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Three Essays on International Finance

by

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Chapter 1: Portfolio Home-Bias with Recursive Preferences and Long-Run Risk

Abstract

We study the cause of equity home-bias in a two-country open-economy model featuring recursive preferences and long-run productivity growth risk. With these two properties, the intertemporal marginal rate of substitutions (IMRS) is mainly determined by persistent shocks to productivity growth. Therefore, when these shocks are calibrated to be highly correlated between the home and foreign country, our model is able to generate the high cross-country IMRS correlations, which are typically associated with high international risk sharing. Consequently, the gains left to be exploited from international portfolio diversification could be markedly small. It is in this context we conjecture that a very minor trading cost imposed on cross-border equity transactions would lead to a substantial amount of equity home-bias. The calibration results confirm this prediction. This may seem hardly surprising since even benchmark models are able to generate home-bias if financial frictions are introduced. What is different about our model is that a given amount of home-bias requires significantly smaller trading costs than would be required in benchmark models.

1. Introduction

The “equity home-bias” puzzle is one of the widely discussed puzzles in international finance. According to a survey conducted by Lewis (1999), at least since the 1970s, financial economists have noted the proportion of foreign equities held by domestic investors in their portfolios is too small relative to the predictions of standard portfolio theory. French and Poterba (1991) are the first to document the extent of the equity home-bias. They report that American investors hold roughly 94 percent of their equity wealth in the U.S. stock market whereas the Japanese hold about 98 percent of theirs at home. Given that benchmark models yield low international risk sharing based on consumption data, this finding is widely regarded as puzzling because it appears the investors are foregoing important opportunities for diversification of risk.

The model in the paper is a two-country, open-economy, general equilibrium model. It features recursive preferences and long-run output growth risk. These are two salient properties that distinguish our model from the canonical open-economy real business cycle models. First, we allow recursive preferences instead of power utility. The latter is the functional form commonly used in those benchmark models. Second, the productivity growth is impacted by not only transitory shocks around the trend growth rate of productivity, which is the shock typically focused on in benchmark models, but also shocks to the stochastic trend of productivity, which we dub “long-run risk”.

To keep things as simple as possible, and to highlight the role of the productivity growth process in international risk sharing and equity home-bias, we treat production as exogenous and driven by the productivity process. This is of course identical to an economy with stochastic endowments. To solve for the steady-state equity allocation, we follow the method developed by Devereux and Sutherland (2006) and Tille and van Wincoop (2010). It is based upon a second-order approximation of the Euler equations and a first-order approximation of the model’s other equations. The steady-state equity allocation is then solved from a fixed-point problem.

With power utility, the intertemporal marginal rate of substitution (IMRS) is determined by consumption growth alone. That is why the home bias arises in the first place – because the stylized fact is that consumption growth is poorly correlated across countries, which, with power utility, is equivalent to the poorly correlated IMRS. Note that international risk sharing under the complete markets leads to the equal IMRS across countries. However benchmark models predict the poorly correlated IMRS based on the actual consumption data. At the same time, a significant equity home-bias is observed. The two phenomena – poorly correlated consumption growths and equity home-bias – are conflicting in the benchmark models and puzzle the economists. They wonder why the investors not hold more foreign equities in their portfolios to share the idiosyncratic risks with foreigners so that the consumption growth and consequently the IMRS are able to be better correlated across countries. Of course, the benchmark models can generate high international risk sharing. By doing so, they also yield a high cross-country consumption growth correlation, which is counterfactual with the consumption data.

We believe any model that will make home-bias less a puzzle needs to generate the IMRS to be highly cross-country correlated. Put in other words, in order to be consistent with equity home-bias phenomenon, there has to be little diversifiable risk left for international portfolio diversification. Otherwise, the puzzle always arises – why the investors not hold more foreign equities to allow their IMRS to be better correlated across countries? Meanwhile, we cannot solve the home-bias puzzle by compromising the model's prediction of consumption growth correlation, that is, this correlation should still be able to match the consumption data.

The two modifications we made are just able to do this job. The reason why our model is capable of explaining the equity home-bias puzzle is described intuitively as follows. With recursive preferences, both the investor's consumption growth and his portfolio return are necessary for determining the IMRS. Consumption is subject (at least) to the world resource constraint. In contrast, asset prices, due to their forward-looking nature, are more impacted by trend shocks than by transitory ones. Therefore, trend shocks shall dominate transitory shocks in determining the equity return. Consequently, highly correlated trend / permanent shocks lead to highly correlated equity returns across countries. Accordingly, Ammer and Mei (1996) and Bansal and Lundblad (2002) argue that long-run risk might be the driving force behind high international stock market co-movements despite the lack of correlation of fundamentals. Moreover, with recursive preferences, the portfolio return shall dominate consumption growth in determining the IMRS. In a nutshell, the IMRS in our model is mainly determined by the trend shock. To reach this result, we need both recursive preferences and long-run risk/trend shocks. Next, when we calibrate the trend shocks to be highly correlated, the IMRS become highly correlated across countries. We reach this result not at the expenses of model's prediction of consumption growth correlation, which is still predicted to be low and to be able to match the consumption data. This is done because the transitory shocks are calibrated to be less correlated. The aggregate productivity process that is composed of the trend and transitory shocks in our model can still match the Solow residual data.

In short, in our model, the productivity link, a common trend shared by two countries in technology process, is attributed to bringing the IMRS to move together.

The reason that the IMRS is linked with international risk sharing is as follows. According to Brandt, Cochrane, and Santa-Clara (2006), how much risk is not shared is measured by how different the IMRS is across countries; whereas the volatility of the IMRS in these countries reflects how much risk there is to share. Therefore, they propose the following formula to measure the degree of international risk sharing.

$$IRSI = 1 - \frac{\sigma^2\left(m_{t+1}^h - m_{t+1}^f\right)}{\sigma^2\left(m_{t+1}^h\right) + \sigma^2\left(m_{t+1}^f\right)}, \qquad (1)$$

where $IRSI$ stands for the International Risk Sharing Index, σ^2 denotes the unconditional variances, and m_{t+1}^h (m_{t+1}^f) denotes the logarithm of the intertemporal marginal rate of substitution of home (foreign) agent between period t and $t+1$. When there is no scale issue involved, that is, the volatility of the domestic IMRS equals to that of the foreign IMRS, the risk sharing index is just the same as the cross-country correlation of the IMRS.

Brandt, Cochrane, and Santa-Clara (2006) also argue that portfolios do not need to be similar across countries for the IMRS to be similar. There are also other means to achieve risk sharing. International portfolio diversification is only one of them to facilitate risk sharing across countries.

It is in the context of our result of high risk sharing index that we conjecture the gains left to be exploited from international portfolio diversification could be markedly small. We then apply reasoning akin to that of Cole and Obstfeld (1991). They argue that if the gains from international portfolio diversification are small, even minor impediments to cross-border asset trade can wipe the gains out and produce the properties of autarky. Our calibration results are consistent with this point: a minor trading cost imposed on cross-border equity transactions leads to substantial equity home-bias in our model.

This result may seem hardly surprising since even benchmark models are capable of generating home-bias if financial frictions are imposed. But the point of this paper is that a given amount of equity home-bias requires markedly smaller financial frictions in our model than would be required in benchmark models. The reason is as follows. Benchmark models would predict low risk sharing based on low consumption growth correlation from the data. Therefore, the models would leave substantial gains yet to be exploited from international portfolio diversification and thus require large trading costs to induce the same magnitude of home-bias.

Specifically, to generate the same result of an 85% home-bias (i.e., the investor holds 85% of his wealth in domestic equities vs. 15% in equities from abroad), the international trading cost required in our model is only $\frac{1}{41}$ of that employed by Coeurdacier (2009). Similarly, a comparison between our model and Tille and van Wincoop (2010) reveals that the trading cost in our model is only $\frac{1}{1.6}$ of that in their model to generate an 80% home-bias.

In section two we review the literature on the cause of equity home-bias and on models featuring recursive preferences and "long-run risk". Section three specifies our model. Section four then reports predictions of the model after calibration. Finally, section five offers final remarks.

2. Review of the Literature

French and Poterba (1991) and Tesar and Werner (1995), among others, find portfolios tend to be strongly biased toward domestic securities. Tesar (1995) reports the estimated weights on domestic equity holdings ranging from 96 percent in the United States, to 93 percent in Canada, to 75 percent in the United Kingdom (Tesar, 1995, p. 107).

There has been a long list of papers addressing the issue of equity home-bias, and to date, various explanations have been offered for its cause. Some studies argue a desire to hedge the risk associated with labor income is responsible for a bias in equity allocation. For example, Baxter and Jermann (1997) show that in a neoclassical model, the correlation between labor income and capital return is positive. In particular, under Cobb-Douglas production function, shares of these two factors are constant, which implies labor income is perfectly correlated with capital's share. Therefore, to hedge labor income risk, investors need to bias their portfolio towards foreign equities. Heathcote and Perri (2007) and Engel and Matsumoto (2006) reexamine this issue and both reach the opposite conclusion to that of Baxter and Jermann. They show that under specific circumstances, domestic labor income and capital share could be negatively correlated, making domestic stocks hedge against labor income risk. Hence, investors should bias portfolio towards domestic equities. Employing a two-goods model, Heathcote and Perri (2007) show that with relative price fluctuations labor income and capital return could negatively correlated. Eagel and Matsumoto instead consider a case of sticky prices. They argue that when prices are sticky, the output is demand determined in the short run. As a result, a positive shock would reduce wage and employment while leave output unchanged. This will raise capital return at the expense of labor income.

