The Role of Multinational Production in a Risky Environment*

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Abstract

This paper explores the aggregate consequences of Foreign Direct Investment (FDI) on the opportunities for risk diversification available to consumers. The crucial difference between FDI and other international financial flows is that the former involves technology flows across countries. We present a model where firm-embedded productivity can be transferred costly across countries through the activity of multinational firms. We find that risk patterns affect multinationals' location decisions and, in turn, these decisions change the scope for international risk diversification even in a world with complete financial markets.

JEL: F41, F23. Key Words: Foreign Direct Investment, multinational firms, international risk sharing.

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1 Introduction

The exchange of financial assets across borders enables consumers to better diversify country specific risk. The literature on international risk sharing has extensively analyzed the properties of these financial assets such as bonds, equity of foreign firms, including multinational firms with productive activities in foreign markets. This literature does not typically distinguishes Foreign Direct Investment (FDI) from other financial flows in regard of its consequences for international risk sharing opportunities. However, FDI is different from other financial flows in that it also represents a channel through which countries exchange goods, capital, ideas, and technologies.[1] An important fraction of firm productivity seems to be transferable only within the boundaries of the firm.[2] Thus, FDI flows entail transfers of firm-specific technology across countries that is otherwise immobile.

This paper explores the aggregate consequences of FDI flows on the opportunities for risk diversification available to consumers. We emphasize the role played by FDI in transferring technologies across countries and reshaping international goods' and factors' markets. The activity of multinational firms has then consequences for the pattern of consumption risk. We uncover a number of novel implications stemming from treating FDI simultaneously as a financial and technology flow in a risky environment.

First, when Multinational Production (MP) activities are both treated as a financial and technology flow, their role in international risk sharing goes beyond the mere substitution for a portfolio of international financial assets. The international technology transfers entailed by MP have implications for the pattern of world risk as it alters the relative impact of country shocks on world markets. In other words, while international financial assets enable agents to redistribute output across countries in different states of the world, MP alters the amount of

[1]The characterization of multinational firms as developers of technologies has been central to models explaining multinational firms activity (see Caves (1996) and Markusen (2002) for an overview of this literature).

[2]See Helpman (1984), Antras (2003), Antras and Helpman (2004).

output available in each of these states.

Second, the overall effect of MP on consumption risk crucially depends on the direction of FDI flows. The consumption risk premium is reduced if firms locate their production in countries with shocks least correlated with world aggregate risk. By increasing productivity in countries where affiliates are located, MP changes the impact of host country shocks on world markets, and increases production in those states of nature that world output is relatively scarce.

We present a multi-country model where the only source of uncertainty is the existence of country shocks, in the spirit of Backus, Kehoe, and Kydland (1992), and where risk-averse consumers have access to a full set of contingent claims. With a freely-tradable final consumption good, consumers attain perfect risk sharing: consumption in each country fluctuates with world output that experiences states of (relative) scarcity and abundance.

To emphasize that FDI entails transfers of productivity that is otherwise immobile, we introduce a "firm-imbedded" productivity parameter which can be broadly understood as technology, managerial know-how, or organizational capital.[3] Firms are heterogenous in their productivity and compete monopolistically. They can serve foreign markets by opening affiliates there after paying a fixed entry cost. The same firm productivity parameter characterizes the parent company and its affiliates.[4]

In a risky environment, the natural question is which type of shocks affect MP activities. We model affiliates to exclusively supply the host market, so their demand is driven by the host country fluctuations.[5] This is aimed at describing the vast majority of multinational sales: according to UNCTAD (2009) around 20% of gross production by foreign affiliates is sold outside

[3]See McGrattan and Prescott (2009) and Burstein and Monge (2009) for different interpretations of this firm specific "factor".

[4]See Doms and Jensen (1998), Criscuolo and Martin (2005), Bloom et al. (2007). With the goal of disentangle whether US productivity advantage can be attributed to the US environment or its firms, they find that affiliates tend to replicate the productivity advantage of the parent firm when opening affiliates in a foreign market.

[5]That is, we consider "Horizontal FDI", where investment in a foreign production facility is designed to serve customers in the foreign market.

the country of production. The source of country fluctuations is a productivity shock that affects the cost of labor in the destination market. One can think of alternative specifications that would add other considerations to our results. For example, that productivity shocks are specific to the multinational firm regardless of where its affiliates are located. Yet, as long as there are shocks that affect all production located in a country, our result holds: The location decisions of firms change the weight given to host country shocks in overall world output.

The world described in this paper is analogous to a Lucas-type endowment economy where the number of *trees* in a country represents the number of firms located in a country, and the country shocks affect the amount of *fruits* delivered by each tree located in the economy. Since risk-averse consumers have access to a complete set of contingent securities, consumption only fluctuates with world non-diversifiable risk -that is, the world amount of *fruits* in each state of nature–. Yet, consumption volatility could be further reduced if *trees* were transferred to economies with shocks least correlated with world output.

By modeling the location decision of firms, technology transfer across countries occurs endogenously. The predicted effect of MP on consumption risk is ambiguous. With complete financial markets, firms internalize consumers' desire for smooth consumption. Then, everything else equal, they find optimal to open affiliates in economies least correlated with world risk, typically small countries. In doing so, they tend to reduce overall consumption risk. However, production has economies of scale, which provides incentives to open affiliates in large markets and negatively affects consumption smoothness.

We calibrate entry costs to the observed pattern of bilateral MP flows, country shocks to the time series properties of real GDP per capita, and country's size to a measure of equipped labor, for a set of OECD countries. Our calibration suggests that large countries tend to be net exporters of technologies. However, as country shocks are strongly correlated, technology transfers embedded in MP flows reduce the consumption risk premium by only 0.21% relative to a world with no MP. But, this small number is composed of two offsetting effects: a positive effect on world risk due to having very heterogenous shock processes across countries ("risk effect "); and a negative effect that acts by reducing world risk coming from the fact that countries are heterogenous in the size of their equipped labor force ("size effect").

Our model is closed to the literature on trade in the context of country specific risk.[6] In particular, Grossman and Razin (1984, 1985) introduce production risk into a model that jointly determines the international pattern of trade and capital flows. They analyze the choice between risky and risk-free production across asymmetric countries, and find, as we do, that it is efficient to locate risky production in the small economy. We build on that result by endogenizing the location decision of firms.

We also add to the literature on foreign direct investment and risk diversification. This literature typically considers models with imperfect access to financial markets, and multinational production enables firms to hedge country risk. Our paper, on the contrary, considers integrated and sophisticated financial markets that allow firms and consumers to perfectly share country specific risk. We think this is a relevant benchmark, especially for developed economies, which concentrate most of multinational activities. Indeed, using a large cross-country time-series data set, Alburqueque et al (2005) find that FDI flows are increasingly explained by world factors, consistent with integrated and well functioning world financial markets.

The paper has the following structure. Section 2 presents the set-up of the model. Section 3 characterizes the equilibrium. Section 4 describes the main mechanism of the model, and present the calibration exercise. Section 5 concludes.

[6]See Svensson (1988), Obstfeld and Cole (1991), Tesar (1993), Backus and Smith (1993), Baxter and Crucini (1995), among others.

2 Model

We present multi-country stochastic model with a complete set of state-contingent claims. There is an homogenous final consumption good that is freely tradable, and a continuum of intermediate goods. The sources of uncertainty are country-specific shocks that affect productivity in the final good sector. This structure of shocks is similar to the one in Backus, Kehoe, and Kydland (1992).

Firms in the intermediate goods' sector are heterogenous in productivity, and compete monopolistically, along the lines of Melitz (2003). The only way they can serve foreign consumers is by opening affiliates in that market; no trade is allowed in this sector. Crucially, affiliates inherit their parent specific productivity at a cost.

Our analysis distinguishes between two assets: shares of firms, some of which are multinationals; and a portfolio of other risky and risk-free assets -a complete set of Arrow-Debreu securities.

2.1 Set-up

There are I countries, each of size L_i, endowed with $Y_i(0)$ units of consumption good. There are two periods: an initial period *before* uncertainty is realized in which trade in Arrow-Debreu securities and FDI (that is, the set up of foreign production facilities) take place; and a second period *after* uncertainty is realized in which production takes place. This set-up is aimed at capturing that FDI decisions present irreversibilities that make reallocation costly after the productivity shock is realized. Agents consume in both periods.

Let the vector $s \in S$ denote the state of the world economy in the second period characterized by the realization of country shocks, $\mathbf{A} = [A_1, ..., A_I] \in R_+^I$. We assume that there is a finite number of states, $S = \{s_1, ..., s_N\}$, each occurring with probability $\Pr(s) > 0$, $\sum_{s=1}^{N} \Pr(s) = 1$.

