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# A New Open Economy Macroeconomic Model with Endogenous Portfolio Diversification and Firms Entry

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XARXA DE REFERÈNCIA EN ECONOMIA APLICADA

# A New Open Economy Macroeconomic Model with Endogenous Portfolio Diversification and Firms Entry

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**Abstract**

This paper provides a new benchmark for the analysis of the international diversification puzzle in a tractable new open economy macroeconomic model. Building on Cole and Obstfeld (1991) and Heathcote and Perri (2009), this model specifies an equilibrium model of perfect risk sharing in incomplete markets, with endogenous portfolios and number of varieties.

Equity home bias may not be a puzzle but a perfectly optimal allocation for hedging risk. In contrast to previous work, the model shows that: (i) optimal international portfolio diversification is driven by home bias in capital goods, independently of home bias in consumption, and by the share of income accruing to labour. The model explains reasonably well the recent patterns of portfolio allocations in developed economies; and (ii) optimal portfolio shares are independent of market dynamics.

KEYWORDS: Home bias, equity puzzle, New open economy macroeconomics, NOEM, extensive margin.

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# 1 Introduction

Home bias in investment is one of the main puzzles in international finance. Investors tend to invest mostly in domestic assets, apparently without taking advantage of the possibilities of international risk diversification. Lying on the border between international macroeconomics and finance, the home bias in portfolio selection has important implications for economic analysis and policy-making.

Traditional theory, starting from Lucas' (1982) seminal paper, tends to claim that in a frictionless world with perfectly mobile factors, a portfolio should be allocated based on perfect pooling. However, what is the benchmark for perfect diversification? It may be that a small proportion of foreign equity is, indeed, optimal.

This paper explores the demand for diversification due to investment fluctuations in a Cole and Obstfeld (1991) economy. Using the terms of trade (TOT) mechanism to hedge risk works only when there is no possibility of intertemporal transmission of consumption, i.e., of the mere existence of some investment that destroys the power of TOT to offset productivity shocks. It provides insurance only in a "static sense". If households account for future expectations they need another strategy to ensure perfect risk sharing: some portfolio diversification.

I build upon Heathcote and Perri (2009, henceforth H&P) to analyze the international equity puzzle in a tractable new open economy macroeconomics (NOEM) model. Unlike H&P, I disentangle the technology of the consumption goods from that of the capital goods and introduce dynamics to the markets.

My model is novel in a number of ways:

1. First, I differentiate the Cobb-Douglas aggregator for the capital goods used in the creation of the firms from that of the consumption goods. This distinction is useful to ensure that one is not overlooking the role of preferences in the model. Indeed, I show that the parameter tied to investment demand produces the optimal bias in portfolio.[1]

2. Second, I explore the interrelation between investment allocation and firms allocation, by adding the extensive margin in the markets.[2] For this exploration, I assume that the introduction of a new variety requires an initial sunk cost and some time to build up the plant before beginning production. In the case of flexible prices, the allocation of the firms, and thus of the number of varieties supplied in the market, is independent of the ownership of their shares. Consequently, the constant allocation of investment is optimal even with market dynamics.[3]

[1] Apart from H&P, Coeurdacier (2009) also proposes a theoretical two-country model with frictions in both the goods and financial markets and finds a relationship between trade openness in the goods market and home bias in portfolios. However, both papers place consumption goods and physical capital goods in a single market.

[2] See Bergin and Corsetti (2005, 2008) and Bilbiie et al. (2005) for theoretical assessments of the relevance of the extensive margin in different contexts.

[3] Although this experiment is beyond the scope of this paper, if one assumes nominal

3. Finally, the role of the undiversifiable labour income must not be dismissed. As in H&P, the technology parameter (i.e., the labour income share) crucially affects the degree of diversification, with a negative relationship. I focus on an incomplete-market framework[4] where only shares of firms and an international riskless bond are traded, and all goods are tradable.

The optimal proportion of diversification predicted by this theoretical model is compatible with the international portfolios observed across 24 developed economies. Concerning the bias on capital goods, a large part of the literature agrees that physical capital is mostly bought or built domestically. It is not difficult to defend this claim: first, construction (of the plants and some equipment installation) is almost entirely local, and it represents a large proportion of the total set-up costs; second, equipment trade is tied to costs arising from overseas marketing, the negotiations for foreign purchases, transportation, tariffs and non-tariff barriers, the distribution in foreign markets, adaptations to foreign conditions and standards, installation in foreign production facilities, the need to train foreign workers to use the equipment and the provision of parts, maintenance and customer service from abroad. All of these features make capital home bias even greater than that of consumption goods. I explore the empirical evidence for 24 OECD countries in Section 5.[5]

The roadmap for the remainder of the paper is the following: Section 2 provides a brief literature review. Section 3 presents the setup of the model. Section 4 gives us the equilibrium results. Section 5 develops the empirical analysis. The conclusions are in Section 6. An appendix with the algebraic details is available upon request. This is not necessary for the understanding of the text and conclusions of the paper.

## 2 Literature Review

The first question worth addressing is whether diversification increases the level of consumer welfare. If it does not, the lack of diversification of the international portfolio would not be such a puzzle but simply the result of agents' optimal decisions. Van Wincoop (1999) performed an accurate empirical estimation of

rigidities and a monetary policy that replicates the flexible price equilibrium allocation, the previous result holds independently of the price regime of the economy. I tried to introduce nominal rigidities in prices, assuming first producer currency pricing (PCP) and then local currency pricing (LCP). In both cases, the optimal level of diversification coincides with that of the flexible price regime. However, when the authorities apply a general monetary policy, the endogenous portfolio arising from the benchmark setup is no longer constant.

[4] It provides perfect risk sharing, although it is not a complete market offering a full set of Arrow-Debreu securities.

[5] See Eaton and Kortum (2001) for an exhaustive empirical study on equipment trade. Notice, however, that the analysis refers only to equipment and disregards construction. In the model I present, one must consider "construction goods" to be aggregated in the composites for consumption and capital. Thus, the correct proportion of capital produced domestically must necessarily be higher than the levels indicated by Eaton and Kortum.

the magnitude of these gains. He found that welfare gains increase with the level of risk aversion and that they are equivalent to an increase in tradables consumption in the range of 1.1-3.5% for a fifty-year horizon and of 2.5-7.9% for a hundred-year horizon.[6] These are very large values. Thus, as Van Wincoop argued, if the potential gains are so significant, a crucial question is raised: why have financial markets not achieved greater risk sharing? One needs to better understand both why investors do not assume diversified positions in existing stock and bond markets and why markets that allow for trade in broad claims on national income (macro markets) have not yet developed.

In Lucas' (1982) seminal paper, households optimally split the portfolio half and half to each country. They live in a one-good endowment economy. Baxter and Jermann (1997) go a step further and introduce production with non-diversifiable labour. They conclude that the international equity puzzle is even worse than Lucas claimed: households should go short in home assets to hedge the extra risk generated by the undiversifiable factor.

Economic research has moved in several directions to explain the home-biased equities puzzle, which still remains an unexplained behaviour. Gehrig (1993), Brennan and Cao (1997) and Martínez-García (2005), for instance, focus on the existence of informational asymmetries as the principal source of the bias, whereas Jeske (2001) and Grinblatt and Keloharju (2000) find empirical evidence against this theory. Another strand of literature, largely in line with the latter, suggests focusing on the costs of diversification as relevant investment allocation barriers.[7] It is also argued that investment may principally be an issue of control rather than the scope of risk sharing. The concentration of the ownership of savings among a relatively small number of individuals may be evidence in favor of this explanation. It seems that the familiarity of investors with a (local) firm, rather than the preferences regarding the aggregated domestic portfolio, causes them to bias their savings towards home assets.[8] The role of non-tradable goods was a well-known direction of research by the nineties. Tesar (1993) shows that the high correlation between savings and investment, the low cross-country correlation between consumption growth rates and the home bias in investment portfolios are consistent with complete financial markets when agents face stochastic fluctuations in the output of non-traded goods. Consumer preferences regarding traded and non-traded goods and regarding the intertemporal allocation of consumption may skew portfolios toward claims on domestic output. In the same direction, Serrat (2001) tries to solve for the optimal portfolios in an endowment general equilibrium model in which agents consume a non-tradable good and a basket of home and foreign tradable goods. Domestic investors own local nontraded assets and the home bias in tradable

[6] He argues that models assuming infinite horizons are extremely sensitive to minor changes in the estimated interest rate. For this reason, he considers different time horizons to measure welfare gains.