The second thread of the study, like Baxter, Jermann, and King (1998), Stockman and Dellas (1989), Tesar (1993), and Pesenti and van Wincoop (2002), suggests that domestic equities are able to hedge output risk of non-traded goods and this factor plays a role in explaining equity home-bias. The third thread links the portfolio bias with the motivation to hedge real exchange rate risk that arises from the presence of trade costs in their models. Among others, Coeurdacier (2009) and Obstfeld (2007) are prominent examples. The forth thread, for example Kang and Stulz (1997) and van Nieuwerburgh and Veldkamp (2009), suggests information asymmetry might be the driving force behind equity home-bias.

Instead, Cole and Obstfeld (1991) study the cause of home-bias from a different perspective. They argue equity home-bias will emerge when the gains from international portfolio diversification are too small to cover the diversification costs. In their model, the movement in a country's terms of trade automatically provides insurance against the country-specific output risk. Consequently, there is not much risk to share in international capital markets. In an extreme case, namely Cobb-Douglas preferences with their implication of unitary price elasticity, "terms of trade responses alone provide perfect insurance against output shocks. In such cases, the gains from international portfolio diversification are nil" (Cole & Obstfeld, 1991, p. 5). In comparison, in our model, highly correlated trend shocks to productivity are responsible for high risk sharing across countries and thus the gains from international portfolio diversification are small.

To solve for the steady-state equity allocation in incomplete markets, we follow a new solution technique developed by Devereux and Sutherland (2006) and Tille and van Wincoop (2010). Their approach is based upon a second-order approximation of the Euler equations and a first-order approximation of the model's other equations. The steady-state equity allocation is then solved from a fixed-point problem. Several recent papers apply this solution method, including Coeurdacier (2009).

We enrich a standard open-economy real business cycle (RBC) model with recursive preferences and "long-run risk". In the finance field, Bansal and Yaron (2004) contribute the pioneering paper featuring these two salient properties. Their model has had some success in solving the equity premium puzzle. Aguiar and Gopinath (2007) are among the first to introduce a stochastic trend of productivity to the canonical open-economy RBC model. They suggest that the predominance of trend shocks relative to transitory shocks for emerging markets and the reverse for developed markets may explain differences in key features of their respective business cycles.

3. Model

In our model, the world is composed of two exchange economies: the home and foreign economy, denoted h and f , respectively. For simplicity, we impose initial symmetry between the two countries. There are two tradable goods in the world economy, and each country produces only one of them but consumes both. Specifically, good H and F denote respectively the type of good the home and foreign country each produces. Asset H and F, two assets traded in the world capital market, are the respective claims to home and foreign output.

3.1. Preferences

Our model features recursive preferences, or non-expected-utility preference, as proposed by Epstein and Zin (1989, 1991) and Weil (1989). With recursive preferences, a representative agent maximizes the following objective function:

$$U_t^i = \left\{ (1-\beta)\beta C_t^{i\,\frac{1-\lambda}{\gamma}} + \left(E_t U_{t+1}^{i\;1-\lambda} \right)^{\frac{1}{\gamma}} \right\}^{\frac{\gamma}{1-\lambda}} \qquad (2)$$

$$\forall i \in \{h, f\},$$

where U_t^i denotes the utility of the agent in country i during period t, C_t^i is her real consumption in period t, the parameter β denotes the subjective discount factor, also known as the time-preference factor, λ denotes the coefficient of relative risk aversion (RRA). In contrast with the case of power utility where the elasticity of intertemporal substitution (EIS) is always the inverse of RRA, recursive preferences allow the EIS to be disentangled from RRA. Therefore, the parameter γ that denotes $\dfrac{1-RRA}{1-1/EIS}$ is not necessarily fixed at unity in our model.

Using dynamic programming, Epstein and Zin (1989) show that the agent's intertemporal marginal rate of substitution with recursive preferences takes the following form:

$$IMRS_{t+1}^{i} = \left[\beta \left(\frac{C_{t+1}^{i}}{C_{t}^{i}} \right)^{\theta-1} \right]^{\gamma} \left[R_{t+1}^{p,i} \right]^{\gamma-1}, \qquad (3)$$

where $R_{t+1}^{p,i}$ is the investor's portfolio return in country i between period t and $t+1$, and the parameter θ denotes $1 - \frac{1}{EIS}$.

3.2. Outputs

Output of each good is assumed to depend only on the following exogenous productivity factors.

$$Y_{H,t} = Z_t \cdot \left(A_t \right)^{\alpha}, \ (4)$$

$$Y_{F,t} = Z_t^{*} \cdot \left(A_t^{*} \right)^{\alpha}, \ (5)$$

here $Y_{H,t}$ and $Y_{F,t}$ are respectively home and foreign output in period t, the parameter α denotes labor's share, and the parameters Z_t and A_t represent two distinct productivity processes. Asterisks denote foreign variables.

Following Aguiar and Gopinath (2007), the two productivity processes are characterized by different stochastic properties. Specifically, $\log(Z_t)$ follows an $AR(1)$ process:

$$\log\left(Z_{i,t}\right) = z_{i,t} = \phi z_{i,t-1} + \varepsilon_{z,t}^{i}, \qquad (6)$$

where $\varepsilon_{z,t}^{i}$ denotes contemporaneous *i.i.d.* innovation in the transitory productivity process in country i, which has zero mean and standard deviation σ_z, and the parameter ϕ measures the persistence of the transitory shock.

The parameter $A_{i,t}$ represents "the cumulative product of growth shocks" (Aguiar & Gopinath, 2007, p. 80). It is characterized by the following stochastic process:

$$\log\left(\frac{A_{i,t}}{A_{i,t-1}}\right) = \log\left(G_{i,t}\right) = g_{i,t} = (1-\omega)\,\overline{g} + \omega g_{i,t-1} + \varepsilon_{g,t}^{i}, \quad (7)$$

here $\overline{g}$ denotes the productivity's long-run mean growth rate, $\varepsilon_{g,t}^{i}$ denotes an *i.i.d.* innovation in the trend productivity process in country i, which has zero mean and standard deviation σ_g, and the parameter ω measures the persistence of trend shocks to productivity.

We allow shocks to be cross-country correlated. Their covariance matrix Σ is defined as follows.

$$\left[\varepsilon_{z,t}, \varepsilon^*_{z,t}, \varepsilon_{g,t}, \varepsilon^*_{g,t}\right]' \sim N(0,\Sigma),$$

$$\Sigma = \begin{bmatrix} \sigma_z^2, & \rho_z\sigma_z^2, & 0, & 0 \\ \rho_z\sigma_z^2, & \sigma_z^2, & 0, & 0 \\ 0, & 0, & \sigma_g^2, & \rho_g\sigma_g^2 \\ 0, & 0, & \rho_g\sigma_g^2, & \sigma_g^2 \end{bmatrix}, \qquad (8)$$

where we denote the parameter $\rho_z \equiv corr\left(\varepsilon_{z,t}, \varepsilon^*_{z,t}\right)$ — the cross-country correlation of transitory productivity shocks. We also define $\rho_g \equiv corr\left(\varepsilon_{g,t}, \varepsilon^*_{g,t}\right)$ — the cross-country correlation of trend shocks.

3.3. The Goods Markets

Following Coeurdacier (2009) and Tille and van Wincoop (2010), we impose trade costs on international trade in goods. Due to trade costs, purchasing power parity does not hold. Therefore, the real exchange rate may deviate from unity when there are movements in the international relative price due to country-specific productivity shocks. Hence, the presence of trade costs will allow our model to illuminate the effect of the real exchange rate movements on portfolio selection.

In Coeurdacier (2009), trade costs are of an “iceberg type”: for $\pi \geq 0$, for each good shipped, $1/(1+\pi)$ goods arrive at the destination. The case $\pi = 0$ stands for zero “iceberg-type” trade costs. However, in Tille and van Wincoop (2010), trade costs are elicited by their assumption of consumption preference for the domestic good. Thus, the agent's consumption index becomes:

$$C_t = \left[\Lambda^{\frac{1}{\mu}} C_{H,t}^{\frac{\mu-1}{\mu}} + (1-\Lambda)^{\frac{1}{\mu}} C_{F,t}^{\frac{\mu-1}{\mu}} \right]^{\frac{\mu}{\mu-1}}, \qquad (9)$$

$$C_t^* = \left[\Lambda^{\frac{1}{\mu}} C_{F,t}^{*\,\frac{\mu-1}{\mu}} + (1-\Lambda)^{\frac{1}{\mu}} C_{H,t}^{*\,\frac{\mu-1}{\mu}} \right]^{\frac{\mu}{\mu-1}}, \qquad (10)$$

where the parameter μ denotes the elasticity of substitution between the home and foreign good, C_t $\left(C_t^*\right)$ denotes the index of total consumption of home (foreign) agent in period t, $C_{H,t}$ and $C_{F,t}$ $\left(C_{H,t}^* \text{ and } C_{F,t}^*\right)$ denote respectively consumption of the home and foreign good by the home (foreign) agent in period t, and the parameter Λ governs consumption preference. Specifically, $\Lambda < \frac{1}{2}$ creates a preference for the good from abroad. Likewise, $\Lambda > \frac{1}{2}$ creates a preference for the domestic good. The case $\Lambda = \frac{1}{2}$ corresponds to symmetric preferences for the two goods.