Productivity shocks to the final good sector are the only source of uncertainty in this world. We make that explicit using the notation $A_i(s)$. Without loss of generality, we assume that $E(A_i) = 1$ for all i.[7]

The representative consumer in country i supplies L_i units of labor and maximizes expected utility from final consumption, with time separable preferences:

$$U = \frac{C_i(0)^{1-\sigma}}{1-\sigma} + \beta \sum_{s \in S} \Pr(s) \frac{C_i(s)^{1-\sigma}}{1-\sigma}, \tag{1}$$

where $\sigma \geq 1$.

Production. There is a continuum of firms of measure one in the intermediate goods' sector producing a continuum of goods. Each intermediate good ω is produced with an only-labor constant returns technology, and firm-specific productivity $z(\omega)$. This parameter is known, and drawn from a country-specific distribution, $G_i(z)$, $z \in [z_{min}, \infty)$, independently distributed across countries. Crucially, firms can open affiliates abroad with the same productivity parameter $z(\omega)$ as the one they have at home. The production function for a firm from country i producing good ω in country j is

$$q_{ij}(\omega, s) = z(\omega) \cdot l_{ij}(\omega, s), \tag{2}$$

where $q_{ij}(\omega, s)$ and $l_{ij}(\omega, s)$ are output and labor requirements, respectively. When $i = j$, $q_{ii}(\omega, s)$ denotes output produced by national firms.[8] Since firms compete monopolistically, the price charged by a firm with productivity z from country i producing in j is given by a mark-up over marginal cost,

$$p_{ij}(z, s) = \frac{\eta}{\eta - 1} \cdot W_j(s) \cdot \frac{1}{z}, \tag{3}$$

[7] In this economy, all asymmetries in $E(A_i)$ are equivalently to differences in labor endowments L_i.

[8] Since the only parameter that varies across differentiated goods is the firm-specific productivity $z(\omega)$ and goods enter symmetrically in preferences, we can rename each good ω by its productivity z.

where $W_j(s)$ denotes the wage in country j, state s. Total expenditure in an intermediate good supplied by an affiliate from country i in j is given by

$$x_{ij}(z,s) = \left(\frac{p_{ij}(z,s)}{P_j(s)}\right)^{1-\eta} Q_j(s)P_j(s), \quad (4)$$

where $P_j(s)Q_j(s)$ is total expenditure in the CES composite intermediate input Q that combines the continuum of goods ω with elasticity of substitution $\eta > 1$, and has associated price index P.

The final consumption good is produced under perfect competition with a constant returns to scale technology that combines labor and the composite intermediate good,

$$Y_i(s) = A_i(s)L_i^f(s)^{\alpha}Q_i(s)^{1-\alpha}, \quad (5)$$

where $0 < \alpha < 1$, and $A_i(s)$ denotes country i's productivity shock.

Provided that it is produced everywhere, the price of the final good is equalized across countries and normalized to one.

Assets Structure. The representative consumer in each country holds two types of assets: shares of firms, $\theta_i(z)$, and fully contingent bonds, $B_i(s)$. Without loss of generality, we assume that consumers in country i own firms from country i only, $\theta_i(z) = 1$ and $\theta_j(z) = 0$ for $j \neq i$.[9] With complete financial markets, the budget constraint for the representative consumer in country i is given by

$$C_i(0) + \sum_{s\in S}\varphi(s)C_i(s) = B_i(0) + \sum_{s\in S}\varphi(s)\left\{L_iW_i(s) + \int_{z\in Z}\pi_i(z,s)\,dG_i(z)\right\}, \quad (6)$$

where $\varphi(s)$ is the date-zero price of an Arrow-Debreu security that pays one unit of final con-

[9]Results are unchanged if national firms are initially owned by national consumers and sold in the international market.

sumption in state s, and B_i^0 is consumers' initial wealth, net of the cost of setting up affiliates. The variable $\pi_i(z,s)$ denotes total profits for a firm from country i, with technology z, in state s given by

$$\pi_i(z,s) = \sum_{j=1}^{I} \iota_{ij}(z)\pi_{ij}(z,s), \tag{7}$$

where $\pi_{ij}(z,s)$ denote profits made in market j, given by $x_{ij}(z,s)/\eta$, and $\iota_{ij}(z)$ is one if the firm produces in country j, and zero otherwise.

The consumer's optimization problem entails the following Euler equation:

$$\varphi(s) = \beta \Pr(s) \left[\frac{C_i(s)}{C_i(0)}\right]^{-\sigma}. \tag{8}$$

Foreign Direct Investment (FDI).[10] Before the realization of country shocks, firms decide whether to serve a market. If a firm from country i decides to enter market j, it pays a one time entry cost f_{ij}. Countries are initially endowed with $Y_i(0)$ units of final goods. Then, the initial net wealth for the representative consumer in country i in equation (6), $B_i(0)$, is given by the value of the initial endowment of the investment good net of total costs of opening affiliates in each country j,

$$B_i(0) = Y_i(0) - \sum_{j=1}^{I} f_{ij} \int_{z\in Z} \iota_{ij}(z) dG_i(z). \tag{9}$$

The value of doing MP in country j for a firm from country i with productivity z is given by the expected discounted flow of profits in that market,

$$V_{ij}(z) = \sum_{s\in S} \varphi(s)\pi_{ij}(z,s), \tag{10}$$

[10]Foreign Direct Investment (FDI) refers to the Balance of Payment flow; in our model occurs only once, i.e. the initial set-up of affiliates abroad. MP refers to the productive activities of affiliates abroad; in our model occurs in the second period.

where $\varphi(s)$ correspond to the price of an Arrow-Debreu security that pays a unit of the consumption good in state s and satisfies the Euler equation (8).

Only firms for which the value of doing MP in market j is larger than the entry cost will open affiliates in that market. Hence, the entry decision is characterized by a cut-off rule defined by the following zero profit condition:

$$V_{ij}\left(\overline{z}_{ij}\right) = f_{ij}. \tag{11}$$

Firms from country i with $z \geq \overline{z}_{ij}$ open affiliates in $j, \iota_{ij}(z) = 1$; the ones with $z < \overline{z}_{ij}$ do not, $\iota_{ij}(z) = 0$.[11] Without loss of generality, we assume that national firms have zero entry costs, $f_{jj} = 0$ so that $\overline{z}_{jj} = z_{\min}$.

Finally, net wealth for the representative consumer in country i in equation (9) can be written as

$$B_i(0) = Y_i(0) - \sum_{j=1}^{I} f_{ij}\left[1 - G_i\left(\overline{z}_{ij}\right)\right]. \tag{12}$$

3 Equilibrium

We define the equilibrium in two steps. First, we characterize equilibrium prices and quantities for each country i and state of nature s as functions of the number of firms in each country. In the second step, we characterize the equilibrium entry decisions of firms across country-pairs.

[11] From (3), $p_{ij}(z,s)$ is inversely related to the firms's productivity z. Thus, with $\eta > 1$, profits increase with z, $\sum_{s\in S}\varphi(s)\frac{\partial}{\partial z}\pi_{ij}(z,s) > 0$ where $\pi_{ij}(z,s) = x_{ij}(z,s)/\eta$. Hence, the optimal entry decision into market j for firms from country i is characterized by a productivity level $\overline{z}_{ij}$ such that $V_{ij}\left(\overline{z}_{ij}\right) - f_{ij} = 0$. For all firms with productivity z above that cut-off, the condition $V_{ij}(z) > f_{ij}$ is satisfied and entering market j is optimal.

3.1 National Equilibrium

Definition 1. *Given the matrix* $\{\overline{z}_{ji}\}_{j=1}^{I}$, *an equilibrium in country* i *and state* s *is defined by the vectors of output, labor demands, and prices for intermediate goods,*
$\left\{\langle q_{ji}(z,s)\rangle_{z\in Z}, \langle l_{ji}(z,s)\rangle_{z\in Z}, \langle p_{ji}(z,s)\rangle_{z\in Z}\right\}_{j=1}^{I}$, respectively, final output $Y_i(s)$, labor demand in the final good sector $L_i^f(s)$, and *wage* $W_i(s)$, *such that*

1. *Firms producing intermediate and final goods maximize profits;*

2. *For each good* z, *market clears,*

$$\left(\frac{p_{ij}(z,s)}{P_j(s)}\right)^{-\eta} Q_j(s) = z \cdot l_{ij}(z,s); \tag{13}$$

3. *Labor market clears,*

$$L_i = L_i^f(s) + \sum_{j=1}^{I} L_{ji}(s), \tag{14}$$

where $L_{ji}(s) = \int_{\overline{z}_{ji}}^{\infty} l_{ji}(z,s)\, dG_j(z)$; and

4. *The law of one price for the final good holds.*

Define $Z_{ji} \equiv \int_{\overline{z}_{ji}}^{\infty} z^{\eta-1} dG_j(z)$, and $Z_i = \sum_{j=1}^{I} Z_{ji}$. The index Z_{ji} aggregates productivity across affiliates from j located in i, and the index Z_i aggregates productivity across all firms producing intermediate goods in country i.