[7] See Obstfeld and Rogoff (2001) for a view in favor of this explanation. They claim that trading costs may be relevant if modeled correctly. See French and Poterba (1991) or Tesar and Werner (1995) for arguments against it.

[8] See, for example, Kang and Stulz (1997) and Mankiw and Zeldes (1991) for a discussion on equity holdings concentration among a small number of better-off individuals.

equities is generated as in Tesar (1993). However, Kollmann (2006) revisits Serrat's model and shows that with a Cobb-Douglas consumption aggregator and complete asset markets, the optimal portfolio remains indeterminate.[9] Some authors have even proposed that the home bias in data is due to a mere error of misspecification (Coeurdacier and Guibaud (2011)). Recently, Engel and Matsumoto (2006) focused on nominal rigidities to generate a negative correlation between labour and capital income, which drives the bias in favor of home equities.

Cole and Obstfeld (1991) depart from the widespread view of most authors that home bias is the result of market frictions or agents' unoptimal behaviour. They present an extreme case where the lack of diversification is efficient. The hedge of risk operates via the terms of trade movements: any variation in the relative value of home output is compensated by a change in relative prices, keeping the nominal intercountry difference of consumption equal to zero. Hence, the effect of country-specific productivity shocks could be perfectly offset through the international transmission. However, they limit the analysis to a labour-economy setup, missing the potential role of investment.

H&P and a small collection of quite recent papers argue that the home bias corresponds to the strategies of optimal rational agents for portfolio diversification. H&P go one step further and include capital in the model. Like Cole and Obstfeld (1991), they rely on relative international price adjustment after shocks as the main mechanism to ensure the diversification of risk. Their main finding is that a time-invariant share of investment on home and foreign firms yields perfect risk sharing. Their model is built on Backus, Kehoe and Kydland (1992, 1995), assuming that households only trade shares in domestic and foreign firms. They allow for capital investment dynamics and imperfect substitutability among traded goods.

Finally, the recent paper by Coeurdacier et al. (2007) addresses three main stylised facts on international portfolios and exchange rate in an incomplete markets scenario. The first of these empirical facts is, precisely, the home equity puzzle. They argue that previous literature fails by accounting only for supply shocks. Indeed, they are the first to introduce two extra types of shocks: redistributive shocks and relative demand shocks, which produce a home-biased portfolio in equilibrium. They do so in a two-country, two-good world.

# 3 The Model

The world consists of two symmetric countries, denoted by $H$ (home) and $F$ (foreign) and an endogenously determined number of varieties, all of them perfectly tradable. The home (foreign) country is inhabited by a continuum of homogeneous households with mass 1 that elastically supply their labour to domestic

[9] See, for example, Pesenti and Van Wincoop (1996, 2002) for empirical evidence against the non-tradable goods explanation. A more recent paper on equity home bias and specialization is Hnatkovska (2010). She uses a two-country two-sector model with tradables and non-tradables.

firms. There is no capital accumulation but only a cost of entry into the market. Firms and agents are homogeneous within countries. However, preferences are symmetrically biased towards domestically-produced goods. The monopolistic firms set prices flexibly by maximizing profits.

## 3.1 Households

Each country is populated by a continuum of households whose preferences are defined over the consumption of $n_t + n_t^*$ goods, which is a composite of home plus foreign final produced varieties. The preferences of home households are represented by

$$U_t = E_t \Sigma_{t=0}^{\infty} \beta^t \left[ \ln C_t - \kappa \ell_t (j) \right], \tag{1}$$

where $0 < \beta < 1$ is the discount factor and $U(.)$ is a utility function defined over the consumption of a basket $C_t$ and a linear disutility of labour effort represented by parameter $\kappa$. Finally, $\ell_t (j)$ is the elastic labour supply of household $j$. The consumption basket is given by a Cobb-Douglas aggregator over the bundles of tradables produced in the home $(C_H)$ and foreign $(C_F)$ countries (i.e., a constant elasticity of substitution (CES) basket with unitary elasticity),

$$C_t = C_{H,t}^{\gamma} C_{F,t}^{1-\gamma}, \tag{2}$$

where $\gamma < 1$. $C_H$ and$C_F$ are CES aggregators over the $n\,(n^*)$ varieties produced in the home(foreign) country. For simplicity, I assume identical elasticities of substitution, $\sigma$, in both countries:

$$C_{H,t} = \left( \int_0^{n_t} c_t (h)^{\frac{\sigma-1}{\sigma}} dh \right)^{\frac{\sigma}{\sigma-1}}, \tag{3}$$

$$C_{F,t} = \left( \int_0^{n_t^*} c_t (f)^{\frac{\sigma-1}{\sigma}} df \right)^{\frac{\sigma}{\sigma-1}}. \tag{4}$$

Here, $h$ and $f$ denote a specific variety of the corresponding country. Households all over the world finance the creation of firms in both countries. To construct her portfolio of investment, the home household purchases a fraction $\lambda_{F,t+1}$ of the shares issued by foreign-country firms and $\lambda_{H,t+1}$ of the shares issued by domestic firms, which will start producing in the next period. The household affords her consumption expenditure and investment using the dividends received from currently active firms at home and abroad, in proportion to her current portfolio allocation: $\lambda_{H,t}$, $\lambda_{F,t}$, and her labour income. The budget constraint is

$$B_{t+1} + \lambda_{H,t+1} \int^{n_{t+1}} q_t (h) \, dh + e_t \lambda_{F,t+1} \int^{n_{t+1}^*} q_t^* (f) \, df + \tag{5}$$

$$+ \int^{n_t} p_t (h) \, c_t (h) \, dh + \int^{n_t^*} p_t (f) \, c_t (f) \, df =$$

$$= \lambda_{H,t} \int^{n_t} \pi_t(h) dh + e_t \lambda_{F,t} \int^{n_t^*} \pi_t^*(f) df + w_t \ell_t (j) + (1 + i_t) B_t,$$

where $\pi_t(h)$ $(\pi_t^*(f))$ are the profits of a single home (foreign) firm in home (foreign) currency; $e_t$ is the nominal exchange rate $(p_t(h) = e_t p_t^*(h))$; $c_t(h)$ the domestic demand for good $h$; $n_t$ is the number of firms allocated at home; and $w_t$ is the wage. $B_t$ is the international riskless bond. Finally, $\gamma$ indicates the home bias on consumption preferences. An initial investment is needed for a new firm to start producing. The cost to conduct this investment at home (abroad) is $q_t(h)$ $(q_t^*(f))$.

## 3.2 Firms

A continuum of $n(n^*)$ tradable-good firms in the home (foreign) country act in a monopolistically competitive economy. All of them sell their products in both home and foreign markets. A sunk cost is paid at time $t$ to develop a new variety, which will enter the market at $t+1$ and disappear at the end of that period (full amortization). This cost is financed by issuing equities in the international stock market, i.e., both home and foreign agents have access to shares of any firm created all over the world.