We will include both parameters that govern "iceberg-type" trade costs and consumption preference in our model in order to compare the predictions of our model with those of Coeurdacier (2009) and Tille and van Wincoop (2010).

For simplicity, we normalize the price of the home good to unity. Table 1-1 lists the goods prices prevailing in country h and f.

Table 1-1			
Goods prices			
	The good	The price in country h	The price in country f
1	Good H	$P_{H,t} = 1$	$P^*_{H,t} = (1+\pi)\times 1$
2	Good F	$P_{F,t} = (1+\pi) P^*_{F,t}$	$P^*_{F,t}$

Having the individual goods prices and the consumption indexes at hand, the corresponding price indexes are:

$$P_t = \left[\Lambda P_{H,t}^{1-\mu} + (1-\Lambda) P_{F,t}^{1-\mu}\right]^{\frac{1}{1-\mu}} = \left[\Lambda + (1-\Lambda)(1+\pi)^{1-\mu}\left(P^*_{F,t}\right)^{1-\mu}\right]^{\frac{1}{1-\mu}}. \quad (11)$$

$$P^*_t = \left[\Lambda\left(P^*_{F,t}\right)^{1-\mu} + (1-\Lambda)\left(P^*_{H,t}\right)^{1-\mu}\right]^{\frac{1}{1-\mu}} = \left[\Lambda\left(P^*_{F,t}\right)^{1-\mu} + (1-\Lambda)(1+\pi)^{1-\mu}\right]^{\frac{1}{1-\mu}}.$$
(12)

The demand functions for each individual good are listed below:

$$C_{H,t} = \Lambda\left(\frac{P_{H,t}}{P_t}\right)^{-\mu} C_t = \Lambda\left(\frac{1}{P_t}\right)^{-\mu} C_t \qquad (13)$$

$$C_{F,t} = (1-\Lambda)\left(\frac{P_{F,t}}{P_t}\right)^{-\mu} C_t = (1-\Lambda)\left[\frac{(1+\pi) P^*_{F,t}}{P_t}\right]^{-\mu} C_t \quad (14)$$

$$C^*_{F,t} = \Lambda\left(\frac{P^*_{F,t}}{P^*_t}\right)^{-\mu} C^*_t \qquad (15)$$

$$C^*_{H,t} = (1-\Lambda)\left(\frac{P^*_{H,t}}{P^*_t}\right)^{-\mu} C^*_t = (1-\Lambda)\left[\frac{(1+\pi)}{P^*_t}\right]^{-\mu} C^*_t. \qquad (16)$$

From (13), (14), (15) and (16), we have the goods market clearing conditions.

$$Y_{H,t} = C_{H,t} + (1+\pi)C^*_{H,t} = \Lambda\left(\frac{1}{P_t}\right)^{-\mu} C_t + (1+\pi)(1-\Lambda)\left[\frac{(1+\pi)}{P^*_t}\right]^{-\mu} C^*_t. \qquad (17)$$

$$Y_{F,t} = (1+\pi)C_{F,t} + C^*_{F,t} = (1+\pi)(1-\Lambda)\left[\frac{(1+\pi)P^*_{F,t}}{P_t}\right]^{-\mu} C_t + \Lambda\left(\frac{P^*_{F,t}}{P^*_t}\right)^{-\mu} C^*_t. \qquad (18)$$

3.4. The Asset Markets

Since equity is a claim on each country's output, the returns on home and foreign equities are defined respectively as follows:

$$R_{H,t+1} = \frac{Q_{H,t+1}}{Q_{H,t}} + \frac{Y_{H,t+1}}{Q_{H,t}}, \qquad (19)$$

$$R_{F,t+1} = \frac{Q_{F,t+1}}{Q_{F,t}} + \frac{Y_{F,t+1}P^*_{F,t+1}}{Q_{H,t}}, \qquad (20)$$

where Q represents the ex-dividend asset price, and in particular, $Q_{i,t}$ denotes the end-of-period-t price of equity i. Asset prices and asset returns are all in terms of the numeraire home good.

Given the returns on individual assets, the portfolio returns of the home and foreign investor are, respectively:

$$R_{t+1}^{p,h} = \left[K_{H,t+1}^{h} R_{H,t+1} + \left(1 - K_{H,t+1}^{h}\right) e^{-\tau} R_{F,t+1} \right] P_t \big/ P_{t+1}, \quad (21)$$

$$R_{t+1}^{p,f} = \left[K_{H,t+1}^{f} e^{-\tau} R_{H,t+1} + \left(1 - K_{H,t+1}^{f}\right) R_{F,t+1} \right] P_t^{*} \big/ P_{t+1}^{*}, \quad (22)$$

where $K_{H,t+1}^{h}$ denotes the proportion of the home investor's wealth held in equity H at the beginning-of-period $t+1$, and correspondingly $\left(1-K_{H,t+1}^{h}\right)$ is the proportion of her wealth in equity F at the same time. Similarly, the foreign investor puts $K_{H,t+1}^{f}$ of his wealth in equity H and $\left(1-K_{H,t+1}^{f}\right)$ in equity F. The investor's portfolio return is measured in terms of her (his) domestic consumption basket.

As in Tille and van Wincoop (2010), we introduce financial frictions by assuming that investing in equity abroad entails a cost. Specifically, for every dollar invested abroad, the return between period t and $t+1$ is $e^{-\tau} R_{i,t+1}$, which, for $\tau > 0$, is less than $R_{i,t+1}$, the return offered to the domestic investor in the same period of time. Note that the magnitude of the trading cost has to be second-order to ensure a well-behaved portfolio selection; otherwise, after the first-order approximation of both the home and foreign Euler equations, we would arrive at two contradictory results:

$$E_t\left(\hat{r}_{H,t+1}\right)=E_t\left(\hat{r}_{F,t+1}-\tau\right)\rightarrow E_t\left(\hat{r}_{H,t+1}\right)<E_t\left(\hat{r}_{F,t+1}\right)$$
and
$$E_t\left(\hat{r}_{H,t+1}-\tau\right)=E_t\left(\hat{r}_{F,t+1}\right)\rightarrow E_t\left(\hat{r}_{H,t+1}\right)>E_t\left(\hat{r}_{F,t+1}\right),$$

where $\hat{r}_{i,t+1}\equiv\log\left(R_{i,t+1}\right)-\log\left(\bar{R}\right)$. When the trading cost is assumed to be second-order in magnitude, it will no long appear in the first-order approximation. The above equations then become as follows. Now there is no contradiction between these two equations.

$$E_t\left(\hat{r}_{H,t+1}\right)=E_t\left(\hat{r}_{F,t+1}\right)$$
and
$$E_t\left(\hat{r}_{H,t+1}\right)=E_t\left(\hat{r}_{F,t+1}\right),$$

3.5. The Evolution of Wealth

For simplicity's sake, we follow Tille and van Wincoop (2010) and assume that the financial trading cost causes no loss in aggregate wealth; but instead it is a fee paid to a domestic broker. Consequently, it will not affect the evolution of wealth:

$$W_{t+1}=\left[K^h_{H,t+1}R_{H,t+1}+\left(1-K^h_{H,t+1}\right)R_{F,t+1}\right]{P_t}/{P_{t+1}}\left(W_t-C_t\right), \qquad (23)$$

$$W_{t+1}^{*}=\left[K_{H,t+1}^{f}e^{-\tau}R_{H,t+1}+\left(1-K_{H,t+1}^{f}\right)R_{F,t+1}\right]P_{t}^{*}\Big/P_{t+1}^{*}\left(W_{t}^{*}-C_{t}^{*}\right), \quad (24)$$

where W_t is the beginning-of-period-t measure of the home investor's wealth[1], and its foreign counterpart is denoted with an asterisk. The investor's wealth is measured in terms of the domestic consumption basket.

In each country, after part of the wealth is consumed, the remaining beginning-of-period wealth is then invested in two equities. This leads to the following asset market clearing conditions:

$$Q_{H,t}=K_{H,t+1}^{h}\left(W_{t}-C_{t}\right)P_{t}+K_{H,t+1}^{f}\left(W_{t}^{*}-C_{t}^{*}\right)P_{t}^{*}. \quad (25)$$

$$Q_{F,t}=\left(1-K_{H,t+1}^{h}\right)\left(W_{t}-C_{t}\right)P_{t}+\left(1-K_{H,t+1}^{f}\right)\left(W_{t}^{*}-C_{t}^{*}\right)P_{t}^{*}. \quad (26)$$

3.6. The First-Order Conditions

Based on the IMRS of recursive preferences shown in (3), we derive a series of Euler equations. In particular, the Euler equations for the home investor are:

[1] For details, including the definition, of the beginning-of-period wealth, see Chapter 2, p. 75; and Supplement to Chapter 2, p. 718-722, in Obstfeld and Rogoff (1996).

$$E_t\left\{\left[\beta\left(\frac{C_{t+1}}{C_t}\right)^{\theta-1}\right]^{\gamma}\left[R_{t+1}^{p,h}\right]^{\gamma-1}R_{H,t+1}\right\}=1$$
$$and \tag{27}$$
$$E_t\left\{\left[\beta\left(\frac{C_{t+1}}{C_t}\right)^{\theta-1}\right]^{\gamma}\left[R_{t+1}^{p,h}\right]^{\gamma-1}\left(e^{-\tau}R_{F,t+1}\right)\right\}=1.$$

Euler equation shows, in equilibrium, the consumer is indifferent between two intertemporal choices: consuming one more unit of good today or investing it today and consuming it tomorrow would, in equilibrium, lead to exactly the same utility level.