Since entry decisions are taken at date zero before uncertainty is resolved, the productivity of the marginal firm from country j entering market i, $\overline{z}_{ji}$, does not vary across states s. Thus, Z_i and Z_{ji} are constant across states of nature s.

The law of one price in the final good sector implies that unit costs of production for this good are equalized across countries. With Cobb-Douglas production functions and perfect competition, from (5), we get that

$$A_i\left(s\right) = \phi_0 \cdot W_i(s)^{\alpha} \cdot P_i(s)^{1-\alpha}, \tag{15}$$

where ϕ_0 is a positive constant.[12] Using (3) and (15), the wage and price index for the composite intermediate good in country i and state s are, respectively,

$$\begin{aligned} W_i(s) &= \phi_1 \cdot A_i(s) \cdot Z_i^{\frac{1-\alpha}{\eta-1}}, && (16) \\ P_i(s) &= \phi_2 \cdot A_i(s) \cdot Z_i^{\frac{\alpha}{1-\eta}}, && (17) \end{aligned}$$

where ϕ_1 and ϕ_2 are positive constants.[13] As expected, wages depend positively on aggregate productivity, both in the intermediate good sector Z_i and final good sector $A_i\left(s\right)$. Moreover, the effect of country shocks $A_i\left(s\right)$ on wages translate one-to-one into the price of the intermediate good $P_i\left(s\right)$, which is larger in states with higher realizations of $A_i\left(s\right)$.

From the final good production function in (5), expenditures in the composite intermediate input and labor are, respectively,

$$\begin{aligned} P_i(s)Q_i(s) &= (1-\alpha)Y_i(s), && (18) \\ W_i(s)L_i^f(s) &= \alpha Y_i(s). && (19) \end{aligned}$$

Labor market equilibrium in (14) implies that total output in the final good sector in country i, state s, is:[14]

$$Y_i\left(s\right) = \phi_3 \cdot L_i \cdot Z_i^{\frac{1-\alpha}{\eta-1}} \cdot A_i(s), \tag{20}$$

[12] $\phi_0 \equiv \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)}$.

[13] $\phi_1 \equiv \phi_0^{-1}\left(\frac{\eta-1}{\eta}\right)^{1-\alpha}$ and $\phi_2 \equiv \phi_0^{-1}\left(\frac{\eta-1}{\eta}\right)^{\alpha}$.

[14] Using the market clearing condition for good z in (13), and (18), the aggregate labor demand in the intermediate goods sector for firms from country j producing in i is $L_{ji}(s) = \frac{(\eta-1)(1-\alpha)}{\eta}\frac{Z_{ji}}{Z_i}\frac{Y_i(s)}{W_i(s)}$. Combined with (19) and (14), we obtain $Y_i\left(s\right) = \frac{\eta}{\eta-1+\alpha}W_i\left(s\right)L_i$, which leads to expression (20).

where ϕ_3 is a positive constant.[15] $Y_i(s)$ is proportional to the country-wide productivity shock $A_i(s)$ with the proportionality factor increasing with the size of the economy L_i and the overall productivity of firms located in i, Z_i.

Finally, using (3), (4), and the price index in (17), profits for a firm with productivity z from country j operating in country i are

$$\pi_{ji}(z,s) = \frac{1-\alpha}{\eta} \cdot \frac{z^{\eta-1}}{Z_i} \cdot Y_i(s) = \phi_3 \frac{1-\alpha}{\eta} \cdot z^{\eta-1} \cdot L_i \cdot Z_i^{\frac{1-\alpha}{\eta-1}-1} \cdot A_i(s). \tag{21}$$

Profits co-move one-to-one with the productivity shock in the *host* market $A_i(s)$ through its effect on host country final output $Y_i(s)$. Market shares, $\frac{1-\alpha}{\eta} \cdot \frac{z^{\eta-1}}{Z_i}$, are constant across states of nature, but larger for firms with higher z, and in markets with lower Z_i (i.e. less competition).

3.2 International Equilibrium

Definition 2. *For a given vector of initial endowments, $\{Y_i(0)\}_{i=1}^{I}$, the international equilibrium is defined by the matrix $\{\overline{z}_{ij}\}_{i,j}$, the vector of prices for Arrow-Debreu securities $\{\varphi(s)\}_{s\in S}$, the vector of consumption and holdings of Arrow-Debreu securities $\{C_i(0); C_i(s)\}_{i=1}^{I}$* and $\{B_i(s)\}_{i=1}^{I}$, *respectively, for each $s \in S$, such that*[16]

1. *The Euler equation in (8) is satisfied, for all countries $i = 1, ..., I$;*

2. *The budget constraint in (6) is satisfied, for all countries $i = 1, ..., I$;*

3. *The productivity cutoffs $\{\overline{z}_{ij}\}_{i,j}$ satisfy the zero profit conditions in (11), for all country pairs $i, j = 1, ...I$;*

4. *Arrow-Debreu securities are in zero net supply, for each $s \in S$, $\sum_{i=1}^{I} B_i(s) = 0$;*

[15] $\phi_3 \equiv \phi_1 \frac{\eta}{\eta-1+\alpha}$.

[16] This equilibrium is efficient. See the Appendix for the formulation of the corresponding social planner problem.

5. *The world resource constraint for the final good is satisfied, for each* $s \in S$,

$$\sum_{i=1}^{I} C_i(0) = \sum_{i=1}^{I} Y_i(0) - \sum_{i=1}^{I}\sum_{j=1}^{I}[1 - G_i(\overline{z}_{ij})] f_{ij}. \tag{22}$$

$$\sum_{i=1}^{I} C_i(s) = \sum_{i=1}^{I} Y_i(s) \tag{23}$$

The world described in this paper is analogous to a Lucas-type endowment economy with risky output in every country i given by equation (20), $Y_i(s) = \phi_3 Z_i^{\frac{1-\alpha}{\eta-1}} L_i A_i(s)$. We can interpret $\phi_3 L_i Z_i^{\frac{1-\alpha}{\eta-1}}$ as the number of "trees", and $A_i(s)$ as the amount of "fruits" delivered in state s by each tree located in i.

Define the average world shock $A_W(s)$ as the weighted average of country-specific shocks,

$$A_W(s) \equiv \sum_{i=1}^{I} \varpi_i A_i(s) \tag{24}$$

with

$$\varpi_i \equiv \frac{L_i Z_i^{\frac{1-\alpha}{\eta-1}}}{\sum_{i=1}^{N} L_i Z_i^{\frac{1-\alpha}{\eta-1}}}. \tag{25}$$

World output can then be expressed as

$$Y_W(s) = \sum_{i=1}^{I} Y_i(s) = \phi_3 \cdot A_W(s) \cdot L_W Z_W, \tag{26}$$

where $L_W Z_W \equiv \sum_{i=1}^{I} L_i Z_i^{\frac{1-\alpha}{\eta-1}}$. World output increases with a positive productivity shock to any country, $dY_W/dA_i > 0$, and the impact of country i's shock on $Y_W(s)$ increases with the country's share of world production ϖ_i, $d^2Y_W/dA_i d\varpi_i > 0$. In other words, the number of efficiency units of labor located in each country determines the impact of country-specific shocks on world output.

With frictionless trade in the final good and complete financial markets, perfect international risk sharing is attained. The ratio of consumptions between any country pair is constant across states of nature, $C_i(s)/C_j(s) = C_i(0)/C_j(0)$, and consumption in any country i is a constant share of the world output of the final good,

$$C_i(s) = \mu_i Y_W(s), \tag{27}$$

where $\sum_{i=1}^{I} \mu_i = 1$. It is clear that, even though consumers perfectly share country-specific risks, consumption fluctuates with world output across states of nature. Frictionless goods and financial markets guarantee the efficient distribution of goods across countries, but they do not change the amount of goods available in each state of nature. However, there are other international flows that affect the world amount of goods produced in each state, and act by altering the patterns of production across countries. Examples are migration flows and, as stressed in this paper, technology flows. We emphasize a specific form of technology transfer across countries: the one embedded in the productive activities of affiliates of multinational firms.

By opening affiliates abroad, multinational firms transfer technology to foreign countries. In this respect, FDI flows are fundamentally different from other international financial flows: they entail technology transfers that alter productivity in the receiving country.[17] By affecting aggregate firm-specific productivity Z_i, and hence ϖ_i, MP changes the allocation of "trees" across countries, and the impact of country-specific shocks on world aggregate fluctuations. Moreover, as shown in Lemma 1, consumption risk is reduced when affiliates locate in economies with shocks least correlated with aggregate risk.

Lemma 1. *Let* $\Psi_i \equiv cov\left(A_W^{-\sigma}; A_i\right)$, *and let* ρ *be the consumption risk premium defined by*

[17] In the Appendix, we present a version of the model with physical capital that is freely movable across countries. In this extension, the results from the basic model are amplified.