To produce a new home variety at time $t+1$, entrepreneurs must incur a startup cost of $q_t(h) = P_{k,t}K_t$ at time $t$. Firms are fully depreciated after one year of production. $K_t$ is a composite good containing both home and foreign varieties and following a Cobb-Douglas aggregator whose size of which is randomly determined every period,

$$K_t = K_{H,t}^{\delta} K_{F,t}^{(1-\delta)},$$

where $K_{H,t}$ and $K_{F,t}$ are the baskets of home and foreign final goods used in capital. The lower the $K_t$ $(K_t^*)$ the more efficient the home (foreign) country is in the creation of new firms or varieties. $P_{k,t}$ is the CPI for the basket $K_t$.[10] Finally, $\delta$ indicates the bias in the preferences of capital goods. Furthermore,

$$K_{H,t} = \left( \int_{h=0}^{n_t} k_t(h)^{1-\frac{1}{\sigma}} dh \right)^{\frac{\sigma}{\sigma-1}} ; K_{F,t} = \left( \int_{f=0}^{n_t^*} k_t(f)^{1-\frac{1}{\sigma}} df \right)^{\frac{\sigma}{\sigma-1}}, \tag{6}$$

with * on all the K and k for the foreign country. Hence, total investment at home is

$$I_{H,t} = n_{t+1} q_t(h) = n_{t+1} P_{K,t} K_t.$$

[10] One may easily have different CES aggregators and/or an extra parameter of productivity for K in the model (e.g., of the type $K_{i,t} = A_{Ki,t}\left(\int_{h=0}^{n_t} k_t(h)^{\frac{\varrho-1}{\varrho}} dh\right)^{\frac{\varrho}{\varrho-1}}$, where $i = H, F$ and $\varrho$ stands for the elasticity of substitution between capital goods, which may differ from $\sigma$, the elasticity between consumption goods). However, the setup presented in this paper disregards this alternative to concentrate only on the scope explained in the introduction. In this case, the closed-economy version will have $P = P_K$, as the unique differentiation between C and K is, by assumption, the Cobb-Douglas parameter $(\delta \neq \gamma)$.

Once created, firms produce a differentiated variety with a homogeneous technology that requires only labour:

$$Y_t(h) = A_{H,t}\ell_t(h)^{\theta}. \tag{7}$$

The state of the economy is then summarised by

$$\{A_{H,t}, A_{F,t}\}.$$

$\theta$ is the share of output going to labour. $(1-\theta)$, which belongs to capital, is distributed among investors via dividends. $Y_t(h)$ is the production of one firm, and $k_t\,(h)$ is the demand for the final good $h$ by new entrants to build up their plants. $p_t(h)$ is the price of variety $h$, which is flexibly set by the monopolistic firm, and $\ell_t\,(h)$ is labour demand for good $h$.

# 4 Equilibrium

## 4.1 The Household's Problem

Households maximise utility subject to the budget constraint. The first-order conditions are the following:

$$\frac{\kappa}{w_t} = \xi_t = \frac{1}{P_t C_t} \tag{8}$$

$$\text{or } w_t = \kappa P_t C_t, \tag{9}$$

$$C_{H,t} = \gamma \frac{P_t C_t}{P_{H,t}},\ C_{F,t} = (1-\gamma)\frac{P_t C_t}{P_{F,t}}, \tag{10}$$

$$c_t\,(h) = C_{H,t}\left(\frac{p_t\,(h)}{P_{H,t}}\right)^{-\sigma},\ c_t\,(f) = C_{F,t}\left(\frac{p_t\,(f)}{P_{F,t}}\right)^{-\sigma}, \tag{11}$$

$$\frac{1}{P_t C_t} = \beta\,(1+i_t)\,E_t\frac{1}{P_{t+1}C_{t+1}}, \tag{12}$$

$$q_{H,t} = E_t Q_{t,t+1}\Pi_{H,t+1}, \tag{13}$$

$$e_t q^*_{F,t} = E_t Q^*_{t,t+1} e_{t+1}\Pi^*_{F,t+1}, \tag{14}$$

where $Q_{t,t+1}$ is the discount factor of future dividends and $q_{H,t}$ $(q^*_{F,t})$ is the country aggregate of $q_t\,(h)$ $(q^*_t\,(f))$. Equation (8) is the endogenous supply of hours of labour; (10) shows the allocation of the consumption expenditure among home- and foreign-produced goods, which is constant due to the Cobb-Douglas assumption; (13) and (14) provide us with the free entry conditions for new firms. Firms will enter the market as long as the initial fixed cost is lower than or equal to the expected profits. $\Pi_{H,t}$ are the aggregate profits of all domestic firms. Finally, (12) is the usual Euler equation, the intertemporal rate of substitution between the consumption in periods $t$ and $t+1$. The welfare-based price index is

$$P_t = \frac{P^{\gamma}_{H,t}P^{1-\gamma}_{F,t}}{\Gamma}, \tag{15}$$

where $\Gamma = \gamma^{\gamma}(1-\gamma)^{1-\gamma}$. Also,

$$Q_{t,t+1} = \frac{1}{1+i_t} = \beta E_t\left(\frac{P_t C_t}{P_{t+1}C_{t+1}}\right) = \beta E_t\left(\frac{\mu_t}{\mu_{t+1}}\right)$$

is the intertemporal rate of substitution between the consumption in periods $t$ and $t+1$. Foreign households solve an analogous problem with symmetric preferences, i.e., they prefer the foreign-produced goods, $f$, as much as home households prefer home-produced ones, $h$.

## 4.2 The Firm's Problem

During the creation of the variety, home firms choose the demand of each capital good, $k_t(h)$ and $k_t(f)$, by solving the following minimization problems:

$$\min_{k_t(h)} \int_0^{n_t} p_t(h)k_t(h)dh - \zeta_t\left(\left(\int^{n_t} k_t(h)^{1-\frac{1}{\sigma}}\, dh\right)^{\frac{\sigma}{\sigma-1}} - K_{H,t}\right).$$

The first-order condition is

$$k_t(h) = \left(\frac{p_t(h)}{P_{H,t}}\right)^{-\sigma} K_{H,t} \tag{16}$$

and

$$\min_{k_t(f)} \int_0^{n_t^*} p_t(f)k_t(f)dh - \zeta_t^*\left(\left(\int^{n_t^*} k_t(f)^{1-\frac{1}{\sigma}}\, df\right)^{\frac{\sigma}{\sigma-1}} - K_{F,t}\right),$$

and thus,

$$k_t(f) = \left(\frac{p_t(f)}{P_{F,t}}\right)^{-\sigma} K_{F,t},$$

where the shadow price, $\zeta_t = P_{H,t} = n_t^{\frac{1}{1-\sigma}} p_t(h)$ and $\zeta_t^* = P_{F,t}$. The optimal baskets of home and foreign capital are

$$K_{H,t} = \delta\frac{P_{k,t}K_t}{P_{H,t}}\ ,\ K_{F,t} = (1-\delta)\frac{P_{k,t}K_t}{P_{F,t}}.$$

Firm $h$ today has a demand for variety $h$, to be used in building firms, of $n_{t+1}k_t(h)$. $\sigma > 1$ is the intratemporal elasticity of substitution among goods, and the price indexes for capital are,

$$P_{K,t} = \frac{(P_{H,t})^{\delta}(P_{F,t})^{1-\delta}}{\Gamma_\delta}\ ,\ P_{K,t}^* = \frac{\left(P_{H,t}^*\right)^{1-\delta}\left(P_{F,t}^*\right)^{\delta}}{\Gamma_\delta},$$

where $\Gamma_\delta = \delta^{\delta}(1-\delta)^{1-\delta}$.[11]

[11] The condition for stability requires that $1 > \theta\frac{\sigma-1}{\sigma}$.

Moreover, firms choose the amount of labour that minimises costs,

$$\min w_t \ell_t(h),$$

subject to the technology constraint. Thus, the first order condition is

$$\phi_t = \frac{w_t}{\theta A_{H,t}} \ell_t(h)^{1-\theta} = \text{mg cost},$$

where $\phi_t$ is the Lagrange multiplier. Once operative, firms maximise profits:

$$\max_{p_t(h)} p_t(h) Y_t(h) - w_t \ell_t(h), \tag{17}$$

subject to the technology restriction and demand. Thus, the optimal price is

$$p_t(h) = \frac{\sigma}{\sigma - 1} \frac{1}{\theta} \frac{w_t}{A_{H,t}^{\frac{1}{\theta}}} Y_t(h)^{\frac{1}{\theta}-1}.$$

Prices consist of a constant mark-up over the expression of marginal costs which depends crucially on the level of production, due to the non-linear technology.