Analogously, the Euler equations for the foreign investor are:

$$E_t\left\{\left[\beta\left(\frac{C_{t+1}^{*}}{C_t^{*}}\right)^{\theta-1}\right]^{\gamma}\left[R_{t+1}^{p,f}\right]^{\gamma-1}\left(e^{-\tau}R_{H,t+1}\right)\right\}=1$$
$$and \tag{28}$$
$$E_t\left\{\left[\beta\left(\frac{C_{t+1}^{*}}{C_t^{*}}\right)^{\theta-1}\right]^{\gamma}\left[R_{t+1}^{p,f}\right]^{\gamma-1}R_{F,t+1}\right\}=1.$$

3.7. The Solution Procedure (1): A Second-Order Approximation of the Euler Equations

The standard method for solving a dynamic general equilibrium model is to log-linearize the system to a first-order approximation around its steady state. However, this practice is not appropriate here in solving for the steady-state equity allocation. The reason is that, up to a first-order approximation, we would derive the following from the Euler equations: $E_t\left(\hat{r}_{H,t+1}\right)=E_t\left(\hat{r}_{F,t+1}\right)$, which implies home and foreign assets are treated as identical, and thus portfolio choice is indeterminate.

Portfolio selection depends in part on the variance and covariance of asset returns. As argued in Devereux and Sutherland (2006) and Tille and van Wincoop (2010), these second moments only show up when the home and foreign Euler equations are each log-linearized to a second-order approximation. A second-order approximation of the Euler equations contain both the second-order components of the log-linear approximation (for instance $\hat{\tilde{c}}_{t+1}^{2}\equiv\left[\log\left(\tilde{C}_{t+1}\right)-\log\left(\bar{\tilde{C}}\right)\right]^2$) and the first-order components (for instance $\hat{\tilde{c}}_{t+1}\equiv\log\left(\tilde{C}_{t+1}\right)-\log\left(\bar{\tilde{C}}\right)$). But the cross-country difference of a second-order approximation of the Euler equations involves only the product of the first-order components, with second-order components being cancelled out. We then apply the standard method to solve these first-order components, that is, we log-linearize the system to a first-order approximation around its steady state including the steady-state equity allocation. Eventually, following Devereux and Sutherland (2006) and Tille and van Wincoop (2010), the steady state portfolio selection is solved from a fixed-point problem.

Because shocks on the growth rate of productivity affect the level of productivity permanently, trend shocks affect productivities A and A^* permanently. Hence the levels of home and foreign output are non-stationary. Before log-linearization of the system around its steady state, where all exogenous shocks are set to zero, we need to de-trend the variables. Following Aguiar and Gopinath (2007), we de-trend all variables — except for the goods prices P, portfolio selection K, and asset return R - as follows: $\tilde{X}_t = \frac{X_t}{A_{t-1}}$. As pointed out by Aguiar and Gopinath (2007), this way of de-trending ensures that if X_t is in the investor's information set as of time $t-1$, so is $\tilde{X}_t$.

Wealth too might be non-stationary given that even transitory shocks could have a permanent effect on the distribution of wealth when the asset market is incomplete. With complete asset markets, investors are able to insure every state of nature, which essentially eliminates all uncertainties. Incomplete markets leave investors with some risks to bear. The spanning condition states that, "The existence of *S* assets with linearly independent return vectors provides market risk-sharing opportunities as rich as those provides by *S* Arrow-Debreu securities with linearly independent return vectors" (Obstfeld and Rogoff, 1996, p. 336), where *S* is the number of the state of nature. Accordingly, if the number of independent assets is less than the number of the state of nature, asset markets are incomplete. An extreme case would be the riskless bond as the only asset available in the market. In this case, transitory shock could even permanently affect wealth distribution: the country hit by a positive transitory shock will smooth consumption by holding more amount of bond, which raises its permanent income by the interest payment it will receive in every future period. Devereux and Sutherland (2006) admit that this non-stationary property will make the *unconditional* second moments from the model unbounded. “But, as shown above, the optimal portfolio requires only *conditional* moments, which always exist” (Devereux & Sutherland, 2006, p. 17, footnote 13).

To get the cross-country difference of a second-order approximation of the Euler equations, we first derive from (27) the home Euler equation for excess return:

$$E_t\left\{\left(\tilde{C}_{t+1}\right)^{(\theta-1)\gamma}\left(G_t\right)^{(\theta-1)\gamma}\left(R_{t+1}^{p,h}\right)^{(\gamma-1)}\left(R_{H,t+1}-e^{-\tau}R_{F,t+1}\right)\right\}=0. \quad (29)$$

Its foreign counterpart is then derived from (28):

$$E_t\left\{\left(\tilde{C}_{t+1}^{*}\right)^{(\theta-1)\gamma}\left(G_t^{*}\right)^{(\theta-1)\gamma}\left(R_{t+1}^{p,f}\right)^{(\gamma-1)}\left(e^{-\tau}R_{H,t+1}-R_{F,t+1}\right)\right\}=0. \quad (30)$$

After second-order approximating (29), we get:

$$E_t\left(\hat{r}_{H,t+1}-\hat{r}_{F,t+1}\right)+\frac{1}{2}E_t\left[\hat{r}^2_{H,t+1}-\left(\hat{r}^2_{F,t+1}-\tau\right)\right]$$
$$+(\theta-1)\gamma E_t\left[\hat{\hat{c}}_{t+1}\left(\hat{r}_{H,t+1}-\hat{r}_{F,t+1}\right)\right]+(\gamma-1)E_t\left[\hat{r}^{p,h}_{t+1}\left(\hat{r}_{H,t+1}-\hat{r}_{F,t+1}\right)\right]=0. \quad (31)$$

Likewise, a second-order approximation of (30) is:

$$E_t\left(\hat{r}_{H,t+1}-\hat{r}_{F,t+1}\right)+\frac{1}{2}E_t\left[\left(\hat{r}^2_{H,t+1}-\tau\right)-\hat{r}^2_{F,t+1}\right]$$
$$+(\theta-1)\gamma E_t\left[\hat{\hat{c}}^*_{t+1}\left(\hat{r}_{H,t+1}-\hat{r}_{F,t+1}\right)\right]+(\gamma-1)E_t\left[\hat{r}^{p,f}_{t+1}\left(\hat{r}_{H,t+1}-\hat{r}_{F,t+1}\right)\right]=0. \quad (32)$$

Finally, by subtracting (32) from (31), we get the cross-country difference of a second-order approximation of the Euler equations.

$$\tau+(\theta-1)\gamma E_t\left[\left(\hat{\hat{c}}_{t+1}-\hat{\hat{c}}^*_{t+1}\right)\left(\hat{r}_{H,t+1}-\hat{r}_{F,t+1}\right)\right]$$
$$+(\gamma-1)E_t\left[\left(\hat{r}^{p,h}_{t+1}-\hat{r}^{p,f}_{t+1}\right)\left(\hat{r}_{H,t+1}-\hat{r}_{F,t+1}\right)\right]=0. \quad (33)$$

3.8. The Solution Procedure (2): A First-Order Approximation of the System around $\bar{K}^h_H$

Equation (33) shows that the cross-country difference of a second-order approximation of Euler equations includes only the product of the first-order components, without any second-order terms involved. Also, all variables in (33) are in their cross-country difference terms. To focus on the cross-country differences, rather than the variables per se, following Tille and van Wincoop (2010) we re-write the system in terms of the variables' world average and the cross-country difference terms. A variable's world average term is defined as:

$$x_t^A = \frac{1}{2}\left(x_{H,t} + x_{F,t}\right). \quad (34)$$

Its cross-country difference is:

$$x_t^D = \left(x_{H,t} - x_{F,t}\right). \quad (35)$$

From (34) and (35), any home and foreign variables can be re-written in terms of the world average and the cross-country difference as follows, respectively:

$$\begin{aligned} & x_{H,t} = x_t^A + \frac{1}{2} x_t^D \\ & \textit{and} \qquad\qquad (36) \\ & x_{F,t} = x_t^A - \frac{1}{2} x_t^D. \end{aligned}$$

Accordingly, we re-write the system by substituting (36) into (4)-(28). Focusing on the cross-country difference terms, the system consists of two exogenous state variables g_t^D *and* z_t^D, one endogenous state variable w_t^D, and three control (jump) variables c_t^D, q_t^D, *and* $p_{f,t}^*$. After applying the method of undetermined coefficients, we solve the system as follows.

$$
\begin{aligned}
w_{t+1}^{D} &= w_{\varepsilon g}\varepsilon_{g,t+1}^{D} + w_{\varepsilon z}\varepsilon_{z,t+1}^{D} + w_{g}g_{t}^{D} + w_{z}z_{t}^{D} + w_{w}w_{t}^{D} \\
c_{t}^{D} &= c_{g}g_{t}^{D} + c_{z}z_{t}^{D} + c_{w}w_{t}^{D} \\
q_{t}^{D} &= q_{g}g_{t}^{D} + q_{z}z_{t}^{D} + q_{w}w_{t}^{D} \\
p_{f,t}^{*} &= p_{g}g_{t}^{D} + p_{z}z_{t}^{D} + p_{w}w_{t}^{D},
\end{aligned}
\qquad (37)
$$

where all coefficients contain only the steady state equity allocation and parameters of the system.