$u\left[E\left(C_i\right)(1-\rho)\right] = E\left[u\left(C_i\right)\right]$. Consider two countries j and h such that $\Psi_j > \Psi_h$: when technology flows such that $d\varpi_j = -d\varpi_h > 0$ ($d\varpi_j = -d\varpi_h < 0$), ρ decreases (increases).

Proof: See Appendix. □

A crucial assumption for this result is that affiliates bear the shock specific to the host country. We assume that country shocks only affect affiliates through their impact on the unit cost of inputs. Thus, it is natural to assume these shocks affect all firms located in a country, irrespectively of their origin. A different shock specification could add other considerations to the result in Lemma 1. Yet, as long as there are shocks that affect all production located in a country, this result holds.

In the next section we characterize the equilibrium with endogenous the location of firm and derive its implications for consumption risk premium

4 Multinational Production in a Risky Environment

In this model, the only reason firms do MP is to gain market access. More precisely, firms from country j supply market i by opening affiliates there. Consistent with previous literature, the factors that determine the convenience of opening foreign affiliates are entry costs, market size of the host economy, and the degree of competition in the host market. In addition, in an environment with aggregate risk, the stochastic process governing country shocks affects the equilibrium number of firms entering foreign markets.

Combining (10) and (21), the value of doing MP for a firm with productivity z from country i in country j, net of entry costs is

$$\frac{1-\alpha}{\eta} \cdot \frac{z^{\eta-1}}{Z_j} \cdot \sum_{s \in S} \varphi(s) Y_j(s) - f_{ij}, \tag{28}$$

where $Y_j(s) = \phi_3 \cdot L_j \cdot Z_j^{\frac{1-\alpha}{\eta-1}} \cdot A_j(s)$, as specified in equation (20). It is easy to see the factors that give incentives to firms to do MP into a market. The size of the labor force L_j, by increasing total output $Y_j(s)$, increases profits in all states s, in country j, and hence increases the value of doing MP. Aggregate productivity of firms located in country j, Z_j, affects the value of doing MP in two offsetting ways. On the one hand, more productive competing firms reduce market shares of an affiliate, which negatively affects profits in all s. On the other hand, higher aggregate productivity of firms in the host market increases final output and hence expenditure in country j.

Assumption 1. *$\eta > 2 - \alpha$.*

Under Assumption 1, the competition effect dominates, and the value of doing MP in (28) decreases with aggregate productivity of firms Z_i.[18] Finally, as pointed out in previous literature, higher entry costs, f_{ij}, also reduce the net value of doing MP into market j.

4.1 MP and Country Risk

In a risky environment, the stochastic properties of country shocks are a factor determining the value of doing MP for a firm with productivity z from country i in j.

Replacing (27) in (8), the price of an Arrow-Debreu security in state s is

$$\varphi(s) = \phi_4 \cdot \Pr(s) \cdot Y_W(s)^{-\sigma}, \tag{29}$$

where ϕ_4 is a positive constant, and $Y_W(s)$ world output in equation (26).[19] The value of doing MP in country j can be expressed as $V_{ij}(z) = \phi_5 \cdot \frac{z^{\eta-1}}{Z_j} \cdot E\left[Y_W^{-\sigma} \cdot Y_j\right]$, where ϕ_5 is a positive

[18] $\frac{dV_{ij}(z)}{dZ_j} = \sum_{s \in S} \varphi(s) \left\{ \frac{\partial \pi_{ij}(z,s)}{\partial Z_j(s)} + \frac{\partial \pi_{ij}(z,s)}{\partial Y_j(s)} \frac{\partial Y_j(s)}{\partial Z_j} \right\} = -\left(1 - \frac{1-\alpha}{\eta-1}\right) \frac{V_{ij}(z)}{Z_j} < 0.$

[19] $\phi_4 \equiv \beta \left(\sum_k C_k(0)\right)^{\sigma}$.

constant.[20] Crucially, the discounted flow of profits depends on the correlation between the marginal utility of consumption, which co-moves with $Y_W(s)^{-\sigma}$, and output in the host country, $Y_j(s)$. Intuitively, a flow of profits is more valuable if its realizations are larger in states when Arrow-Debreu prices are high, or equivalently, the marginal utility of consumption is high, which signals that world output is relatively scarce.

Further replacing $Y_j(s)$ and $Y_W(s)$ with (20) and (26), respectively, the value of an affiliate with productivity z located in country j can be expressed in terms of the correlation between the shock in the host country, A_j, and the world average productivity shock, A_W,

$$V_{ij}(z) = \phi_6 \cdot \frac{z^{\eta-1}}{Z_j} \cdot \varpi_j \cdot E\left[A_W^{-\sigma} \cdot A_j\right], \tag{30}$$

where ϕ_6 is a positive constant.[21] The stochastic properties of $A_j(s)$ determine the value of a foreign affiliate located in j. As suggested by equation (30), everything else equal, it is more profitable to locate affiliates in economies with shocks less correlated with world risk $A_W(s)$. This is the intuition behind the following proposition.

Proposition 1. *Let* $\Psi_i \equiv cov\left(A_W^{-\sigma}; A_i\right)$. *Assume that* $L_i = L$, *for all* i, *and* $f_{ij} = f$, *for all* $i \neq j$. *Then, the location of affiliates is such that, for any country pair* i, h: $\Psi_i > \Psi_h$ *if and only if* $\overline{z}_{ji} < \overline{z}_{jh}$, *for all* $j \neq i, h$.

Proof: See Appendix. □

In a symmetric world, where countries only differ in the stochastic process of their shocks, the number of foreign affiliates and, therefore, production, is largest in those economies with shocks least correlated with world risk. This is because with frictionless financial markets, the price of financial assets reflects consumers risk aversion, and firms use such prices to discount profits.

[20] $\phi_5 \equiv \phi_3 \phi_4 \frac{1-\alpha}{\eta}$.

[21] $\phi_6 \equiv \phi_5 \phi_3^{1-\sigma} \left[\sum_{i=1}^{I} L_i Z_i^{\frac{1-\alpha}{\eta-1}}\right]^{1-\sigma}$.

Hence, the equilibrium location of production across countries is efficient.[22] Applying Lemma 1, consumption risk, measured as the difference between certainty equivalent and expected consumption, lowers when FDI flows are allowed.

This result can be reversed if the assumption of symmetry is removed. In particular, if entry cost are larger in those economies with shocks least correlated with world risk, MP flows are directed towards economies that co-move the most with world aggregate fluctuations. In this case, MP flows may increase consumption risk premium. Asymmetries in country size are discussed in the next subsection.

4.2 MP and Country Size

Results in the previous subsection abstracted from size differences across countries and just focused on differences in the stochastic process of country shocks. Proposition 1 assumed that countries were symmetric in size and fixed costs of entry. Now, we focus on asymmetries coming from country's size, L_i, but assume that shocks are i.i.d across countries.

Notice that the size of L_i determines the effect of country i's shock on world output, as indicated by equation (24), $\varpi_i = L_i Z_i^{\frac{1-\alpha}{\eta-1}} / \sum_{i=1}^{I} L_i Z_i^{\frac{1-\alpha}{\eta-1}}$. A shock to a large economy has a stronger impact on world production. Consequently, world output tends to co-move with large economies rather than smaller ones. The following lemma formalizes this intuition.

Lemma 2. *Let* $\Psi_i \equiv cov\left(A_W^{-\sigma}; A_i\right)$. *Assume that* $\{A_i(s)\}_{i=1}^{I}$ *is i.i.d. across countries. If* $L_j > L_h$*, then* $\Psi_j < \Psi_h$.

Proof: See Appendix. □

With i.i.d. shocks, large economies are the ones that strongly co-move with world shocks. As emphasized in Proposition 1, this characteristic negatively affects MP inflows into larger

[22] The social planner problem is shown in the Appendix

economies. However, production is subject to economies of scale so larger markets attracts more MP flows. Then, as it can be seen from (30), the host country weight ϖ_i affects the value of an affiliate in two offsetting ways: it directly increases the discounted flow of profits as the market is larger but such profits flow has a less attractive stochastic pattern that results in lower $E\left(A_W^{-\sigma}; A_i\right)$. The overall effect of country size on location is ambiguous and so is the effect of MP flows on the consumption risk premium. The following proposition characterizes the response of the consumption risk premium to different directions of MP flows.

Proposition 2. *Let ρ be the consumption risk premium defined by $u\left[E\left(C_i\right)(1-\rho)\right] = E\left[u\left(C_i\right)\right]$. Assume that $\{A_i(s)\}_{i=1}^{I}$ is i.i.d. across countries. If $L_h = \max\{L_i\}_{i=1}^{I}$, then technology flows of the form $dZ_{jh} > 0$ increase the consumption risk premium. If $L_h = \min\{L_i\}_{i=1}^{I}$, then technology flows of the form $dZ_{jh} > 0$ decrease the consumption risk premium.*

Proof: See Appendix. □

4.3 The effects of MP Liberalization on Consumption Risk

The interaction among country size, entry cost, and the stochastic properties of country shocks determine the location pattern of affiliates. In turn, these patterns dictate how MP flows affect the consumption risk premium. In this numerical exercise, we calibrate the MP entry costs to observed bilateral MP, country size to a measure of equipped labor, and country shocks to the observed time series properties of real GDP per capita, for a set of OECD countries.[23] We use the calibrated version of the model to perform counterfactual exercises that highlight the effects of the location patterns of affiliates of multinational firms on the consumption risk premium.