### 4.3 Market Clearing

The clearing conditions for the domestic and foreign goods markets are the following:

$$c_t(h) + c_t^*(h) + n_{t+1} k_t(h) + n_{t+1}^* k_t^*(h) = Y_t(h); \tag{18}$$

$$c_t(f) + c_t^*(f) + n_{t+1} k_t(f) + n_{t+1}^* k_t^*(f) = Y_t(f). \tag{19}$$

A firm satisfies four sources of demand: those of the home and foreign households and those of the firms that will produce next year in the home and foreign countries.

The labour market is emptied when

$$n_t \ell_t(h) = \ell_t(j); \tag{20}$$

$$n_t^* \ell_t^*(f) = \ell_t^*(j^*). \tag{21}$$

Finally, the financial markets in equilibrium must fulfill

$$B_t = -B_t^*; \tag{22}$$

$$\lambda_{H,t} = 1 - \lambda_{H,t}^*; \tag{23}$$

$$\lambda_{F,t} = 1 - \lambda_{F,t}^*. \tag{24}$$

Under this non-linear technology, one can write home aggregate profits as a constant fraction of total revenue, although this fraction is different from that found under constant returns to scale (with linear technology $\Pi_H^{CRS} = \frac{1}{\sigma} P_H Y_H < \Pi_H^{DRS}$).

This fraction depends on both the elasticity of substitution and the technological parameter. Hence,

$$\Pi_{H,t} = P_{H,t}Y_{H,t}\left(1 - \frac{\sigma - 1}{\sigma}\theta\right) = \left(\frac{\sigma\left(1-\theta\right)+\theta}{\sigma}\right)P_{H,t}Y_{H,t}. \tag{25}$$

Notice that $\frac{\sigma(1-\theta)+\theta}{\sigma} - \frac{1}{\sigma} > 0$. The amount of profits over total income is higher due to the diminishing returns to scale in the technology. One can also write the labour cost as a fraction of the output of the firms:

$$w_t \ell_t\left(h\right) = \frac{\sigma - 1}{\sigma}\theta p_t\left(h\right) Y_t\left(h\right). \tag{26}$$

## 4.4 The labour Demand

The f.o.c. for home firms was

$$\ell_t\left(h\right) = \left[\frac{w_t}{A_{H,t}}\frac{1}{\theta}\frac{1}{\phi_t}\right]^{\frac{1}{\theta-1}}.$$

I use the technology restriction to get the Lagrangian multiplier $\phi_t = p_t\left(h\right)\frac{\sigma-1}{\sigma}$ so that

$$\ell_t\left(h\right) = \left[\frac{\sigma-1}{\sigma}\frac{A_{H,t}}{w_t}p_t\left(h\right)\right]^{\frac{1}{1-\theta}}.$$

Households supply an elastic amount of labour. It increases with the increment of the returns to scale of their effort, i.e. the higher $\theta$ is, the more productive labour is, and the higher the willingness to work. labour supply goes up for higher levels of $A_{H,t}$, the productivity of technology, and for higher prices, because, in this case, they need more income to be able to consume the same amount of goods. Finally, given prices, they supply less labour when wages are high.

## 4.5 Optimal Diversification Level $\lambda$

Let us conjecture that an equilibrium allocation exists with $B = 0$ and constant portfolio demand $\lambda^*_{H,t} = \lambda_{F,t} = \lambda$ for symmetric countries ($L_t = L^*_t = 1$) such that

$$P_t C_t = e_t P^*_t C^*_t, \tag{27}$$

i.e., where households achieve perfect risk sharing. So that $Q_t = e_t Q^*_t$, stochastic discount rates are the same across countries. Hereafter, it is shown that this allocation is indeed an equilibrium allocation by characterizing the associated vector of equilibrium prices and verifying that prices and quantities satisfy households' first-order conditions, market clearing conditions and the resource constraints.

Let us define the following relative variables in nominal terms:

$$\begin{aligned}
\triangle\mathbb{C} &= P_tC_t - e_tP_t^*C_t^*, \qquad (28)\\
\triangle\mathbb{k} &= n_{t+1}P_{k,t}K_t - e_tn_{t+1}^*P_{k,t}^*K_t^* = I_{H,t} - e_tI_{F,t}^*,\\
\triangle\yen &= P_{H,t}Y_{H,t} - e_tP_{F,t}^*Y_{F,t}.
\end{aligned}$$

These equations are the intercountry differences in consumption, investment and output in nominal terms. Moreover, from the goods market clearing conditions,

Home Output

$$P_{H,t}Y_{H,t} = P_{H,t}\frac{\gamma P_tC_t}{P_{H,t}} + e_tP_{H,t}^*\left(1-\gamma\right)\frac{P_t^*C_t^*}{P_{H,t}^*} + n_{t+1}P_{H,t}\frac{\delta P_{k,t}K_t}{P_{H,t}} + \\ +n_{t+1}^*e_tP_{H,t}^*\left(1-\delta\right)\frac{P_{k,t}^*K_t^*}{P_{H,t}^*}.$$

Foreign Output

$$P_{F,t}^*Y_{F,t} = \gamma P_t^*C_t^* + \frac{P_tC_t}{e_t}\left(1-\gamma\right) + n_{t+1}\frac{P_{H,t}}{e_t}\left(1-\delta\right)\frac{P_{k,t}K_t}{P_{H,t}} + \\ +n_{t+1}^*P_{H,t}^*\frac{\delta P_{k,t}^*K_t^*}{P_{H,t}^*}.$$

By taking the differences, I have an expression for the output absorption in the economy, i.e., the allocation of output into different uses.[12]

$$\triangle\mathbb{Y} = \left(2\gamma-1\right)\triangle\mathbb{C} + \left(2\delta-1\right)\triangle\mathbb{k}. \qquad (29)$$

The difference in nominal output is due to the differences in consumption and investment. The size of each of them in $\triangle\yen$ depends on the corresponding parameter of the Cobb-Douglas aggregator in $C$ or $K$, $\delta$ or $\gamma$. Hence, in the conjectured equilibrium,

$$\triangle\mathbb{Y}|_{\triangle\mathbb{C}=0} = \left(2\delta-1\right)\triangle\mathbb{k}. \qquad (30)$$

Let us take the home and foreign households' aggregate budget constraints,

$$P_tC_t = w_t\ell_tL_t + \left(1-\lambda\right)n_t\pi_t\left(h\right) + \lambda e_tn_t^*\pi_t^*\left(f\right) - \left(1-\lambda\right)I_{H,t} - e_t\lambda I_{F,t}^*,$$

$$P_t^*C_t^* = w_t^*\ell_t^*L_t^* + \frac{1}{e_t}\lambda\Pi_{H,t} + (1-\lambda)\Pi_{F,t}^* - \frac{1}{e_t}\lambda I_{H,t} - \left(1-\lambda\right)I_{F,t}^*$$

and substitute the expressions for profits and labour income as a function of GDP (eq. 25 and 26).

$$\begin{aligned}
P_tC_t &= \frac{\sigma-1}{\sigma}\theta P_{H,t}Y_{H,t} + \left(1-\lambda\right)\left(1-\frac{\sigma-1}{\sigma}\theta\right)P_{H,t}Y_{H,t} + \\
&\quad \lambda e_t\left(1-\frac{\sigma-1}{\sigma}\theta\right)P_{F,t}^*Y_{F,t} - \left(1-\lambda\right)I_{H,t} - \lambda e_tI_{F,t}^*\\
&\quad +\left(1+i_t\right)B_t - B_{t+1}
\end{aligned}$$

[12]This equation is the equivalent of number 31 in H&P.