Based on (19), we derive the cross-country difference in asset returns as follows.

$$
r_{t+1}^{D} = \hat{r}_{H,t+1} - r_{F,t+1} = g_{t}^{D} + \rho\tilde{q}_{t+1}^{D} + (1-\rho)\tilde{y}_{t+1}^{D} - (1-\rho)p_{f,t+1}^{*} - \tilde{q}_{t}^{D}, \quad (38)
$$

where the parameter ρ denotes $\beta e^{\theta\bar{g}}$.

Substituting (37) into (38), we have:

$$
r_{t+1}^{D} = F_{rg}g_{t+1}^{D} + F_{rz}z_{t+1}^{D} + F_{rw}w_{t+1}^{D} + (1-q_{g})g_{t}^{D} - q_{z}z_{t}^{D} - q_{w}w_{t}^{D}. \quad (39)
$$

From (21), we get the cross-country difference in the portfolio returns:

$$
\hat{r}_{t+1}^{p,h} - r_{t+1}^{p,f} = (2K-1)(r_{H,t+1} - r_{F,t+1}) + (1-2\upsilon)p_{f,t}^{*} - (1-2\upsilon)p_{f,t+1}^{*}, \quad (40)
$$

where the parameter K refers to $\bar{K}_{H}^{h}$, the proportion of the home investor's wealth held in equity H in the steady state, and the parameter υ denotes $\frac{\Lambda}{\left[\Lambda+(1-\Lambda)(1+\pi)^{1-\mu}\right]}$, which measures trade costs.

3.9. The solution to the steady-state portfolio selection problem

Substituting (37), (39), and (40) obtained from a first-order approximation, into (33), the cross-country difference of a second-order approximation of the Euler equations, we get:

$$\begin{aligned}
&\tau+2(\theta-1)\gamma\left[\left(c_g+w_{\varepsilon g}\right)\left(F_{rg}+F_{rw}w_{\varepsilon g}\right)\right]\left(1-\rho_g\right)\sigma_g^2 \\
&+2(\theta-1)\gamma\left[\left(c_z+w_{\varepsilon z}\right)\left(F_{rz}+F_{rw}w_{\varepsilon z}\right)\right]\left(1-\rho_z\right)\sigma_z^2 \\
&+2(\gamma-1)\left(F_{rg}+F_{rw}w_{\varepsilon g}\right)\left[(2K-1)\left(F_{rg}+F_{rw}w_{\varepsilon g}\right)-(1-2\upsilon)\left(p_g+p_w w_{\varepsilon g}\right)\right]\left(1-\rho_g\right)\sigma_g^2 \\
&+2(\gamma-1)\left(F_{rz}+F_{rw}w_{\varepsilon z}\right)\left[(2K-1)\left(F_{rz}+F_{rw}w_{\varepsilon z}\right)-(1-2\upsilon)\left(p_z+p_w w_{\varepsilon z}\right)\right]\left(1-\rho_z\right)\sigma_z^2 \\
&=0.
\end{aligned}$$
(41)

Finally, we solve for the steady-state equity allocation K from (41).

3.10. The International Risk Sharing Index

We suggest that the equity home-bias puzzle might be closely related to the issue of international risk sharing. In particular, when facing the same level of financial trading cost, our model generates more amount of home-bias than benchmark models do. This could be attributed to better risk sharing arising in our model from highly correlated trend shocks chosen in our calibration.

To highlight this point, we display the model's results for the international risk sharing index. Following Brandt, Cochrane, and Santa-Clara (2006), the risk sharing index is measured as follows.

$$IRSI = 1 - \frac{\sigma^2\left(m_{t+1}^f - m_{t+1}^d\right)}{\sigma^2\left(m_{t+1}^f\right) + \sigma^2\left(m_{t+1}^d\right)}$$

4. Parameterization and Predictions of the Model

4.1. Parameterization

Based on the literature, we choose the parameter values as follows. The value of the parameter α, labor's share, is set to be 0.68, a standard value in the literature. Based on the estimation by Aguiar and Gopinath (2007), the value of $\bar{g}$, the long-run mean growth rate of productivity, is set to be 0.0073 at a quarterly rate, which is equivalent to an annual rate of 3%. The value of the parameter β, the time-preference factor, is set to be 0.997. The long-run mean quarterly return on risky assets $\bar{r}$ is pinned down at an average annual rate of 6% by $\beta = \bar{G}^{1-\theta} / \bar{R}$.

We consider several options for the parameter value of RRA and the EIS: $RRA = \{1.8,\ 1.5,\ 1.2\}$ and $EIS = \{0.4,\ 0.5,\ 0.6,\ 0.7,\ 0.8,\ 1.2\}$. The debate on the exact values of these two parameters is still unsettling. For example, Prescott (1986) documents that the findings of past empirical research make a strong case of RRA being not far from unity. With power utility, this implies the value of the EIS not far from unity either. However, with recursive preferences, the two values are disentangled from each other. Epstein and Zin (1991) estimate them in the case of recursive preferences. They find that the EIS is less than one and RRA is close to one. In addition, they find consumer prefers the late resolution of uncertainty, which implies $RRA < \frac{1}{EIS}$. Because our model also features recursive preferences, we set these values based mainly on the estimation by Epstein and Zin (1991). However, Bansal and Yaron (2004) argue that a value of the EIS greater than unity is crucial for their model featuring recursive preferences to have some success in solving equity premium puzzle. Being aware of the uncertainty surrounding the value of the EIS, we consider it in a range that covers all the following scenarios, namely $EIS < 1$, the EIS close to 1, and $EIS > 1$.

Regarding the parameters governing the productivity processes, we choose the values of σ_z and σ_g by matching the volatility of the output growth process Δy in the model with the data of the unconditional variance of dividend growth, rather than with the variance of productivity growth. We make this choice based on the following considerations. Our model features an exogenous production driven only by the productivity processes. Therefore dividends from holding the equities that are claims to countries' uncertain outputs equal to outputs. To study the portfolio problem, we can no longer focus exclusively on the model's quantity side but ignore its (asset) price side.

After all, the data show the dividend and productivity process are in stark difference: "The volatility of stock markets is much higher than the volatility of business cycles: in the US, business cycles volatility is as low as 2% on annual basis, whereas stock returns volatility is as large as 15%. The volatility of dividend growth is somewhere in between those two values, around $6-7\%$ (see Campbell [1999])" (Coeurdacier, 2008, p. 25).

We choose the values of the parameters $\sigma_{\varepsilon,g}$, ω, ϕ that govern the exogenous shock processes based on the estimation by Aguiar and Gopinath (2007). In particular, the value of the quarterly volatility of trend shocks is taken from column 1 of table 4 where two parameter $\sigma_{\varepsilon,g}$ and $\sigma_{\varepsilon,z}$ are estimated by matching exactly the two empirical moments, which are the standard deviations of income and consumption. With $\sigma_{\varepsilon,g}$ set at 0.88%, the volatility of trend shocks to dividend, σ_g, then has to be 2.64% after we choose the leverage ratio to be 3, a number based on Bansal and Yaron (2004). Moreover, the value of σ_z — the quarterly volatility of transitory shocks to dividends

— is set at 2.32% to ensure an annual volatility of 6% for aggregate dividend growth. In addition, the persistence of trend shocks and transitory shocks, denoted ω and ϕ, is set to be 0.29 and 0.97 respectively. These two numbers are taken from column 4 of table 4 in Aguiar and Gopinath (2007) where the full set of productivity parameters are estimated by matching 10 empirical moments, including the autocorrelation of income and the contemporaneous correlation between consumption and income.

In respect of the parameters governing cross-country shock correlations, we set the cross-country correlation of the trend shocks (denoted ρ_g) and the correlation of the transitory shocks (denoted ρ_z) to be 0.98 and 0.25, respectively. Values like these are used by Colacito and Croce (2008). Actually, the value of ρ_g in their paper is unity due to their assumption of a common long-run risk across countries. Meanwhile, they choose the cross-country correlation of the transitory shocks to consumption growth at a level to ensure that the overall international correlation of consumption growth is on the order of 0.3, as observed in the data.

With regard to the empirical evidence on the cross-country correlation of long-run risk, Colacito and Croce (2008) estimate it by using the U.S. and the U.K. data from 1929 to 2006. They find that the cross-country correlation of long-run shocks to consumption growth seems to change over time. As far as the data from the last two decades are concerned, they estimate this correlation to be 0.90.