Parameters are chosen in the following way. Bilateral fixed costs are calibrated to exactly

[23] We restrict the analysis to the following countries: Australia, Austria, Belgium/Luxemburg, Canada, Denmark, Spain, Finland, France, United Kingdom, Germany, Greece, Italy, Japan, Netherlands, Norway, New Zealand, Portugal, Sweden, and United States.

match the gross value of production of affiliates from country i in j, as share of country j's GDP, for an average over the nineties.[24] The variable L_i is set to a measure of total labor force in which employment is adjusted to account for human and physical capital per worker, for an average over the nineties.[25] We assume that the vector of country shocks follows a log-normal distribution of the form $\log \mathbf{A} \sim N(\mu, \mathbf{\Omega})$, where μ is the vector of average (log) realizations of the shock, and $\mathbf{\Omega}$ is the variance-covariance matrix, across countries. We calibrate the matrix $\mathbf{\Omega}$ to the variance-covariance matrix of the (log of) real GDP per capita observed in the data, for the period 1970-2004, among OECD countries, and the vector μ to the average real GDP per capita observed in the data over the same period.[26] We assume that firm specific productivity is drawn from a Pareto distribution with shape parameter γ (common across countries), $G(z) = 1 - z^{-\gamma}$, that we scale by the size of the country's labor force, L_i, so that $G_i(z) = L_i G(z)$. The remaining parameters are taken from the literature, as shown in the following table.

The calibration procedure and data are described in more detail in the Appendix.

Parameter	Value	Source	Definition
σ	2	Backus, Kehoe, and Kydland (1992)	risk aversion
η	3	Broda and Weinstein (2004)	elast. of substitution for intermediates
γ	4	Helpman, Melitz, and Yeaple (2004)	Pareto parameter, $G(z) = 1 - z^{-\gamma}$
α	0.5	Alvarez and Lucas (2007)	labor share in final good sector

Table 1: Parameters from literature.

Table 2 presents some key variables delivered by the calibred version of the model. The United States are the largest economy: their weight on world risk, given by their share of total effective productive size, is $\varpi_i = 46\%$ according to our calibration. But, since the stochastic process of shocks is very heterogeneous across countries, a large weight in world risk does not uniformly translate into a stronger correlation between the country's shock and the stochastic

[24]Source: UNCTAD. See Ramondo (2008) for a detailed description of these data.
[25]Source: Klenow and Rodriguez-Clare (2005).
[26]Source: Penn World Tables (6.2). We de-trend the log of real GDP per capita series using a Hodrick-Precott filter.

discount factor, $COR\left(A_W^{-\sigma}; A_i\right)$.

Country	Size$^\sharp$ (% of world total)	$COR\left(A_W^{-\sigma}; A_i\right)^\natural$	Median MP Costs†		Technology Flows (%)‡		
			outward	inward	outward	inward	net
Australia	1.5	-0.48	5.4	15	0.8	3.5	-2.7
Austria	0.4	-0.59	2.6	38	0.8	1.5	-0.8
Belgium	0.6	-0.69	2.2	38	1.5	3.2	-1.7
Canada	3.2	-0.68	8.8	10	3.3	11	-8.1
Denmark	0.3	-0.60	0.7	188	0.8	0.4	0.4
Spain	2.1	-0.63	13.4	15	0.8	3.4	-2.6
Finland	0.3	-0.39	0.5	106	1.3	0.6	0.6
France	4.7	-0.69	0.6	5.2	6.0	5.9	0.1
Great Britain	0.051	-0.83	0.9	3.4	9.0	11	-2.1
Germany	9.3	-0.64	0.3	2.3	14	13.4	0.5
Greece	0.4	-0.56	34.2	135	0.0	0.3	-0.3
Italy	3.7	-0.68	4.1	16	1.9	2.8	-0.9
Japan	19.8	-0.62	3.3	35	15	4.0	11
Netherlands	1.1	-0.73	0.3	5.8	8.4	5.7	2.7
Norway	0..3	-0.17	1.0	109	0.6	0.5	0.1
New Zealand	0.2	-0.01	10.4	326	0.1	0.5	-0.4
Portugal	0.4	-0.64	17.1	3.7	0.1	3.4	-3.3
Sweden	0.6	-0.50	0.4	26	2.1	1.8	0.3
United States	46.1	-0.86	1.0	1.0	34	27	7.6

$\sharp$: ϖ_i is the model measure of the share of country i in world effective productive size, as defined in equation (25), in percentage. $\natural$: $COR\left(A_W^{-\sigma}; A_i\right)$ is the correlation coefficient between the shock in country i and the state-dependent part of the stochastic discount factor, given by the model measure of the world average shock A_W as defined in equation (24). $\dagger$: Median Outward MP costs for country $i = \text{median}_{j \neq i}\ f_{ij}$ (relative to $\text{median}_{j \neq US}\ f_{US,j}$); Median Inward MP costs for country $i = \text{median}_{j \neq i}$ f_{ji} (relative to $\text{median}_{j \neq US}\ f_{j,US}$). $\ddagger$: Outward technology flows for country $i = \sum_{j;j \neq i} Z_{ij}$, Inward technology flows for country $i = \sum_{j;j \neq i} Z_{ji}$, and Net = Outward - Inward, as % of world technology flows $\sum_{i,j;i \neq j} Z_{ij}$.

Table 2: Calibrated Model.

The calibrated values for bilateral entry costs for foreign affiliates are summarized in columns III and IV of Table 2. The median entry cost for affiliates of multinational firms abroad from country i is presented relative to the median cost for affiliates abroad of U.S. multinationals (outward). Analogously, the median entry cost for affiliates of foreign multinationals into country i is presented relative to the median cost a foreign multinationals incur when it opens an affiliate in the United States (inward). As expected, those countries with low MP flows (as share of GDP) in the data are characterized by high entry costs, while those countries with relative high MP flows have low entry costs.

Finally, the model provides a measure of the technology transfer embedded in MP flows between country pairs. This is the index for firm specific productivity for affiliates from country i to j, $Z_{ij} \equiv \int_{\bar{z}_{ij}}^{\infty} z^{\eta-1} L_i dG(z)$. Columns V-VII in Table 2 present outward, inward, and net technology flows, respectively, by country (each as a share of total flows in the world). Outward flows from country i are computed as $\sum_{j;j\neq i} Z_{ij}$, while inward flows are $\sum_{j;j\neq i} Z_{ji}$, both as a share of $\sum_{i,j;i\neq j} Z_{ij}$. The model predicts that large countries tend to be net exporters of technologies, having both large technology inflows and outflows. This is similar to what we observe in the data regarding outward, inward, and net MP flows: the correlation between net technology flows predicted by the calibrated model and the observed net MP flows in the data is 0.52.[27]

The next two tables perform counterfactual exercise in order to evaluate the impact of MP flows on aggregate risk.

	Overall Effect	Size Effect†	Risk Effect‡
Change in risk premium (from no MP to observed MP patterns)	-0.21%	-2.01%	1.57%

†: we assume that $cov(A_i, A_j) = 0$, for $i \neq j$, $cov(A_i, A_i) = \text{median}(\sigma_i^2)$, and $E(A_i) = \text{median}(\mu_i)$, for all i. ‡: we assume that $L_i = \sum_{k=1}^{I} L_k / I$, for all i.

Table 3: The effects of MP on world risk. Decomposition.

We calculate the change in the consumption risk premium that results of moving from a world without MP -$f_{ij} \to \infty$ for all $i \neq j$- but complete financial markets, to a world with the observed patterns of MP. According to this exercise, as shown in Table 3, the observed location of MP

[27]Total outward and inward MP flows in the data for each country are presented in table 6 in the Appendix.

activities across countries reduces the consumption risk premium by only 0.21% with respect to a world with complete financial markets but no endogenous reallocation of production.[28]

Two offsetting forces are behind the overall effect of the endogenous reallocation of production on the consumption risk premium. As shown in Table 2, large economies are net sources of technology, while small economies tend to be net recipients. If countries had symmetric risk patterns, flows towards smaller countries should reduce consumption risk, as shown in Proposition 2. However, countries are very different in their risk patterns; this heterogeneity offsets the size effects of MP on risk patterns. To highlight this point, we decompose the overall impact of MP on the consumption risk premium into two effects. First, we isolate the "size" effect. We assume that country shocks are i.i.d. with identical mean and variance given by the sample median, and countries are heterogenous in size L_i as in our calibrated version of the model.[29] Using this environment, we ask how much the consumption risk premium would change if we moved from a world without MP but complete financial markets to a world with the observed cross-country patterns of MP.[30] In line with Proposition 2, since small countries are net receivers of foreign technologies, the presence of MP flows reduces the consumption risk premium by 2.01%. Second, we isolate the "risk" effect, which shows the effect of MP flows on the consumption risk premium assuming that the stochastic process for country shocks across countries is as calibrated from the data, but countries are symmetric in size ($L_i = \sum_{k=1}^{I} L_k/I$, for all i). Again, using this second environment, we ask how much the consumption risk premium would change if we moved from a world without MP but complete financial markets to a world with the observed cross-country patterns of MP. Our calculations suggest that the consumption risk premium increases by 1.57% due to this effect, offsetting the size effect.