and

$$\begin{aligned} P_t^* C_t^* &= \frac{\sigma-1}{\sigma}\theta P_{F,t}^* Y_{F,t} + \lambda \frac{1}{e_t}\left(1-\frac{\sigma-1}{\sigma}\theta\right) P_{H,t} Y_{H,t} + \\ &\quad + (1-\lambda)\left(1-\frac{\sigma-1}{\sigma}\theta\right) P_{F,t}^* Y_{F,t} - \lambda \frac{1}{e_t} I_{H,t} - (1-\lambda) I_{F,t}^* \\ &\quad + (1+i_t^*) B_t^* - B_{t+1}^*, \end{aligned}$$

where $P_{H,t}Y_{H,t}$ is the nominal domestic output ($\mathbb{Y}$); $P_{F,t}^* Y_{F,t}$ is the foreign output ($\mathbb{Y}^*$); and $I$ is the investment of the current period. By imposing $P_t C_t - e_t P_t^* C_t^* = 0$,

$$\begin{aligned} \Delta\mathbb{C} &= \Delta\mathbb{Y}\left[\frac{\sigma-1}{\sigma}\theta + (1-2\lambda)\left(1-\frac{\sigma-1}{\sigma}\theta\right)\right] - \Delta\Bbbk\,(1-2\lambda) \\ &\quad + ((1+i_t) B_t - B_{t+1}) - e_t\left((1+i_t^*) B_t^* - B_{t+1}^*\right). \end{aligned}$$

Plugging in equation (30) and setting the gross and net holding of bonds identically equal to zero, $B=0$,[13] I obtain

$$\Delta\mathbb{C} = \left(1 + 2\lambda\left(\frac{\sigma-1}{\sigma}\theta - 1\right)\right)(2\delta-1)\,\triangle\Bbbk - \Delta\Bbbk\,(1-2\lambda)\,. \tag{31}$$

## 4.6 Terms of Trade

Terms of trade are defined as the price of a country's exports in terms of their imports, i.e., $TOT = \frac{P_{H,t}^*}{P_{F,t}}$. One can derive TOT from the resource constraints. In the case of symmetric countries, which I have assumed $L_t = L_t^* = 1$,

$$\begin{aligned} C_{H,t} + C_{H,t}^* + n_{t+1}K_{H,t} + n_{t+1}^* K_{H,t}^* &= Y_{H,t}; \\ C_{F,t} + C_{F,t}^* + n_{t+1}K_{F,t} + n_{t+1}^* K_{F,t}^* &= Y_{F,t}. \end{aligned}$$

Taking the ratio of the two equations on $\frac{P_t C_t}{P_{F,t}}$ and $\frac{P_t^* C_t^*}{P_{H,t}^*}$ yields an expression for the terms of trade,[14]

$$TOT_{H,t} = \frac{1}{e_t}\frac{Y_{F,t} - n_{t+1}^* K_{F,t}^* - n_{t+1}K_{F,t}}{Y_{H,t} - n_{t+1}K_{H,t} - n_{t+1}^* K_{H,t}^*}.$$

[13] This equation is the equivalent of 32 in H&P.

[14] If I allow for $L_t \neq L_t^*$,

$$\begin{aligned} L_t C_{H,t} + L_t^* C_{H,t}^* + n_{t+1}K_{H,t} + n_{t+1}^* K_{H,t}^* &= Y_{H,t}; \\ L_t C_{F,t} + L_t^* C_{F,t}^* + n_{t+1}K_{F,t} + n_{t+1}^* K_{F,t}^* &= Y_{F,t}. \end{aligned}$$

Then,

$$TOT_{H,t} = \frac{1}{e_t}\frac{\left[\gamma L_t + (1-\gamma) L_t^*\right]\left[Y_{F,t} - n_{t+1}^* K_{F,t}^* - n_{t+1}K_{F,t}\right]}{\left[(1-\gamma) L_t + \gamma L_t^*\right]\left[Y_{H,t} - n_{t+1}K_{H,t} - n_{t+1}^* K_{H,t}^*\right]}.$$

The terms of trade depend on the relative supply of the output net of investment. Given investment, the international transmission is positive: an increase in net home output benefits foreign households by lowering the home output prices. At the same time, a positive productivity shock at home raises investment.

Let $\Gamma = \gamma^{\gamma}(1-\gamma)^{1-\gamma}$. Hence, the price indexes can be rewritten as

$$P_t = \frac{P_{H,t}}{\Gamma}\left(\frac{Y_{H,t} - n_{t+1}K_{H,t} - n^*_{t+1}K^*_{H,t}}{Y_{F,t} - n^*_{t+1}K^*_{F,t} - n_{t+1}K_{F,t}}\right)^{1-\gamma}; \tag{32}$$

$$P^*_t = \frac{P_{H,t}}{e_t\Gamma}\left(\frac{Y_{H,t} - n_{t+1}K_{H,t} - n^*_{t+1}K^*_{H,t}}{Y_{F,t} - n^*_{t+1}K^*_{F,t} - n_{t+1}K_{F,t}}\right)^{\gamma}. \tag{33}$$

For $\gamma = 1/2$, households' preferences are identical, and the real exchange rate $P/P^*$ equals 1. In other words, purchasing power parity holds.[15] For $\gamma \neq 1/2$, instead, home bias in consumption implies that the real exchange rate (RER) is not constant, but changes with the terms of trade:

$$RER_t = \frac{P_t}{e_t P^*_t} = \left(\frac{P_{F,t}}{P_{H,t}}\right)^{1-2\gamma}. \tag{34}$$

With perfect risk sharing, it follows that the ratio between consumption levels is also equal to RER.

$$\frac{C^*_t}{C_t} = \left(\frac{P_{F,t}}{P_{H,t}}\right)^{1-2\gamma}. \tag{35}$$

## 4.7 Transmission Mechanism

Equation (31), which I restate below, is the key equation yielding explanations for investors' behaviour:

$$\Delta\mathbb{C} = \underbrace{\overbrace{(2\delta-1)}^{\text{via Y}}\overbrace{\left(1-2\lambda\left(1-\frac{\sigma-1}{\sigma}\theta\right)\right)}^{\text{via prices}}\triangle\Bbbk}_{\text{indirect effect}}\underbrace{-(1-2\lambda)\,\Delta\Bbbk}_{\text{direct effect}}.$$

To make the mechanism clear, let us assume that a fully anticipated shock consistent with a rise in relative investment occurs (i.e., $\Delta I_{H,t+1}$ whereas $I^*_{F,t+1}$ remains constant).[16] First, consider an environment where the basket of capital goods is biased towards domestic varieties ($\delta > \frac{1}{2}$). Thus, $\lambda < \frac{1}{2}$.

In brief, one can state that the $\Delta I_{H,t+1}$ causes a quantity and a valuation effect, and these disturb perfect risk sharing. The shock generates an increment in home households' wealth whereas foreign wealth decreases. This difference is reflected in the valuation of home output via the increase in prices.

[15] This is the case in Cole and Obstfeld (1991).

[16] A typical example of $\Delta I_H$ is the expectation of a future increase in home productivity, so that agents want to create more firms to take advantage of such improvement.

I can split the overall impact into two simultaneous effects that move in opposite directions. On the one hand, $\Delta\mathbb{k}$ has a negative direct effect on $\Delta\mathbb{C}$. The relative demand for home goods increases because they are used to satisfy the extra investment. Although part of this cost is financed by foreigners through ownership $(\frac{1}{2} > \lambda > 0)$, the home household is forced to reduce her relative consumption. This impact on $\Delta\mathbb{C}$ helps to regulate the financial flows and thus avoids disturbing perfect risk sharing.

Notice that when $\lambda = 0$ (no diversification), the term $(-(1-2\lambda))$ equals $-1$. Thus, an increment of one euro in domestic investment directly implies a one euro reduction in domestic consumption because it generates a one-unit decline in dividends received by home households. By contrast, if $\lambda = 1$ (home households own only foreign assets), the direct term equals 1. Thus, an extra euro of home investment generates a reduction of one euro in foreign consumption because the foreign households finance the whole cost of this investment.

In contrast, the indirect effect, the impact of $\Delta\mathbb{Y}$ on $\Delta\mathbb{C}$, is positive. This effect can also be separated into two parts. The first, $(2\delta - 1)$, captures the extent to which an increase in domestic absorption (in this case, investment) increases the relative value of home output. The second, $(1 - 2\lambda\left(1 - \frac{\sigma-1}{\sigma}\theta\right))$, reflects the impact of a change in relative output on relative consumption. It shows that an increment in relative demand for home goods has a positive effect on the terms of trade for the domestic economy. This effect is negatively related to $\lambda$ and positively to $\theta$ because the larger the non-diversifiable labour's share, the larger the impact of an improvement in the domestic economy's terms of trade on relative consumption, given $\lambda$.[17] Similarly, the smaller the diversification level $\lambda$, the larger the impact of a variation in relative prices on $\Delta\mathbb{C}$.

