ^* are the Lagrange-multipliers associated with (3) and (4), respectively. Solving these two equations for y and y^* and using (3) and (4) to demonstrate that $\lambda = \lambda^*$, we find that

$$y = y^* = \frac{1}{r+2R}\ln\left(\frac{\lambda r}{R}\right) + \frac{R}{r+2R}\left(W_1 - W_0 - \tfrac{1}{2}k\int_0^1\left[u_t^2 + (u_t^*)^2\right]dt\right). \tag{A.1}$$

The optimal sharing rules are $S = y + \tfrac{1}{2}k\int_0^1 u_t^2 dt$ and $S^* = y + \tfrac{1}{2}k\int_0^1 (u_t^*)^2 dt$, where y is given in (A.1).

By substituting the optimal salary functions into (2), the investor's problem can be simplified to

$$\max_{u,u^*,\omega} E\left[-\exp\left\{-a\left(W_1 - b - \tfrac{1}{2}k\int_0^1\left[u_t^2 + (u_t^*)^2\right]dt\right)\right\}\right]$$

subject to (1), where $a \equiv rR/(r+2R)$ and $b \equiv (r/2R)W_0 - (r/2)\ln(\lambda r/R)$ are constants. Let $V(t,W_t)$ be the investor's value function, giving the optimal remaining utility at time t. By Lemma A1 in Sung (1995), the value function solving the above problem satisfies the following dynamic programming equation:

$$0 \equiv \frac{\partial V}{\partial t} + \max_{u,u^*,\omega}\left\{\begin{array}{l}\dfrac{\partial V}{\partial W}\left[\omega u + (1-\omega)u^*\right]W_0 + \tfrac{1}{2}\dfrac{\partial^2 V}{\partial W^2}W_0^2\mathbf{w}'\mathbf{\Sigma\Sigma}'\mathbf{w} \\ + \tfrac{1}{2}ak\left[u^2 + (u^*)^2\right]V(t,W_t)\end{array}\right\}, \tag{A.2}$$

with the terminal condition being $V(t,W_t) = -\exp[-a(W_1 - b)]$. From (A.2), the first-order conditions with respect to u_t, u_t^*, and ω are

$$u_t = -\frac{\partial V/\partial W_t}{V(t,W_t)a}\frac{\omega}{k}W_0 \tag{A.3}$$

$$u_t^* = -\frac{\partial V/\partial W_t}{V(t,W_t)a}\frac{(1-\omega)}{k}W_0 \tag{A.4}$$

$$\omega = \frac{u^* - u}{2W_0\sigma^2(1-\rho)}\frac{\partial V/\partial W}{\partial^2 V/\partial W^2} + \frac{1}{2}. \tag{A.5}$$

Next, we guess that the value function has the form

$$V(t,W_t) = -\exp\left\{-a\left[\begin{array}{l}W_t + (1-t)\left(\omega W_0 u + (1-\omega)W_0 u^*\right) \\ + \tfrac{1}{2}\left(aW_0^2\mathbf{w}'\mathbf{\Sigma\Sigma}'\mathbf{w} - ku^2 - ku^{*2}\right)\end{array}\right]\right\}. \tag{A.6}$$

Using (A.6) in (A.3)-(A.5), we obtain equations (5)-(7). Finally, substituting (A.6) into (A.2) confirms that (A.6) solves the investor's dynamic problem.

A.2 Proof of Proposition 2

We can proceed as under full information to find the optimal sharing rule between the investor and the domestic manager in terms of the optimal control u. The first-order condition with respect to S for the investor's relaxed problem is thus

$$S = \frac{1}{r+R}\ln\left(\frac{\lambda r}{R}\right) + \frac{R}{r+R}\left(W_1 - W_0 - S^*\right) + \frac{r}{r+R}\tfrac{1}{2}k\int_0^1 u_t^2 dt \,. \tag{A.7}$$

Given the optimal sharing rules in (8) and (A.7), the investor's (stochastic) net terminal wealth can be expressed as

$$\begin{aligned} W_1 - S - S^* = \frac{r}{r+R}\Big[& W_1 - \frac{1}{r}\ln\left(\frac{\lambda r}{R}\right) - \frac{R}{r}W_0 - V_0 - \tfrac{1}{2}k\int_0^1 \left[u_t^2 + (u_t^*)^2\right]dt \\ & -k\int_0^1 u_t^*(1-\omega)^{-1}\mathbf{w}^*{}'\boldsymbol{\Sigma} d\mathbf{B}_t - \tfrac{1}{2}rk\int_0^1 \left[u_t^*(1-\omega)^{-1}\right]^2 \mathbf{w}^*{}'\boldsymbol{\Sigma}\boldsymbol{\Sigma}'\mathbf{w}^* dt \Big]. \end{aligned}$$