[28] Indeed, total welfare is increased by 6% from a world with no MP to a world with the observed MP flows, if we only consider the increase in utility in the second period. If we also consider consumption in the initial period, welfare increases by roughly 0.5%.

[29] Using the mean rather than the median for the variance and mean of country shocks delivers very similar results.

[30] Notice that this world with i.i.d. shocks may have a different configuration of MP entry costs in order to replicate the bilateral pattern of MP in the data.

	Benchmark†	No MP‡	frictionless MP$^{\natural}$ from U.S.	frictionless MP$^{\sharp}$ into U.S.
Change in risk premium (from benchmark to:)		0.21%	-7.5%	3.9%
Correlation between Y_i and Y_W:				
Australia	0.48	0.48	0.45	0.51
Austria	0.59	0.59	0.64	0.56
Belgium	0.69	0.69	0.75	0.65
Canada	0.68	0.67	0.68	0.70
Denmark	0.61	0.60	0.57	0.63
Spain	0.63	0.63	0.69	0.60
Finland	0.39	0.39	0.43	0.39
France	0.69	0.68	0.74	0.66
Great Britain	0.83	0.82	0.83	0.83
Germany	0.64	0.64	0.65	0.61
Greece	0.56	0.56	0.58	0.54
Italy	0.68	0.68	0.73	0.66
Japan	0.62	0.63	0.64	0.59
Netherlands	0.73	0.73	0.75	0.72
Norway	0.17	0.17	0.14	0.20
New Zealand	0.01	0.01	0.02	0.03
Portugal	0.64	0.64	0.69	0.60
Sweden	0.50	0.50	0.54	0.50
United States	0.86	0.86	0.81	0.89

†: calibrated version of the model. ‡: $f_{ij} \to \infty$ for all $i \neq j$. $^{\natural}$: $f_{US,j} = 0$, for all j, and $f_{ij} \to \infty$ for all $i \neq j$ and $i \neq US$. $^{\sharp}$: $f_{j,US} = 0$ for all j and $f_{ij} = \infty$ for all $i \neq j$ and $j \neq US$.

Table 4: The effects of MP on world risk.

Table 4 presents another set of counterfactual exercises aimed to highlight how the direction of MP flows affects the consumption risk premium. We calculate the change in the consumption risk premium from a situation with no MP to one where the United States are the only source of MP activities, and another one where the United States are the only destination, respectively. That is, column III presents results for $f_{US,j} = 0$, for all destination countries j and $f_{ij} \to \infty$ for all $i \neq j$ and $i \neq US$, while column IV presents the case in which $f_{j,US} = 0$ for all source countries j and $f_{ij} = \infty$ for all $i \neq j$ and $j \neq US$. We report the correlation between country output Y_i and world output Y_W, for the calibrated version of the model and each counterfactual scenario.

According to our calibrated model, the United States, being the largest country in the sample, have also the strongest co-movement with world risk (0.89). As suggested by Proposition 2, when they are the only source of MP flows in the world (column III), the risk premium is reduced by 7.5% with respect to autarky. In this case, the co-movement between U.S.'s GDP and world's fluctuations drops by 5.5% relative to autarky, as U.S. specific shock affects a lower share of world production. Correspondingly, when the United States are the sole recipient of affiliates from the remaining eighteen OECD countries (column IV), the correlation between U.S.'s GDP and world fluctuations rises by almost 4%. In this case, the rest of the world reduces its capacity to provide insurance against U.S. shocks and the consumption risk premium increases by 3.9%.

5 Conclusions

This paper emphasizes the connection between international technology flows and the pattern of international risk. We analyze the effects of a natural form of technology transfer across countries: the one embedded in the activity of multinational firms.

By modeling Foreign Direct Investment (FDI) as an international technology and portfolio flow, the main contribution of this paper is to uncover an additional channel through which the activities of multinational firms change consumer's welfare. By altering host country's productivity, the activity of multinational firms affects the patterns of world risk even under complete financial markets.

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6 Proofs

6.1 Proof of Lemma 1

Combining the utility function in (1), world output in (20), and consumption in (27), the risk premium ρ_i is constant across countries $i = 1, ..., I$:

$$\rho = 1 - \frac{E\left(Y_W^{1-\sigma}\right)^{\frac{1}{1-\sigma}}}{E\left(Y_W\right)} = 1 - \frac{E\left(A_W^{1-\sigma}\right)^{\frac{1}{1-\sigma}}}{A_0 + 1}.$$

Recall that $A_W(s) \equiv A_0 + \sum_i \varpi_i A_i(s)$. Under the assumption that $E(A_i) = 1$, for all $i = 1, ..., I$, the risk premium decreases if $d\varpi_j = -d\varpi_h > 0$:

$$\frac{d\rho}{d\varpi_j} - \frac{d\rho}{d\varpi_h} = -(1-\rho)\frac{\Psi_j - \Psi_h}{E\left(A_W^{1-\sigma}\right)} < 0. \square$$

6.2 Proof of Proposition 1

By contradiction. Consider for a moment there is country j^* such that the marginal multinational firm from country j^* into country i and h satisfies $\overline{z}_{j^*i} \geq \overline{z}_{j^*h}$.
Since $f_{jk} = f$ for all j, then $V(\overline{z}_{j^*k}) = V(\overline{z}_{jk})$ for all j. Follows from equation (11) that $\overline{z}_{jk} = \overline{z}_k$ for all j. Then, if $\overline{z}_{j^*i} \geq \overline{z}_{j^*h}$, it has to be that $\overline{z}_{ji} \geq \overline{z}_{jh}$ for all j and therefore, $Z_i < Z_h$.
Similarly, since $f_{jk} = f$ for all k, the free entry condition for the marginal firm implies $V(\overline{z}_{j^*i}) = V(\overline{z}_{j^*h})$. Replacing with equation (11), this condition can be rewritten as:

$$\left(\frac{\overline{z}_{j^*i}}{\overline{z}_{j^*k}}\right)^{\eta-1} = \frac{Z_i}{Z_h} \cdot \frac{\sum_{s\in S}\varphi(s)Y_h(s)}{\sum_{s\in S}\varphi(s)Y_i(s)}.$$

From (29) and (20), we know that

$$\frac{\sum_{s\in S}\varphi(s)Y_h(s)}{\sum_{s\in S}\varphi(s)Y_i(s)}=\left(\frac{Z_h}{Z_i}\right)^{\frac{1-\alpha}{\eta-1}}\frac{\left(E\left[A_W^{-\sigma}\right]+\Psi_h\right)}{\left(E\left[A_W^{-\sigma}\right]+\Psi_i\right)}.$$

Then, under Assumption (1) and $\Psi_i > \Psi_h$, it has to be that $\overline{z}_{j^*i} \geq \overline{z}_{j^*h}$ only if $Z_i > Z_h$, which it was proven above not to be the case. Then, it must be that for all $j \neq i, h$: $\overline{z}_{ji} < \overline{z}_{jh}$.□

6.3 Proof of Lemma 2

Define $A_W(s) = A_0 + \sum_{i=1}^{I} \varpi_i A_i(s)$, where A_0 positive and constant across states of nature, and $A_i(s)$ are i.i.d. and positive, for all $i = 1, ..., I$ and $s \in S$. Therefore, $A_W(s) > 0$, for all $s \in S$, which implies the following condition:

$$\frac{d}{d\varpi_i}E\left(A_W^{-\sigma}A_i\right)=-\sigma E\left(A_W^{-\sigma-1}A_i^2\right)<0.$$

Assume for the moment that $Z_j = Z_h$. Then $L_j > L_h$ implies $\varpi_j > \varpi_h$. If $\varpi_j > \varpi_h$, then $E\left(A_W^{-\sigma}A_j\right) < E\left(A_W^{-\sigma}A_h\right)$. Or, equivalently,

$$cov\left(A_W^{-\sigma};A_j\right)+E\left(A_W^{-\sigma}\right)E\left(A_j\right)<cov\left(A_W^{-\sigma};A_h\right)+E\left(A_W^{-\sigma}\right)E\left(A_h\right).$$