Using the decomposition method proposed by Beveridge and Nelson (1981), we derive the variance of the total dividend growth Δy as follows.

$$\sigma_{\Delta y}^2 = \left[\frac{2}{(1+\phi)}\right]\sigma_{\varepsilon,z}^2 + \left[\frac{\alpha^2}{\left(1-\omega^2\right)}\right]\sigma_{\varepsilon,g}^2. \qquad (42)$$

The values we choose of the parameters governing the shock processes imply a quarterly volatility of total dividend growth of 3% (an annual volatility of 6%) in the model, which is a good fit of the actual U.S. data.

In addition, the auto-covariance of the total dividend growth is derived in our model as follows.

$$\operatorname{cov}\left(\Delta y_t, \Delta y_{t-1}\right) = -\frac{(1-\phi)}{(1+\phi)}\sigma_{\varepsilon,z}^2 + \frac{\alpha^2\omega}{\left(1-\omega^2\right)}\sigma_{\varepsilon,g}^2 \qquad (43)$$

The chosen parameter values lead to an auto-correlation of the aggregate dividend growth to be 0.10 in our model. Campbell (2003) documents the data on the auto-correlation of the dividend growth, which is 0.078 for Germany (1978.4-1997.4), 0.313 for U.K. (1970.1-

1999.2), 0.354 for Japan (1970.2-1999.1), and -0.578 for U.S. (1970.1-1998.4).

Likewise, the cross-country covariance of the total dividend growth in our model is:

$$\operatorname{cov}\left(\Delta y_t, \Delta y_t^*\right) = \frac{2}{(1+\phi)}\rho_z \sigma_{\varepsilon,z}^2 + \frac{\alpha^2}{\left(1-\omega^2\right)}\rho_g \sigma_{\varepsilon,g}^2 \quad (44)$$

The chosen parameter values deliver a cross-country correlation of the total dividend growth at 0.54 in our model. We didn't find data of the cross-country correlation of dividend growth. But Stock and Watson (2005) document the cross-country correlation of GDP growth. For a sample period 1960-1983, the correlation is: 0.46 (U.S. vs. U.K.), 0.52 (U.S. vs. Germany), and 0.32 (U.S. vs. Japan).

Our choice of the values of the parameters governing trade costs is based on Coeurdacier (2009) and Tille and van Wincoop (2010). The former considers the "iceberg-type" trade costs within the following range $\pi \in (0, 300\%)$, while the latter captures trade costs through consumption preference Λ, by setting its value at 0.8 to epitomize that the consumer has a preference for the domestic good. In addition, Coeurdacier (2009) argues that his model's result "matches the observed steady-state import share in the US with an average trade cost of 63%" (Coeurdacier, 2009, p. 90). Based on this result, we set

π at 63% and Λ at 0.5 in our baseline parameterization. Meanwhile, the value of the elasticity of substitution between the home and foreign good (denoted μ) is chosen to be 5 in Coeurdacier (2009) and to be 2 in Tille and van Wincoop (2010). We set it at 2.

Finally, regarding the financial trading cost, Tille and van Wincoop (2010) set it (denoted τ) at 0.419%, which implies that the return on equity from abroad is only $e^{-\tau}R_{i,t+1} = 99.58\% R_{i,t+1}$. Compared to the domestic investor, the foreign investor is only able to receive 99.58% of the asset returns. Meanwhile, Coeurdacier (2008) considers a tax on foreign investment. The tax level he chooses is equivalent to a value of τ at 0.25%. Because a given amount of equity home-bias in our model requires markedly smaller financial trading cost than would be required in the benchmark model, we set τ at a very small level. Specifically, we choose τ to be 0.008%, which is only $1/55$ of 0.419%, the magnitude of the financial friction chosen by Tille and van Wincoop (2010).

Table 1-2 summarizes the key parameter values for our model.

Table 1-2		
Parameter Values		
	Parameter	Value
1	The long-run mean growth rate of productivity, $\bar{g}$	0.0073

2	The time-preference factor, β	0.997
3	Labor's share, α	0.68
4	The coefficient of relative risk aversion, RRA	$\{1.8, 1.5, 1.2\}$
5	The elasticity of intertemporal substitution, EIS	$\begin{Bmatrix} 0.4, & 0.5, & 0.6, \\ 0.7, & 0.8, & 1.2 \end{Bmatrix}$
6	The volatility of trend shocks to dividends, σ_g	2.64%
7	The volatility of transitory shocks to dividends, σ_z	2.32%
8	The persistence of trend shocks, ω	0.29
9	The persistence of transitory shocks, ϕ	0.97
10	The cross-country correlation of trend shocks, ρ_g	0.98
11	The cross-country correlation of transitory shocks, ρ_z	0.25
12	Trade costs, π	63%
13	The parameter governing consumption preference, Λ	0.5
14	The elasticity of substitution between the home and foreign good, μ	2
15	The trading cost entailed by investing in equity abroad, τ	0.008%

4.2. Results

Table 1-3 reports our model's predictions for K, which is the proportion of the home investor's wealth held in asset H in the steady state. The proportion of the home investor's wealth held in asset F is thus $1-K$. Due to initial symmetry between the two countries, in the steady state the proportions of the foreign investor's wealth in assets H and F are respectively $1-K$ and K. In table 1-3, we also report the model's results for the international risk sharing index.

Table 1-3			
Our model's predictions for the steady-state equity allocation and the international risk sharing index			
RRA	*EIS*	*K*	*risk sharing index*
1.8	0.4	0.76	0.9631
1.5	0.4	0.82	0.9646
1.2	0.4	0.89	0.9660
1.8	0.5	0.80	0.9698
1.5	0.5	0.86	0.9706
1.2	0.5	0.94	0.9713
1.8	0.6	0.83	0.9736
1.5	0.6	0.89	0.9740
1.2	0.6	0.98	0.9745
1.8	0.7	0.85	0.9758
1.5	0.7	0.92	0.9761
1.2	0.7	1.00	0.9764
1.8	0.8	0.87	0.9773
1.5	0.8	0.93	0.9774
1.2	0.8	1.02	0.9776
1.8	1.2	0.90	0.9796
1.5	1.2	0.96	0.9796
1.2	1.2	1.05	0.9796

As shown in table 1-3, our model predicts a substantial amount of home-bias in equity holding when a very minor financial friction is introduced. Even though portfolios are very different across countries, our model shows that international risk sharing index is actually quite high, which is achieved here through the highly cross-country correlated trend shocks across countries.

In complete-markets, an investor will allocate half of his wealth in home equity and the other half in foreign equity so that he is able to completely insure his risk. In our model, two impediments cause the portfolio to depart from the above complete-market outcome. One is the presence of trade costs and the other is the presence of financial frictions. If neither exists, we would expect no bias in the portfolio. We perform an experiment called "*complete market experiment"* and the results are shown in table 1-4.

Table 1-4		
Complete Markets Experiment		
	Parameter value	Model's result for K
π	0	0.5
Λ	0.5	
τ	0	

The next two experiments aim at assessing the individual effects of each impediment to portfolio selection. In particular, table 1-5 reports the model's results for K when only trade costs are present but the financial friction is absent. To do so, we reset τ to zero and keep all other parameter values unchanged from table 1-2.

Table 1-5		
Results for the steady-state equity allocation when trade costs are included but the financial friction is absent in our model		
RRA	*EIS*	*K*
1.8	0.4	0.4452
1.5	0.4	0.4452
1.2	0.4	0.4452
1.8	0.5	0.5000
1.5	0.5	0.5000
1.2	0.5	0.4555
1.8	0.6	0.5000
1.5	0.6	0.5000
1.2	0.6	0.5000
1.8	0.7	0.4690
1.5	0.7	0.5000
1.2	0.7	0.5000
1.8	0.8	0.4731
1.5	0.8	0.5000
1.2	0.8	0.5000
1.8	1.2	0.5000
1.5	1.2	0.5000
1.2	1.2	0.5000

Table 1-5 shows trade costs lead to minor foreign-bias in equity holding. Because trade costs are responsible for real exchange rate movements, this result implies that the effect of real exchange rate risk on portfolio selection might be a bias away from domestic equity, a finding that is in agreement with Coeurdacier (2008) and Tille and van Wincoop (2010).

Our results for K as per table 1-5 is not far from $K = 0.5$, but nevertheless trade costs alone lead to a severe foreign bias ($K = 0.1$) in Tille and van Wincoop (2010)[2]. We suggest the disparity could be attributed to different levels of risk sharing achieved by productivity connections. In our model with recursive preferences, much risk is shared by highly correlated trend shocks. As a result, the amount of equity foreign bias needed to hedge real exchange rate risk is less in our model than in Tille and van Wincoop (2010).

Next, we trace the individual effect of the financial friction on portfolio selection. We need to set "iceberg-type" trade costs to be zero. To do so, we adapt the value of the parameter π from $\pi = 63\%$ to $\pi = 0$ while keep all other parameter values unchanged from table 1-2. Table 1-6 displays the results of this experiment.

Table 1-6
Predictions for the steady-state equity allocation and the risk sharing index when the financial friction is considered but trade costs are absent in the model

[2] See footnote 19, p. 165, Tille and van Wincoop (2010).