It follows that the investor's problem can be reduced to

$$\max_{u,u^*,\omega} E\left[-\exp\left\{-\alpha\left(\begin{aligned} & W_1 - \beta - k\int_0^1 u_t^*(1-\omega)^{-1}\mathbf{w}^*{}'\boldsymbol{\Sigma} d\mathbf{B}_t \\ & -\tfrac{1}{2}k\int_0^1\left[u_t^2 + (u_t^*)^2 + \tfrac{1}{2}r\left[u_t^*(1-\omega)^{-1}\right]^2\mathbf{w}^*{}'\boldsymbol{\Sigma}\boldsymbol{\Sigma}'\mathbf{w}^*\right]dt \end{aligned}\right)\right\}\right],$$

subject to (1), and where $\alpha \equiv rR/(r+R)$ and $\beta \equiv (1/r)\ln(\lambda r/R) - (R/r)W_0 + U_0$ are constants.

The dynamic programming equation becomes

$$0 \equiv \frac{\partial V}{\partial t} + \max_{u,u^*,\omega}\left\{\begin{aligned} & \frac{\partial V}{\partial W}\left[W_0\left(\omega u + (1-\omega)u^*\right) + \alpha k u^*(1-\omega)^{-1}W_0\mathbf{w}'\boldsymbol{\Sigma}\boldsymbol{\Sigma}'\mathbf{w}^*\right] \\ & +\tfrac{1}{2}\frac{\partial^2 V}{\partial W^2}W_0^2\mathbf{w}'\boldsymbol{\Sigma}\boldsymbol{\Sigma}'\mathbf{w} \\ & +\tfrac{1}{2}\alpha k V(t,W_t)\left[u^2 + u^{*2} + (r+\alpha)\left(u^*(1-\omega)^{-1}\right)^2\mathbf{w}^*{}'\boldsymbol{\Sigma}\boldsymbol{\Sigma}'\mathbf{w}^*\right] \end{aligned}\right\}$$

with the terminal condition being $V(t,W_t)$ = -exp[-$\alpha(W_1 - \beta)$]. Writing out the matrices, the dynamic programming equation can be rewritten in a somewhat simpler form:

$$0 \equiv \frac{\partial V}{\partial t} + \max_{u,u^*,\omega}\left\{\begin{aligned} & \frac{\partial V}{\partial W}W_0\left[\omega u + (1-\omega)u^* + \alpha k u^*\left(1 - \omega(1-\rho)\right)\sigma^2\right] \\ & +\frac{1}{2}\frac{\partial^2 V}{\partial W^2}W_0^2\sigma^2\left(1 + 2\omega^2(1-\rho) - 2\omega(1-\rho)\right) \\ & +\tfrac{1}{2}V(\bullet)\alpha k\left[u^2 + u^{*2} + (r+\alpha)u^{*2}\sigma^2\right] \end{aligned}\right\}. \tag{A.8}$$

The first-order conditions with respect to u, u^*, and ω, respectively, read:

$$u = \frac{-\partial V/\partial W_t}{V(\bullet)\alpha}\frac{\omega}{k}W_0 \tag{A.9}$$

$$u^* = \frac{-\partial V/\partial W}{V(\bullet)\alpha}W_0\left(\frac{(1-\omega)}{k}\frac{1+\alpha\sigma^2}{1+(r+\alpha)\sigma^2} + \frac{\omega}{k}\frac{\alpha\sigma^2\rho}{1+(r+\alpha)\sigma^2}\right) \tag{A.10}$$

$$\omega = \frac{\partial V / \partial W}{2W_0(\partial^2 V / \partial W^2)}\left(\frac{u^* - u}{\sigma^2(1-\rho)} - \alpha k u^* \right) + \frac{1}{2}. \tag{A.11}$$

We use

$$V(t, W_t) = -\exp\left\{ -\alpha \left[W_t - \beta + (1-t)\begin{pmatrix} W_0\left[\omega u + (1-\omega)u^* + \alpha k u^*(1-\omega(1-\rho))\sigma^2\right] \\ -\tfrac{1}{2}\alpha W_0^2\sigma^2\left[1 + 2\omega^2(1-\rho) - 2\omega(1-\rho)\right] \\ -\tfrac{1}{2}k\left[u^2 + u^{*2} + (r+\alpha)u^{*2}\sigma^2\right] \end{pmatrix} \right] \right\}$$

as a trial solution for the value function. Taking the appropriate derivatives and substituting into (A.9)-(A.11) gives (11)-(13). Equations (9) and (10) are obtained by combining (11) and (12) with (8) and (A.7) respectively. Substituting the trial solution into (A.8) confirms that it solves the dynamic programming equation.

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