Since $E(A_j) = E(A_h)$, it follows that $cov\left(A_W^{-\sigma};A_j\right) < cov\left(A_W^{-\sigma};A_h\right)$.
Applying the same logic as in the proof of Proposition 1, the inequality $cov\left(A_W^{-\sigma};A_j\right) < cov\left(A_W^{-\sigma};A_h\right)$ is maintained if Z_j and Z_h are endogenous. The opposite would require $Z_j < Z_h$, which can only be an equilibrium outcome if $cov\left(A_W^{-\sigma};A_j\right) < cov\left(A_W^{-\sigma};A_h\right)$.□

6.4 Proof of Proposition 2

From Lemma 2 follows that $L_h = \max\{L_i\}_{i=1}^{I}$ implies that $\Psi_h = \min\{\Psi_i\}_{i=1}^{I}$. Let $-h$ be a geographic agglomerate of all countries except h. Since shocks are i.i.d.: $\Psi_h < \Psi_{-h}$. From equation (25), follows that:

$$\frac{d\varpi_h}{dZ_h}=-\frac{d\varpi_{-h}}{dZ_h}=\frac{1-\alpha}{\eta-1}\cdot\frac{\varpi_h\left(1-\varpi_h\right)}{Z_h}>0$$

Follows from Lemma 1 that any location of affiliates that results in $dZ_h > 0$, and therefore $d\varpi_h = -d\varpi_{-h} > 0$, increases consumption risk ρ. A symmetric reasoning concludes that for $L_h = \min\{L_i\}_{i=1}^{I}$, technology flows of the form $dZ_{jh} > 0$ decrease ρ.□

6.5 Social Planner Problem

The social planner is constrained to monopolistic competition in the intermediate good market. That is, the social planner problem takes quantities from the national equilibrium in Section 3.1 as given. The efficient allocation is defined by $\{\Gamma_i\}_{i=1}^I$ with $\Gamma_i = \left[C_i(0), \{C_i(s)\}_{s\in S}, \{\overline{z}_{ij}\}_{j=1}^I\right]$ that satisfies the following program:

$$\begin{aligned} & \max_{\{\Gamma_i\}_{i=1}^I} \sum_{i=1}^I \lambda_i \left[u(C_i(0)) + \beta \sum_{s\in S} \Pr(s)\, u(C_i(s))\right] \\ & s.t. \\ \sum_{i=1}^I Y_i(0) &= \sum_{i=1}^I C_i(0) + \sum_{i=1}^I \sum_{j=1}^I [1 - G(\overline{z}_{ji})] f_{ji} \\ \sum_{i=1}^I Y_i(s) &= \sum_{i=1}^I C_i(s) \qquad (s \in S) \\ Y_i(s) &= \phi_3 \cdot L_i Z_i^{\frac{1-\alpha}{\eta-1}} \cdot A_i(s) \end{aligned}$$

where λ_i is weight of country i on the Social Planner's objective function. As in the decentralized economy presented in the paper, the optimal allocation involves perfect international risk sharing,

$$\frac{u'(C_j(s))}{u'(C_j(0))} = \frac{u'(C_i(s))}{u'(C_i(0))}$$

With CRRA preferences, it implies $C_i(s) = \left\{\lambda_i^{1/\sigma}\left[\sum_{j=1}^I \lambda_j^{1/\sigma}\right]^{-1}\right\} \cdot \sum_{i=1}^I Y_i(s)$, as in equation (27) in the body of the paper. The efficient entry decision for a firm from country j into country i is given by a cut-off productivity level $\overline{z}_{ji}$ that satisfies the following first order condition:

$$foc(\overline{z}_{ji}) = \sum_s \mu(s) \frac{dY_i(s)}{d\overline{z}_{ji}} + dG(\overline{z}_{ji}) f_{ji} = -\phi_3 \cdot \left(\frac{1-\alpha}{\eta-1}\right) \frac{\overline{z}_{ji}^{\eta-1}}{Z_i} L_i Z_i^{\frac{1-\alpha}{\eta-1}} \sum_{s\in S} \mu(s) A_i(s) + f_{ji}$$

The multiplier $\mu(s)$ on the world resource constraint in state s is the marginal utility of world output in that state of nature: $\mu(s) = \Pr(s)\, \beta \sum_{i=1}^I \lambda_i u'(C_i(s))$. Thus, with CRRA preferences, the following condition characterizes the efficient location of affiliates:

$$\phi_6 \cdot \frac{\overline{z}_{ji}^{\eta-1}}{Z_i} \cdot \varpi_i \cdot E\left(A_W^{-\sigma} \cdot A_i\right) = f_{ji},$$

where A_W is defined as in the body of the paper: $A_W(s) \equiv \sum_{i=1}^I \varpi_i A_i(s)$. This condition is equivalent to the zero profit condition in (30) for the decentralized problem.

7 Model's Extension: Physical Capital

The model in Section 2 has labor as the only factor of production, which is assumed immobile across countries. In this section, we extend the model in Section 2 to incorporate physical capital as a factor of production which we assume is freely mobile across countries. This extension highlights the difference between MP and capital flows: while the former involves technology flows, the latter does not.[31] International technology transfers imbedded in MP activities increase the marginal product of capital in the host economy. Hence, the activity of multinational firms creates a complementarity between capital and FDI flows which reinforces the location patterns of production analyzed in the basic model.

We assume that investment in physical capital is also done in units of the final good. In the initial period, households decide how much to consume and how much to leave as physical capital. The resulting stock of capital is used to set-up foreign affiliates in period zero, before country shocks are realized. And, in period one, after country shocks are realized, capital is used in production.

Production of an intermediate good done by an affiliate of a firm from country j with productivity z, located in i, is given by

$$q_{ji}(z,s) = z \cdot l_{ji}(z,s)^{\nu} k_{ji}(z,s)^{1-\nu}, \tag{31}$$

while the production of the final good in country i is given by

$$Y_i(s) = A_i(s) \cdot \left[L_i^f(s)^{\nu} K_i^f(s)^{1-\nu}\right]^{\alpha} \cdot Q_i(s)^{1-\alpha}, \tag{32}$$

where $0 < \nu < 1$.

Since capital is freely mobile across countries (and sectors), the equilibrium allocation entails equalization of marginal products across sectors within a country, across countries, and across usages (i.e. setting up foreign affiliates at time zero, and production of goods in period one).

We add to Definition 1 of the national equilibrium, the allocation of physical capital across sectors, in each country i and state s, $\left\{\langle k_{ji}(z,s)\rangle_z, K_i^f(s)\right\}$. In each country, the marginal product of capital across goods in state s, is equalized,

$$\frac{p_{ji}(z,s) \cdot q_{ji}(z,s)}{k_{ji}(z,s)} = \alpha \frac{Y_i(s)}{K_i^f(s)},$$

for all z and s. Combining this condition with the market clearing condition for good z in (4),

[31] This difference is also highlighted by McGrattan and Prescott (2009) in the context of a neoclassical growth model that incorporates both physical and technology capital.

we get:

$$k_{ji}(z,s) = (1-\alpha)\cdot\frac{z^{\eta-1}}{Z_i}\cdot K_i(s), \qquad (33)$$

$$K_i^f(s) = \alpha\cdot K_i(s), \qquad (34)$$

where $K_i(s)$ is total capital in country i and state s, $K_i(s) = K_i^f(s) + \sum_{j=1}^{I} K_{ji}(s)$ with $K_{ji}(s) = \int_{\overline{z}_{ji}}^{\infty} k_{ji}(z,s)\, dG(z)$. Combining (32), (33), and (34), the capital stock in country i, state s, is:

$$K_i(s) = (1-\nu)\cdot Y_i(s). \qquad (35)$$

The characterization of the national equilibrium with physical capital is analogous to the one described in Section 3, with final output in country i given by:

$$Y_i(s) = \widetilde{\phi}_3\cdot L_i\widetilde{Z}_i\cdot A_i(s)^{\frac{1}{\nu}}, \qquad (36)$$

where $\widetilde{Z}_i \equiv Z_i^{\frac{1-\alpha}{\nu(\eta-1)}}$ and $\widetilde{\phi}_3$ is a positive constant.[32] Solving for world output, we get

$$Y_W(s) = \sum_{i=1}^{I} Y_i(s) = \widetilde{\phi}_3\cdot L_W\widetilde{Z}_W\cdot A_W(s)^{\frac{1}{\nu}}, \qquad (37)$$

where $L_W\widetilde{Z}_W \equiv \sum_{i=1}^{I} L_i\widetilde{Z}_i$, and the average world shock is now $A_W(s)^{\frac{1}{\nu}} \equiv \sum_{i=1}^{I}\widetilde{\varpi}_i A_i(s)^{1/\nu}$, with $\widetilde{\varpi}_i \equiv L_i\widetilde{Z}_i/\left(L_W\widetilde{Z}_W\right)$. As in the framework without physical capital, the weight of a country in aggregate fluctuations is given by the size of its labor force L_i, and aggregate productivity of firms located there Z_i.