To sum up, when the shock is anticipated, home output has a higher relative value due to the increment of the demand. In consequence, the distributed dividend, which belongs partly to foreign households, is larger. The increase in the output demand pushes the quantity of labour up, and therefore the total labour income increases, causing households to become richer.

Indeed, the magnitude of this general equilibrium effect is greater than the magnitude of the direct effect when $\lambda$ (the proportion of foreign assets) is inefficiently high and *vice versa*.

To compensate for a situation like this and re-establish perfect risk sharing, $\lambda$ must increase. Therefore, a larger proportion of dividends is redistributed to the foreign households to produce a smooth consumption. In this way, home households pass part of their wealth to the other country and simultaneously reduce the demand effect. The latter occurs because, although they are importing more, these imports are partly financed by giving extra ownership to the foreigners.

In the case in which capital goods are mostly composed of foreign varieties $(\delta < \frac{1}{2} \Rightarrow \lambda > \frac{1}{2})$, all the effects act in the opposite direction. The direct effect is positive, while the indirect effect becomes negative. This change is reasonable

[17] This feature is because most of the revenue goes directly to labor, via wages. Real wages are affected by changes in relative prices. In contrast, when a large part of the household's income comes from dividends, TOT loses its capacity to offset the impact of the shocks.

because the demand generated by the extra investment must now be mostly covered by foreign goods, and therefore foreign output increases in value with respect to home production.

This result yields a basic conclusion: diversification is not a tool to redistribute purchasing power, but to control the excess of demand.[18] And it is the existence of investment that makes diversification necessary, because terms of trade are not able to neutralise the consequences of the shocks.

By setting $\Delta\mathbb{C} = 0$ I solve for $\lambda$,

$$\lambda = \frac{1-\delta}{1+(2\delta-1)\left(\frac{\sigma-1}{\sigma}\theta-1\right)}. \tag{36}$$

Equation (36) is the equilibrium value for $\lambda$, i.e., the diversification level for which the direct and indirect effects of a shock disturbing relative consumption (for instance, a shock in investment) are exactly offset.

Households allocate a positive part of their portfolios to foreign assets, $0 \leq \lambda \leq 1$. Notice that it is not the parameter from the preferences on consumption ($\gamma$) that plays a role in the diversification, but the parameter of the preferences on capital goods ($\delta$). Hence, it is important to disentangle these two, allowing them to be different. The larger the home bias in the preferences for capital goods, the less they diversify. The value of $\lambda$ decreases with $\delta$ and is kept above $\frac{1}{2}$ for $\delta < \frac{1}{2}$ and below $\frac{1}{2}$ for $\delta > \frac{1}{2}$. Thus, like H&P, I find a portfolio biased towards home assets to be the optimal allocation for households to reach perfect risk sharing. A larger trade share (smaller $\delta$) in capital goods implies a weaker terms-of-trade response to changes in relative final demand. Thus, for any given diversification level, the indirect effect of demand changes on relative consumption that works through prices is going to be smaller. Moreover, whilst $\delta \geq \frac{1}{2}$, $\lambda$ decreases with the labour income share because when $\theta$ is high, terms of trade does most of the work in equalizing consumptions. A smaller diversification is needed to produce perfect risk sharing.

In the extreme case of $\delta \to 1$, i.e., the country uses only domestically produced goods as capital in the creation of new firms, households do not diversify at all, $\lambda \to 0$. This result shows, again, that the home bias in consumption preferences is not relevant for diversification, but it also shows that the size of the labour income share alone, without the presence of some bias in demand (here in capital goods), is not important either. The reason is easy to understand: when home agents use only their own goods to create firms, the first term of the indirect effect, the one explaining the impact of relative output on relative consumption, is zero. There is no valuation of home output because flexible prices react one-to-one to the excess of demand, compensating for the shock and ensuring perfect risk sharing. Thus, this result agrees with Cole and Obstfeld's result. Finally, when the bundle of capital goods is equally divided

[18] Notice that $\delta$ and $\lambda$ appear multiplied by 2. When investment at home goes up, the home country increases the demand both for domestic goods (by $\delta$) and for foreign goods (by $1-\delta$) and $e_t P^*_{F,t} K^*_{F,t} = (1-\delta) P_{K,t} K_t$,$P_{H,t} K_{H,t} = \delta P_{K,t} K_t$. Thus, $\Delta\mathbb{k}$ includes the term $(2\delta-1)$. By the same token, $P_t C_t - e_t P^*_t C^*_t = ... - (1-\lambda) P_{K,t} K_t - (-\lambda) P_{K,t} K_t = (2\lambda-1) P_{K,t} K_t$.

between home and foreign varieties, households need perfect pooling (i.e., they divide their portfolios perfectly between home and foreign equities) to achieve perfect risk sharing, as in H&P paper.

In H&P, the share of diversification of the portfolio is

$$\left[1-\lambda^{HP}\right]=\left[\frac{1-\omega}{1+\theta^{HP}-2\omega\theta^{HP}}\right]_{\omega=\frac{1}{2}}=\frac{1}{2},$$

where $\theta^{HP}$ is the capital income share; $\omega$ is the parameter of the Cobb-Douglas aggregator in consumption (i.e., the indicator of the bias in consumption); and $1-\lambda^{HP}$ is the level of diversification in the portfolio (i.e., the equivalent of $\lambda$ in this paper.)

The reason is that when the demand on capital goods is equally allocated between home and foreign goods, any increase in either home or foreign investment pushes the demand for domestic and foreign varieties in the same proportion, keeping the terms of trade invariable (the indirect effect is zero). Thus, if agents rely on perfect pooling, they share the weight of the financing whichever country is affected by the shock.

The model provides an example of complementarity between terms-of-trade movements and income transfers via asset holdings in insuring against consumption risk from productivity fluctuations.

Relative price movements already provide some consumption risk insurance, but it is not perfect because trade flows among countries move terms of trade in response, not only to consumption but also to investment needs. These needs are possibly driven by expectations of future returns to capital. Portfolio diversification provides a way to insulate terms of trade from the components of demand due to investment. Hence, income flows from assets cover the demand for local inputs by foreign firms: the higher the proportion of investment that is local, the lower the need to diversify.

## 4.8 Allocation of Firms

Firms are allocated in the home or the foreign country based on the free entry conditions (FECs). These conditions provide us with a system of two difference equations to solve for $n$ and $n^*$. At Home, the FEC is

$$P_{K,t}K_t=P_{H,t}K_{H,t}+P_{F,t}K_{F,t}=E_tQ_{t,t+1}\pi_{t+1}\left(h\right).$$

After some algebra, one finds a system of two non-linear differentiated equations on $n$ and $n^*$,

$$n_{t+1}\left[K_{H,t}\frac{Y_t(h)^{\frac{1}{\theta}-1}}{A_{H,t}^{\frac{1}{\theta}}}\left(1-\beta\left(1-\frac{\sigma-1}{\sigma}\theta\right)\right)+K_{F,t}\frac{Y_t(f)^{\frac{1}{\theta}-1}}{e_tA_{F,t}^{\frac{1}{\theta}}}\right]=\beta\left(1-\frac{\sigma-1}{\sigma}\theta\right)\theta\frac{\sigma-1}{\sigma\kappa}$$

$$E_t\left[\begin{array}{c} L_{t+1}\gamma+L_{t+1}^*\left(1-\gamma\right)\left[\frac{A_{F,t+1}}{A_{H,t+1}}\right]^{\frac{1}{\theta}}\left[\frac{Y_{t+1}(h)}{Y_{t+1}(f)}\right]^{\frac{1}{\theta}-1}\frac{n_{t+1}}{n_{t+1}^*}+ \\ +\frac{1}{\theta}\frac{\sigma\kappa}{\sigma-1}\frac{Y_{t+1}(h)^{\frac{1}{\theta}-1}}{A_{H,t+1}^{\frac{1}{\theta}}}n_{t+2}^*K_{H,t+1}^* \end{array}\right]$$