RRA	*EIS*	*K*	*IRSI*
500	0.4	0.50	0.9726
1.001	0.4	1.01	0.9726
1.8	0.4	0.78	0.9726
1.5	0.4	0.84	0.9726
1.2	0.4	0.93	0.9726
1.8	0.5	0.81	0.9752
1.5	0.5	0.88	0.9752
1.2	0.5	0.97	0.9752
1.8	0.6	0.83	0.9769
1.5	0.6	0.90	0.9769
1.2	0.6	1.00	0.9769
1.8	0.7	0.85	0.9779
1.5	0.7	0.92	0.9779
1.2	0.7	1.03	0.9779
1.8	0.8	0.86	0.9786
1.5	0.8	0.93	0.9786
1.2	0.8	1.04	0.9786
1.8	1.2	0.88	0.9798
1.5	1.2	0.96	0.9798
1.2	1.2	1.07	0.9798

Because it causes investing abroad to be less attractive than investing in domestic equity, we expect the inclusion of the financial friction alone will lead to a bias towards domestic equity. Our model's results confirm this prediction. However, a large amount of home-bias in equity does not prevent the IMRS from being highly correlated across countries, which is attributed in our model to a high cross-country correlation of trend productivity shocks. Therefore, the model is able to generate simultaneously home-bias in equity holding and the highly correlated IMRS across countries.

Moreover, table 1-6 exhibits that the less risk-averse the investor becomes (the smaller RRA) the greater the amount of home-bias. When he becomes a risk lover (referring to the case of $RRA = 1.0001$ in table 1-6), the investor concerns exclusively about the equity returns but little about risk. Therefore, he would hold most of his portfolio in domestic equity to take advantage of its generous rate of return (Table 1-6 shows, in this case, $K = 1.01$). Conversely, if he is very risk-averse, indicated by a large value of RRA (referring to the case of $RRA = 500$ shown in table 1-6), the investor cares a lot about risk and less about returns. He would be willing to pay trading costs en route to investing abroad in order to hedge the country-specific risk he is exposed to. As a result, the investor will hold a well diversified portfolio (Table 1-6 shows $K = 0.50$ in this case).

4.3. Comparison between our results and those of others

First, we conduct an experiment to compare the results of our long-run risk model with a model featuring a single AR(1) shock to the level of productivity. To compare two models, we need to have identical values for the Solow Residual process.

Table 1-7

Parameter values in the experiment that compares the AR(1) model with the long-run risk model

	Our model	AR(1)	
$\bar{g}$	0.0073	0	
σ_g	2.64%	0	
Volatility of the dividend growth process	$sd(\Delta y) = 3\%$	$\sigma_z = 2.9925\% \rightarrow$	$sd(\Delta y) = 3\%$
Cross-country correlation of the dividend growth process	$corr(\Delta y, \Delta y^*) = 0.5354$	$\rho_z = 0.5354 \rightarrow$	$corr(\Delta y, \Delta y^*) = 0.5354$
Autocorrelation of the dividend growth process	$corr(\Delta y_t, \Delta y_{t-1}) = 0.1042$	*To get auto-corr of the total dividend growth* $= 0.1042$, *we need an unreasonable* $\phi = 1.2$. $\phi = 0.99 \rightarrow$ *We set* $\phi = 0.99$, *a level as close as possible to* 1.2, *but still less than* 1.	$corr(\Delta y_t, \Delta y_{t-1}) = -0.005$

Table 1-8

Comparison between the results of the AR(1) model and those of the long-run risk model

RRA	*EIS*	Long-run risk model	AR(1) model

		K	*IRSI*	*K*	*IRSI*
1.8	0.4	0.76	0.9631	**0.67**	**0.5354**
1.5	0.4	0.82	0.9646	**0.72**	**0.5354**
1.2	0.4	0.89	0.9660	**0.80**	**0.5354**
1.8	0.5	0.80	0.9698	**0.67**	**0.5354**
1.5	0.5	0.86	0.9706	**0.72**	**0.5354**
1.2	0.5	0.94	0.9713	**0.80**	**0.5354**
1.8	0.6	0.83	0.9736	**0.67**	**0.5354**
1.5	0.6	0.89	0.9740	**0.72**	**0.5354**
1.2	0.6	0.98	0.9745	**0.80**	**0.5354**
1.8	0.7	0.85	0.9758	**0.67**	**0.5354**
1.5	0.7	0.92	0.9761	**0.72**	**0.5354**
1.2	0.7	1.00	0.9764	**0.80**	**0.5354**
1.8	0.8	0.87	0.9773	**0.67**	**0.5354**
1.5	0.8	0.93	0.9774	**0.72**	**0.5354**
1.2	0.8	1.02	0.9776	**0.80**	**0.5354**
1.8	1.2	0.90	0.9796	**0.67**	**0.5354**
1.5	1.2	0.96	0.9796	**0.72**	**0.5354**
1.2	1.2	1.05	0.9796	**0.80**	**0.5354**

Table 1-8 shows that, with the Solow Residual processes set to be close between the two types of models, the long-run risk models generate more home-bias than the $AR(1)$ model does. On average, the former predicts 24% more amount of home-bias than the latter does. Table 1-8 also reports the different risk sharing between them. Risk sharing indexes are above 95% in the long-run risk models. However, these indexes are much lower although portfolios are more diversified in the AR(1) models. We suggest the correlation of the IMRS achieved through productivity linkage between the two countries is lower in the AR(1) models than in the long-run risk models. Compared to the long-run risk models, the AR(1) models are left with more risks to share in the world capital market and they indeed hold better-diversified portfolios. Yet the AR(1) models yield lower risk sharing indexes. The financial trading costs prevent more risks from being shared when the gain is not worth the cost.

Next, we compare our result with two specific examples: Coeurdacier (2008) and Tille and van Wincoop (2010). To compare two models we need to set identical values for the shared parameters. To do so, in each experiment, we reset those in our model to the values chosen by the comparison paper. We then compare, between the two models, the difference in the magnitude of the trading cost needed to generate a certain amount of home-bias. Tables 1-9 and 1-10 display the results of the comparison between our model and respectively Coeurdacier (2008) and Tille and van Wincoop (2010).

Table 1-9
Comparison between the results of Coeurdacier (2008) and ours

	Coeurdacier (2008)	**Our model**	
π	1.26	1.26	
Λ	0.5	0.5	
μ	5	5	
RRA	2	2	
EIS	0.5	0.5	
Volatility of the dividend growth process	$sd(\Delta y) = 3.5\%$	$\left.\begin{matrix}\sigma_g = 2.64\% \\ \sigma_z = 2.80\%\end{matrix}\right\} \rightarrow$	$sd(\Delta y) = 3.5\%$
Cross-country correlation of the dividend growth process	$corr\left(\Delta y, \Delta y^*\right) = 0.3$	$\left.\begin{matrix}\rho_g = 0.98 \\ \rho_z = 0.03\end{matrix}\right\} \rightarrow$	$corr\left(\Delta y, \Delta y^*\right) = 0.3$
Autocorrelation of the dividend growth process	$corr\left(\Delta y_t, \Delta y_{t-1}\right) = 0$ *due to the fact that his model is static*	$\left.\begin{matrix}\omega = 0.29 \\ \phi = 0.80\end{matrix}\right\} \rightarrow$	$corr\left(\Delta y_t, \Delta y_{t-1}\right) = 0.01$
model's result for *K*	0.85	0.85	
model's result for *IRSI*	n.a.	0.9792	
The trading cost needed to generate such a result for *K*	0.25%	$\left(1/41\right) * 0.25\% = 0.006\%$	

Table 1-10

Comparison between the results of Tille and van Wincoop (2010) and ours

	Tille and van Wincoop (2010)		Our model	
π	0		0	
Λ	0.8		0.8	
μ	2		2	
RRA	10		10	
EIS	0.1		0.1	
Volatility of the dividend growth	$sd(\varepsilon) = 5\%\ annual = 2.5\%\ quarterly \rightarrow$	$sd(\Delta y) = 2.51\%$	$\left.\begin{matrix}\sigma_g = 2.64\% \\ \sigma_z = 1.41\%\end{matrix}\right\} \rightarrow$	$sd(\Delta y) = 2.51\%$
Cross-country correlation of the dividend growth	$cor(\varepsilon, \varepsilon^*) = 0 \rightarrow$	$cor(\Delta y, \Delta y^*) = 0$	$\left.\begin{matrix}\rho_g = 0.74 \\ \rho_z = -0.96\end{matrix}\right\} \rightarrow$	$cor(\Delta y, \Delta y^*) = 0$
Auto-correlation of the dividend growth	$cor(\varepsilon_t, \varepsilon_{t-1}) = 0.99 \rightarrow$	$cor(\Delta y_t, \Delta y_{t-1}) = -0.005$	$\left.\begin{matrix}\omega = 0.20 \\ \phi = 0.46\end{matrix}\right\} \rightarrow$	$cor(\Delta y_t, \Delta y_{t-1}) = -0.004$
model's result for *K*	0.80		0.80	
model's result for *IRSI*	n.a.		0.7309	
The trading cost needed to generate such a result for *K*	0.419%		$\left(1/1.6\right) * 0.419\% = 0.261\%$	

Table 1-9 reports that the financial trading cost needed to generate home-bias $K = 0.85$ is 0.25% in Coeurdacier (2008) vs. 0.006% in our model, ours being $1/41$ of his. From table 1-9, the degree of risk sharing generated from our model is as high as 0.9792. With most risk having been shared, it is hardly surprising that the trading cost our model relies on to induce home-bias is so small. Table 1-10 shows that, to allow both models to yield a home-bias $K = 0.80$, the trading cost required is 0.419% in Tille and van Wincoop (2010) vs. 0.261% in our model, our level being $1/1.6$ of theirs. Compared with the result in table 1-9, risk sharing here is at a relatively low level of 0.7309. This is because trading cost is higher here than that in table 1-9.