Qualitatively, results are identical to those for the basic model. Thus, Proposition 1 still holds. Everything else equal, foreign affiliates locate in economies with shocks least correlated with world shocks. In that scenario, the existence of MP flows reduces the consumption risk premium in all countries.[33]

The inclusion of physical capital reinforces the results in the previous sections. From (35) and (37), the allocation of capital across countries is given by

$$K_i(s) = \widetilde{\varpi}_i\left(\frac{A_i(s)}{A_W(s)}\right)^{\frac{1}{\nu}}\sum_{j=1}^{I} K_j(s).$$

This expression entails two features of international capital flows that are worth emphasizing.

[32] $\widetilde{\phi}_3 \equiv \left[\alpha^{\alpha}(1-\alpha)^{1-\alpha}(1-\nu)^{(1-\nu)}\right]^{\frac{1}{\nu}}\left(\frac{\eta}{\eta-1+\alpha}\right)$.

[33] The parameter Ψ_i in Proposition 1 is now defined as $\Psi_i \equiv cov\left(A_W^{-\sigma/\nu}; A_i^{1/\nu}\right)$.

First, while capital flows fluctuate with the (relative) magnitude of country shocks, the weight $\widetilde{\varpi}_i$ is constant across states. This is a direct consequence of the assumption that setting-up an affiliate requires a once-and-for-all cost incurred before uncertainty is realized. In this way, this assumption captures a striking pattern in the data: while financial capital flows are extremely reactive to transitory shocks, MP, as it involves longer term investment, is not.[34]

Second, the capital stock for country i in any state, is higher when more productive firms are located there (higher Z_i that implies higher $\widetilde{\varpi}_i$). This result is particularly relevant for our analysis. Opening foreign affiliates involves technology transfers to the host economy, and that affects the marginal product of all factors there. With mobile capital, MP and capital flows are complements: the more affiliates located in country i, the higher the marginal product of capital there and, therefore, the larger the capital inflows into that economy. This complementarity, by inducing further capital flows into a country, reinforces the shift of production towards economies with shocks least correlated with world risk, and strengths the result in Proposition 1.

8 Calibration Procedure

We calibrate the variable L_i in the model to a measure of equipped labor constructed by Klenow and Rodriguez-Clare (2005), that takes into account physical as well as human capital, an average over the nineties. The United States is normalized to one, $L_{US}1$.

Firm specific productivity in each country follows a Pareto distribution, characterized by the same parameter γ, and scaled by the size of the labor force, $G_i = L_i(1 - z^{-\gamma})$. Thus, the aggregate productivity of firms operating in their own country is

$$Z_{jj} = L_j \frac{\gamma}{\gamma + 1 - \eta}.$$

We calibrate MP entry costs in the model to match the observed gross production of affiliates from country i in country j as share of j's GDP (an average over the nineties), $sh_{ij} = E\left(X_{ij}/Y_j\right)$, as follows. Using the following relationship from the model,

$$\frac{sh_{ij}}{sh_{jj}} = \frac{X_{ij}}{X_{jj}} = \frac{Z_{ij}}{Z_{jj}},$$

we obtain the aggregate productivity index for affiliates from i in j, Z_{ij},

$$Z_{ij} \quad = \quad L_j \frac{sh_{ij}}{sh_{jj}} \cdot \frac{\gamma}{\gamma + 1 - \eta}.$$

[34] For documentation on this fact see, for example, Lipsey (2001), Albuquerque (2003), and Bachetta and Van Wincoop (2000).

Thus, the cut-off productivity level $\overline{z}_{ij}$ is given by

$$\overline{z}_{ij} = \left(\frac{L_j}{L_i}\frac{sh_{ij}}{sh_{jj}}\right)^{-\frac{1}{(\gamma+1-\eta)}}.$$

The stochastic process for the vector $\mathbf{A} = [A_1, ..., A_I]$ is set to match the stochastic properties for the vector of the real GDP per capita (PPP adjusted) observed in the data over the period 1970-2004, $\mathbf{rgdpl_t} = [rgdpl_{1t}, ..., rgdpl_{It}]$, as follows.[35] In the model, real output (that is equivalent to real GDP) for country i in state s is given by equation (20), that in logs is

$$\log Y_i(s) = \log \phi_3 + \log L_i + \frac{1-\alpha}{\eta-1}\log Z_i + \log A_i(s).$$

Thus, it is clear that $\log Y_i(s)/\overline{Y}_i = \log A_i(s)$, with $\overline{Y}_i$ aggregating the non-state contingent terms. We assume that $\log \mathbf{A} \sim N(\mu, \mathbf{\Omega})$. For the vector μ, we use the average of the (log of) real GDP per capita over the period 1970-2004, for country i, denoted by $E(\log Y_i)$, and calculate $E(\log A_i) = E(\log Y_i) - \log L_i - \frac{1-\alpha}{\eta-1}\log Z_i$, where Y_i/L_i is real GDP per capita from the data, and Z_i is calibrated as explained above. We normalize $E(\log A_{US}) = 1$.[36] For $\mathbf{\Omega}$, we take the variance-covariance matrix of the (log of) real GDP per capita across countries in the data, de-trended using a Hodrick-Prescott filter, for the same period 1970-2004. To simulate the model, we draw 500,000 vectors of shocks (each of size $I \times 1$) from a log-normal distribution characterized by (μ, **Omega**). Then, we recover the matrix of shocks in levels, for each state and each country, and set $\Pr(s) = 1/S$.

Combining the calibrated cut-offs $\{z_{ij}\}_{i,j=1}^{I}$, the process for $\mathbf{A}$, we use the zero profit conditions from the model to derive the implied bilateral entry costs. We normalize U.S. domestic entry costs $f_{US,US} = 1$. Hence, the zero profit condition for U.S. domestic firms is:

$$C(0)^{-\sigma} = \frac{1-\alpha}{\beta} \cdot \frac{\overline{z}_{US,US}^{\eta-1}}{Z_{US}} \cdot E_s[\varphi; Y_{US}],$$

where $C(0) = \sum_{k=1}^{I} C_k(0)$, and $\varphi(s) = \beta \times Y_w^{-\sigma}(s) \times Pr(s)$ with $Y_W(s) = \sum_{k=1}^{I} Y_k(s)$. Thus,

$$f_{ij} = \overline{z}_{ij}^{\eta-1} \cdot \frac{E_s\{\varphi; Y_j\}}{E_s\{\varphi; Y_{US}\}}.$$

9 Data

[35] The variable used from Penn World Tables (6.2) is "rgdpl".

[36] Here, we do not de-trend the real GDP per capita series.

Country	equipped-labor† (as share of U.S.)	S.D. real GDP pc‡	Average real GDP pc‡ (as share of U.S.)
Australia	0.06	0.015	0.976
Austria	0.02	0.018	0.978
Belgium	0.03	0.019	0.971
Canada	0.11	0.027	0.979
Denmark	0.02	0.020	0.984
Spain	0.08	0.032	0.943
Finland	0.02	0.046	0.963
France	0.16	0.017	0.974
United Kingdom	0.16	0.023	0.968
Germany	0.27	0.019	0.974
Greece	0.02	0.035	0.925
Italy	0.13	0.016	0.963
Japan	0.52	0.024	0.968
Netherlands	0.04	0.022	0.977
Norway	0.02	0.022	0.989
New Zealand	0.01	0.028	0.964
Portugal	0.02	0.039	0.925
Sweden	0.03	0.026	0.977
United States	1.00	0.022	1

†: from Klenow and Rodriguez-Clare (2005), average over the nineties. ‡: mean and standard deviation of (log of) real GDP per capita (at constant prices and PPP-adjusted) from PWT 6.2 (RGDPL). H-P Filtered.1970-2004.

Table 5: Summary statistics.

	Outward MP	Inward MP	Net Flows	Equipped-labor
		as % of GDP		relative to U.S.
Australia	0.10	0.28	-0.19	0.09
Austria	0.13	0.29	-0.15	0.04
Belgium	0.22	0.46	-0.25	0.05
Canada	0.26	0.46	-0.20	0.13
Denmark	0.17	0.12	0.05	0.03
Spain	0.03	0.25	-0.21	0.13
Finland	0.48	0.23	0.25	0.03
France	0.18	0.20	-0.02	0.22
Great Britain	0.32	0.35	-0.02	0.21
Germany	0.29	0.29	0.01	0.29
Greece	0.01	0.07	-0.06	0.04
Italy	0.07	0.15	-0.07	0.23
Japan	0.16	0.06	0.10	0.45
Netherlands	1.00	0.50	0.50	0.07
Norway	0.18	0.17	0.01	0.03
New Zealand	0.04	0.25	-0.20	0.02
Portugal	0.04	0.58	-0.54	0.03
Sweden	0.36	0.32	0.04	0.04
United States	0.16	0.18	-0.01	1.00

†: Outward MP is total gross value of production for foreign affiliates from country i; Inward MP is total gross value of production for foreign affiliates in country l. Both magnitudes as share of country's GDP.

Table 6: Outward, Inward, and Net MP Flows. Data.