and, symmetrically,

$$n^*_{t+1}\left[K^*_{F,t}\frac{Y_t(f)^{\frac{1}{\theta}-1}}{A_{F,t}^{\frac{1}{\theta}}}\left(1-\beta\left(1-\frac{\sigma-1}{\sigma}\theta\right)\right)+K^*_{H,t}\frac{Y_t(h)^{\frac{1}{\theta}-1}}{A_{H,t}^{\frac{1}{\theta}}}e_t\right]=\beta\left(1-\frac{\sigma-1}{\sigma}\theta\right)\theta\frac{\sigma-1}{\sigma\kappa}$$

$$E_t\left[\begin{array}{c} L^*_{t+1}\gamma+L_{t+1}\left(1-\gamma\right)\left[\frac{A_{H,t+1}}{A_{F,t+1}}\right]^{\frac{1}{\theta}}\left[\frac{Y_{t+1}(f)}{Y_{t+1}(h)}\right]^{\frac{1}{\theta}-1}\frac{n^*_{t+1}}{n_{t+1}}+ \\ +\frac{1}{\theta}\frac{\sigma\kappa}{\sigma-1}\frac{Y_{t+1}(f)^{\frac{1}{\theta}-1}}{A_{F,t+1}^{\frac{1}{\theta}}}n_{t+2}K_{F,t+1} \end{array}\right]$$

Although an analytical solution for $n$ and $n^*$ cannot be provided, it is worth noticing that the expressions above do not depend on $\lambda$ at all. Hence, the decision on the allocation of plants of production is completely disconnected from the decision on the ownership of firms made by agents in the home and foreign countries. Therefore, it follows that the dynamics of markets do not invalidate the main result, i.e., constant biased $\lambda$, found in a perfectly competitive world.

# 5 Empirical Analysis

Equation (36) provides a prediction of the share of foreign assets in aggregate portfolios and links the imports share of physical capital $(1-\delta)$ with international diversification. In this section, I compare these predictions with the data to assess the extent to which the model can explain the behaviour of international diversification in developed countries during recent decades.

My model, similar to H&P's, focuses on a two-symmetric-country model, whereas different international portfolios belong to highly heterogeneous countries.[19] For the moment, I address this caveat by limiting the empirical analysis to 24 relatively homogeneous countries with open financial markets: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the United States. These countries are high income economies under World Bank classification.

As is discussed in the following subsections, I use exactly the same measure and databases for aggregate portfolio diversification and for national wealth that are used by H&P. My data differs from their data only in two ways: (i) due to my theoretical model, I consider the level of international openness in the capital goods market instead of the level of openness in total trade; and (ii) I use actual values of labour income share instead of a standard accepted value.

H&P enrich their empirical study by assessing whether factors omitted in the model, such as size or level of development, are important empirical factors in explaining diversification patterns. They conclude that the control variables

[19] H&P, for example, experimented with countries with different levels of population and found that the structure of their portfolios barely diverged from the prediction in the two-symmetric-country model.

are not statistically related to diversification, as long as their openness variable (which drives the main result) is retained.[20] I take these results to be fair and limit my analysis to the relationship between openness in the capital goods market and in the financial markets.

### 5.1 Trade in Capital

Based on the theoretical interpretation of the transmission mechanism, I need the presence of home bias in physical capital to lead the biased aggregate portfolios. Capital in the model is built period by period to create new varieties and it is not accumulated. The parameter $\delta$ that appears in equation (36) belongs to the technology of creation of this capital. Hence, the most suitable measure of $(1-\delta)$ in the data should be the share of imports in gross fixed capital formation. The trade share in capital goods is defined as

$$(1-\delta)_{it} = \frac{M_{k,it}}{GFCF_{it}},$$

where $M_{k,it}$ is the cost of imports in capital goods of country $i$ in period $t$, and $GFCF_{it}$ is the gross fixed capital formation. Both the imports content of GFCF and GFCF itself come from the OECD database.

Since 1995, OECD has collected data on the imports content of gross fixed capital formation every five years. The series is not available for all OECD countries but only for 24 of them. All these countries show a share of imports below fifty percent in their capital formation.[21] Table 1 provides some examples of these shares.

| | $(1-\delta)$ | | |
|---|---|---|---|
| **Country** | **1995** | **2000** | 2005 |
| Australia | 0.13 | 0.14 | 0.12 |
| France | 0.12 | 0.13 | 0.11 |
| Ireland | 0.43 | 0.25 | 0.17 |
| Japan | 0.03 | 0.05 | 0.06 |
| United States | 0.10 | 0.08 | 0.08 |

Table 1: M over GFCF. Source: OECD, own calculations.

[20] H&P repeat the regressions for a larger group of countries that includes developing economies and find that, although the strong link between trade and diversification remains, income per capita becomes an important determinant of diversification, with richer countries being more diversified. Hence, it is necessary to restrict the data to relatively homogeneous countries due to the structure of the model.

[21] Ireland shows the highest level of imports over gross fixed capital formation in 1995, at 43%, although the share decreases to 17% in 2005. The lowest level is for Japan, which does not exceed 6%.

## 5.2 Diversification

The reciprocal of equation (36) provides us with a linear relationship between the reciprocal of diversification, $\frac{1}{\lambda}$, and the reciprocal of the trade share of capital goods, $\frac{1}{1-\delta}$:

$$\frac{1}{\lambda} = 2\left(1 - \Pi\theta\right) + \Pi\theta \frac{1}{1-\delta}, \tag{37}$$

where $\Pi = \frac{\sigma-1}{\sigma}$ relates the reciprocal of international diversification with the elasticity of substitution. There are two aims of this section: to determinate whether the predicted link in equation (37) is present in the data and to observe the explanatory power of the theoretical model.

The level of international diversification in the general equilibrium macroeconomic model derived here, $\lambda$, is a broad measure of diversification. In the data, I must choose an aggregated measure of both the ratio of gross foreign assets and the ratio of gross foreign liabilities to country wealth. I use the Lane and Milesi-Ferretti (2006)[22] dataset to obtain total foreign assets and liabilities. These measures include portfolio equity investment, foreign direct investment, debt (including loans or trade credit), financial derivatives and reserve assets (excluding gold). Total country wealth is defined as the value of the entire domestic capital stock plus gross foreign assets, less gross foreign liabilities: $W = K + FA - FL$. H&P develop an accurate discussion of the method to construct the most suitable measure of capital. I rely on their series, which borrow the initial value for capital stock from Dhareshwar and Nehru (1993) and build time series by accumulating net investment from the Penn World Tables 6.2.[23] Hence, international diversification for country $i$ in period $t$ is

$$\lambda_{it} = \frac{FA_{it} + FL_{it}}{2\left(K_{it} + FA_{it} - FL_{it}\right)}.$$

Theoretical macroeconomic literature tends to assume a labour income share around 0.66. Because diversification in my model depends crucially on this share, I preferred to use the actual values provided by OECD. Although they are not drastically different among developed countries, they show some heterogeneity and change over time. See some examples in table 2.

Finally one must address the elasticity of substitution among varieties. A large number of previous studies explores how to measure the actual value of

[22] The original database the authors used in that paper ends in 2004. I based my analysis on their updated webpage version of the dataset, published online in 2009.