4.4. Sensitivity analysis

As noted above, risk shared through the productivity channel depends, to a large extent, on the cross-country correlation of trend shocks ρ_g. Table 1-11 reports the model's results when ρ_g is calibrated with a slightly higher value than 0.98.

Table 1-11
Results for K and $IRSI$ when ρ_g is calibrated with a slightly higher value

RRA	*EIS*	$\rho_g = 0.98$		$\rho_g = 0.99$	
		K	*IRSI*	*K*	*IRSI*
1.8	0.4	0.76	0.9631	**0.88**	**0.9756**
1.5	0.4	0.82	0.9646	**0.95**	**0.9766**
1.2	0.4	0.89	0.9660	**1.05**	**0.9775**
1.8	0.5	0.80	0.9698	**0.96**	**0.9814**
1.5	0.5	0.86	0.9706	**1.04**	**0.9818**
1.2	0.5	0.94	0.9713	**1.14**	**0.9823**
1.8	0.6	0.83	0.9736	**1.02**	**0.9846**
1.5	0.6	0.89	0.9740	**1.11**	**0.9848**
1.2	0.6	0.98	0.9745	**1.22**	**0.9851**
1.8	0.7	0.85	0.9758	**1.07**	**0.9865**
1.5	0.7	0.92	0.9761	**1.16**	**0.9866**
1.2	0.7	1.00	0.9764	**1.27**	**0.9868**
1.8	0.8	0.87	0.9773	**1.11**	**0.9877**
1.5	0.8	0.93	0.9774	**1.20**	**0.9878**
1.2	0.8	1.02	0.9776	**1.32**	**0.9879**
1.8	1.2	0.90	0.9796	**1.18**	**0.9896**
1.5	1.2	0.96	0.9796	**1.27**	**0.9896**
1.2	1.2	1.05	0.9796	**1.40**	**0.9897**

The intuition behind this experiment is described as follows. With recursive preferences, a larger correlation of trend shocks yields a higher correlation of the IMRS, which in turn lead to a larger amount of equity home-bias for a given magnitude of the trading cost. Table 1-

11 confirms this prediction. A mere 1% rise of the value of ρ_g from 0.98 to 0.99 leads to, on average, a 1% increase in the degree of international risk sharing, which in turn leads to a 25% increase in the amount of equity home-bias for a certain level of trading cost on cross-border equity transaction.

Table 1-12 reports model's results when the parameter ρ_g is calibrated with a very small value.

Table 1-12

Results for K and $IRSI$ when ρ_g is calibrated with a value close to zero

RRA	*EIS*	$\rho_g = 0.98$		$\rho_g = 0.1$		
		K	*IRSI*	*K*	*IRSI*	*consumption growth correlation*
1.8	0.4	0.76	0.9631	**0.4925**	**0.1953**	**0.9997**
1.5	0.4	0.82	0.9646	**0.4948**	**0.1822**	**0.9985**
1.2	0.4	0.89	0.9660	**0.4983**	**0.1663**	**0.9576**
1.8	0.5	0.80	0.9698	**0.4930**	**0.1770**	**0.9994**
1.5	0.5	0.86	0.9706	**0.4953**	**0.1639**	**0.9994**
1.2	0.5	0.94	0.9713	**0.4988**	**0.1494**	**0.9738**
1.8	0.6	0.83	0.9736	**0.4934**	**0.1601**	**0.9983**
1.5	0.6	0.89	0.9740	**0.4957**	**0.1483**	**0.9994**
1.2	0.6	0.98	0.9745	**0.4991**	**0.1360**	**0.9875**
1.8	0.7	0.85	0.9758	**0.4936**	**0.1454**	**0.9964**

1.5	0.7	0.92	0.9761	**0.4959**	**0.1355**	**0.9981**
1.2	0.7	1.00	0.9764	**0.4993**	**0.1258**	**0.9964**
1.8	0.8	0.87	0.9773	**0.4937**	**0.1332**	**0.9935**
1.5	0.8	0.93	0.9774	**0.4960**	**0.1254**	**0.9951**
1.2	0.8	1.02	0.9776	**0.4995**	**0.1181**	**0.9989**
1.8	1.2	0.90	0.9796	**0.4940**	**0.1065**	**0.9713**
1.5	1.2	0.96	0.9796	**0.4963**	**0.1048**	**0.9650**
1.2	1.2	1.05	0.9796	**0.4997**	**0.1032**	**0.9386**

Table 1-12 shows that when the trend shocks is less correlated the model's results for risk sharing are also low. Given that little risk shared through the productivity channel, the investor would optimally diversify his portfolio to share as much risk as he can in the international capital market. Therefore, our model predicts that $K \approx 0.5$. Low level of risk sharing and a well-diversified portfolio are hard to reconcile in the benchmark models featuring power utility. However, models with recursive preferences have no difficulty to predict both results simultaneously. Note that low risk sharing outcome in table 1-12 is Pareto optimal, in the sense that there is nothing an investor can do to further improve his risk sharing by international portfolio diversification.

As we discussed in the introduction section of this paper, with recursive preferences, both the investor's consumption growth and his portfolio return are necessary for determining the intertemporal marginal rate of substitutions (IMRS). Furthermore, trend shocks as opposed to transitory shocks are the primary determinant of the investor's portfolio return and in turn of his IMRS. With recursive preferences, even though it ensures a budget constraint to support an equal consumption growth across countries (see the last column in table 1-12), the result of $K \approx 0.5$ would not lead to an identical portfolio return across countries because portfolio returns are measured in terms of investors' domestic consumption baskets. Therefore, it is possible with recursive preferences for the result of $K \approx 0.5$ to be associated with poor risk sharing. Specifically,

$$m_{t+1}^{h} - m_{t+1}^{f} = m_{t+1}^{D} = (\theta - 1)\gamma E_t\left(\hat{\tilde{c}}_{t+1}^{D} - \hat{\tilde{c}}_{t}^{D}\right) + (\theta - 1)\gamma \hat{g}_t^{D} + (\gamma - 1) E_t\left(\hat{r}_{t+1}^{p,D}\right)$$

$$\begin{aligned} m_{t+1}^{D} &= (\theta - 1)\gamma E_t\left(\hat{\tilde{c}}_{t+1}^{D} - \hat{\tilde{c}}_{t}^{D}\right) + (\theta - 1)\gamma \hat{g}_t^{D} \\ &+ (2K - 1)(\gamma - 1) E_t\left(\hat{r}_{t+1}^{D}\right) - (1 - 2\upsilon)(\gamma - 1) E_t\left(\hat{p}_{F,t+1}^{*} - \hat{p}_{F,t}^{*}\right) \end{aligned} \quad (45)$$

When $K \approx 0.5$, the first and the third terms in (45) approach zero because $\left(\hat{\tilde{c}}_{t+1}^{D} - \hat{\tilde{c}}_{t}^{D}\right)$ and $(2K - 1)$ approach zero respectively. However, the second and the forth term could be far from zero because neither $\hat{g}_t^{D}$ nor $\left(\hat{p}_{F,t+1}^{*} - \hat{p}_{F,t}^{*}\right)$ seems to be close to zero. The less correlated trend shocks lead to low risk sharing through its impact on the international relative price, $E_t\left(\hat{p}_{F,t+1}^{*} - \hat{p}_{F,t}^{*}\right)$, which in turn affects the investor's portfolio return, $E_t\left(\hat{r}_{t+1}^{p,D}\right)$.

5. Final Remarks

This paper studies the cause of equity home-bias in a two-country open-economy setup. The model features recursive preferences and long-run productivity growth risk. When calibrated with highly correlated trend productivity shocks, our model is able to predict a substantial amount of equity home-bias after a minor trading cost is imposed on cross-border equity transactions. Furthermore, for a given amount of home-bias, our model requires markedly smaller trading cost than would be required in benchmark models.

A relevant issue to equity home-bias is the high turnover rate on cross-border equity transaction. One could consider extending the present paper by including gross capital flows in the study. We expect the trading cost employed in our model is small enough not to stifle gross capital flows. Therefore, such a model has the potential of reconciling the equity home-bias and the high turnover by foreign investors. However, for the benchmark model to yield the same amount of home-bias as our model does, it has to rely on relatively greater trading costs, which could suppresses gross capital flows and thus be at odds with the reality of high turnover. Therefore, the benchmark model might have difficulty in explaining simultaneously equity home-bias and high turnover.

On a technical issue regarding how to solve a model that studies gross capital flow, note that the zero-order component of portfolio allocation is solved based on a second-order approximation of the Euler equations. Analogously, gross capital flows are related to the first-order component of portfolio share differences, which could be solved based on a third-order approximation of the Euler equations.

In addition, much work remains to be done on seeking more and solid empirical evidence for the properties of trend versus transitory shocks to productivity.

Regarding policy implication, we suggest countries making choice between further integration into world capital markets and the retention of independent macroeconomic policy to reexamine the gains from international portfolio diversification, in light of our finding.

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