[23] I also tried two other options. First, I based an analysis on C. Kamps (2004), who publishes his dataset on the Kiel Institute for World Economics webpage. This workbook contains net capital stock estimates for the period 1960 - 2001 for 22 OECD countries. These estimates are constructed by applying the Perpetual Inventory Method, following the practice of the U.S. Department of Commerce, Bureau of Economic Analysis. However, I would have been forced to drop two countries from my already reduced dataset. Second, I defined $\lambda = \frac{FA+FL}{Total\ Market\ capitalization}$. However, I omitted it because it does not cover such a large measure of assets and liabilities as total wealth in H&P does.

| | $\theta$ | | |
|---|---|---|---|
| **Country** | **1995** | **2000** | **2005** |
| Australia | 0.66 | 0.64 | 0.61 |
| France | 0.69 | 0.67 | 0.67 |
| Ireland | 0.66 | 0.57 | 0.58 |
| Japan | 0.63 | 0.62 | 0.58 |
| United States | 0.67 | 0.68 | 0.65 |

Table 2: Labor income share. Source: OECD.

different kinds of elasticities of substitution (depending on whether they consider the existence of, for instance, durable and non-durable goods or tradable and non-tradable goods).[24] Broda and Weinstein (2006), in an international context, find that elasticities have been declining over time as goods become more and more differentiated. These authors observe different elasticities for different countries. Bergin (2003) finds that the suitable value of the elasticity of substitution for a NOEM model with a CES consumption basket would be slightly over 1 for Australia, slightly below 1 for a country like the United Kingdom and as high as 6 for Canada. Unfortunately, he only carries out the study for the three mentioned countries. The lack of country-specific data for my elasticity forces me to choose a common arbitrary value for $\sigma$, which reduces the accuracy of the model predictions. For my model to offer a quantitatively compelling account of the patterns of international diversification, I should set $\sigma$ around 2.5. This value is in the range of standard accepted values in open macro.

### 5.3 Comparing the Predictions to the Data

In this subsection I use average diversification across countries for the three years for which I have data (1995, 2000 and 2005) and explore the linear relationship of its reciprocal with the reciprocal of the average of imports content of capital goods depicted by equation (37). I estimate by Ordinary Least Squares (OLS) and Least Absolute Deviation (LAD) the following equation:

$$\frac{1}{\lambda} = \beta_0 + \beta_1 \frac{1}{1-\delta} + \varepsilon, \tag{38}$$

where $\varepsilon$ is an error term. The theoretical relationship (37) states that $\beta_0 = 2(1 - \Pi\theta)$ and $\beta_1 = \Pi\theta$. Thus, to test if equation 37 is true, I will test the null hypothesis

$$H_0 : \beta_0 = 2\left(1 - \beta_1\right). \tag{39}$$

Table 3 presents the results. Column [1] reports the OLS regression of equation (38). As one can see, $\hat{\beta}_0 = 0.18$ and does not differ significantly from

[24] See, for example, Feenstra (1994), Bergin (2003), Broda and Weinstein (2006) and Imbs and Méjean (2010).

zero. The estimated slope coefficient $\hat{\beta}_1 = 0.34$ and differs significantly from zero at the one-percent significance level. At the bottom of the table, I present the F test corresponding to the null hypothesis in (39). The calculated Fisher statistic is $F(1;22) = 7.87$. The 1% critical value from an F distribution with $(1;22)$ degrees of freedom is $7.95$, and therefore the null hypothesis (39) cannot be rejected. In other words, the theoretical relationship depicted by equation (37) is supported by the empirical evidence. To be sure that this result is not driven by specific countries, I have also excluded some specific countries in Column [1b] and performed a LAD regression (which is more robust to influential observation than OLS). In Column [1b], Ireland and Luxembourg are omitted from the regression. These countries are particularly unusual. Luxembourg is a small country but a huge financial center and the weight of foreign assets and liabilities over wealth is far from the second most diversified country. Ireland experienced a dramatic jump in its portfolio allocation towards foreign assets and liabilities between one observation in time and the next, making the mean of the three year points quite uninformative for this country. Excluding these two countries, I obtain $F(1;20) = 4.37$. The 1% critical value from an F distribution with $(1;20)$ degrees of freedom is $8.10$, and again, I cannot reject the theoretical relationship (37). Column [2] presents the LAD regression. The F test is $5.03$ and much lower than the 1% critical value from the F distribution with $(1;22)$ degrees of freedom ($7.95$, as already stated). Hence, I do not reject the relationship using a LAD either.[25]

Column [3] presents a calibrated version of the relationship. To do so, I have assumed that $\sigma = 2.5$. As previously discussed, this value is a reasonable and standard value for an elasticity of substitution for a CES basket of consumption. I obtain values that are very close to the estimates of the econometric specifications of Columns [1]-[1b]-[2]. $\Pi\theta = 0.35$ and $2(1-\Pi\theta) = 1.43$. As one can easily see, the $\hat{\beta}_1$ of Columns [1]-[1b]-[2] do not differ significantly from $0.35$; concerning $\hat{\beta}_0$, it does not differ significantly from $1.43$ in Columns [1] and [1b] (i.e., in column [1], the estimated standard error is $0.518$, and the estimated coefficient is $0.18$; knowing that the student t is $2.81$ for 22 degrees of freedom, the 99% confidence interval is $[-1.27; 1.63]$).

[25] H&P's model finds exactly the same link between the constant and the coefficient tied to the reciprocal of trade openness, although in their case $\beta_0 = 2(1-\theta)$ and $\beta_1 = \theta$. Moreover, due to the structure of their model, they use data on total international trade instead of the capital goods market. By replicating their empirical analysis with the data provided in Perri's webpage, one can see that their coefficients do not pass this test.

| | OLS | | LAD | Model |
|---|---|---|---|---|
| | [1] | [1b] | [2] | [3] |
| $\frac{1}{1-\delta}$ | **0.34** | **0.32** | **0.36** | 0.35 |
| | (0.067) | (0.069) | (0.04) | |
| $cons$ | 0.18 | 0.46 | $-0.15$ | 1.43 |
| | (0.518) | (0.548) | (0.448) | |
| | 24 | 22 | 24 | 24 |
| $R^2$ | 0.53 | 0.51 | | |
| $\sigma$ | | | | 2.5 |
| $F(1;n)$ $_{H_0:\beta_0-2(1-\beta_1)}$ | 7.87 | 4.37 | 5.03 | |
| $p-value$ | 0.0103 | 0.0495 | 0.0353 | |

Table 3: Cross-sectional regressions.

# 6 Conclusions

I developed a stylised two-period, two-country model with perfect risk sharing. The dynamic number of firms and the international portfolio diversification are endogenously determined. The model builds on Heathcote and Perri (2009)'s idea of the compatibility of the home bias in portfolio found in actual data with perfect risk sharing.

The model presented here confirms that an equilibrium exists where a home-biased and constant portfolio allocation is able to provide households with perfect risk sharing, i.e., the equity puzzle is not such a puzzle. It shows that the terms of trade play an important role in neutralizing the effects of country-specific shocks on relative consumption, as Cole and Obstfeld (1991) claimed. However, they are not able to offset the disturbances to investment. One needs to diversify assets to control for such disturbances.

There are several main contributions of this analysis. First, it highlights the need to distinguish between the preferences of demand on capital and those on consumption goods. It is the home-bias parameter in the Cobb-Douglas aggregator for physical capital demand that determines the level of diversification. H&P does not identify it because they use the same parameter both for consumption and for capital. Second, I investigated the role of the endogenous number of firms or varieties in the determination of the portfolio allocation. I find that these two endogenous variables are completely independent when the economy has flexible determination of prices, i.e., in the long run. Finally, the ability of the model to explain the patterns of international diversification is tested. An empirical analysis of a cross-section of 24 OECD countries shows a clear positive relationship between the home bias in capital goods and the home bias in aggregate portfolios. The model is able to match the data, although the result is dependent on the value assigned to the elasticity of substitution between goods. Unfortunately, the true country-values for this elasticity are not available. Moreover, the model correctly predicts the link between the constant and the slope present in the actual data in the tested regression.

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**XREAP2010-13**
**Di Paolo, A.** (GEAP & IEB)
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**XREAP2010-15**
**Albalate, D.** (GiM-IREA), **Bel, G.** (GiM-IREA), **Fageda, X.** (GiM-IREA)
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**XREAP2010-16**
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**XREAP2010-17**
**Canova, L.**, **Vaglio, A.**
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**Nieto, S.** (AQR-IREA)**, Ramos, R.** (AQR-IREA)
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**XREAP2011-06**
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**XREAP2011-08**
**Ayuso, M.** (RFA-IREA), **Guillén, M.** (RFA-IREA), **Bolancé, C.** (RFA-IREA)
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**XREAP2011-09**
**Duch-Brown, N.** (IEB), **García-Quevedo, J.** (IEB), **Montolio, D.** (IEB)
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**XREAP2011-11**
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