

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.

A calibration exercise for OECD countries suggests that, consistent with the model, large countries tend to be net exporters of technologies. However, as shocks are strongly correlated across country, technology transfers embedded in MP flows do not substantially reduce the consumption risk premium relative to a world with no MP.

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 distinguish 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.³

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

¹The 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).

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

³See Markusen (1984), Burstein and Monge (2009), and McGrattan and Prescott (2007), among others.

redistribute output across countries in different states of the world, MP alters the amount of 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.⁴ 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.⁵

In a risky environment, the natural question is which type of shocks affect MP activities. One can think that productivity shocks are specific to the multinational firm regardless of where its affiliates are located. Or, that shocks affecting foreign affiliates are specific to the host country of production regardless of whether the plant is domestic or multinational. In this

⁴This specification is similar to Burstein and Monge (2009).

⁵See 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.

paper, we restrict the analysis to “country-embedded” productivity shocks which impact all firms (including foreign affiliates) operating in a country. The location decisions of firms change the amount of production in the host market, and therefore, 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 entry decision to a given market depends on the stochastic properties of the host country shock, the MP entry cost, and the size of the market. In turn, the location patterns of affiliates dictate how MP flows affect the consumption risk premium. We calibrate entry costs to observed 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, consistent with the model, 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 0.5% relative to a world with no MP.

The spirit of our model is close to the one in Acemoglu and Zilibotti (1997) and Martin and Rey (2004). In their set up, the limits to risk diversification are endogenous and given by the number of risky projects that firms undertake. However, in their models, the level of diversification is inefficiently low; entrepreneurs do not internalize the effect of their decision on

consumers' diversification opportunities. In our model with complete markets, financial prices provide firms with the right incentives (and rewards) to lower aggregate risk; the number and geographical allocation of affiliates is then efficient.

Our model also builds on the literature on trade and international risk sharing.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.

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.

2 Model

We present a 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

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

inherit their parent specific productivity at a cost.

Our analysis distinguishes between two assets: shares of firms, some of which are multi-nationals; 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 . 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 and consumption take place.

Let the vector $s \in S$ denote the state of the world economy in the second period characterized by the realization of country shocks, $s = [A_1, \dots, A_I] \in R_+^I$. 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, $E[A_i] = 1$ for all i .⁷ Assume that there is a finite number of states, $S = \{s_1, \dots, s_N\}$, each occurring with probability $\Pr(s) > 0$, $\sum_{s=1}^N \Pr(s) = 1$.

The representative consumer in country i supplies L_i units of labor and maximizes expected utility from final consumption,

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

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

⁷In this economy, all asymmetries in $E[A_i]$ across countries can be equivalently expressed as differences in labor size L_i .

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

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

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,

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

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,

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

⁸Since 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 $0 < \alpha < 1$, 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

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

where $\varphi(s)$ is the date-zero price of an Arrow-Debreu security that pays one unit of final consumption in state s , and B_i^0 is consumers' initial net wealth. The variable $\pi_i(z, s)$ denotes total profits for a firm from country i , with technology z , in state s given by

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

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:

$$\varphi(s) = \frac{\beta \Pr(s)}{\lambda_i} C_i(s)^{-\sigma}, \quad (8)$$

where λ_i is the multiplier on the constraint (6) for consumers in country i .¹⁰

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

¹⁰The multiplier λ_i is also the inverse of the welfare weights of the corresponding planner's problem which is

Foreign Direct Investment (FDI).¹¹ 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} . 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,

$$V_{ij}(z) = \sum_{s \in S} \varphi(s) \pi_{ij}(z, s), \quad (9)$$

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).

Countries are initially endowed with an investment (freely) tradable good K_i . Entry costs are paid in units of this good which international price is denoted by p_k .

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:

$$V_{ij}(\bar{z}_{ij}) = p_k f_{ij}. \quad (10)$$

Firms from country i with $z \geq \bar{z}_{ij}$ open affiliates in j ; the ones with $z < \bar{z}_{ij}$ do not. That is, $\iota_{ij}(z) = 1$ for all $z \geq \bar{z}_{ij}$, and $\iota_{ij}(z) = 0$ for all $z < \bar{z}_{ij}$.¹² Without loss of generality, we assume that national firms have zero entry costs, $f_{jj} = 0$ so that $\bar{z}_{jj} = z_{\min}$.

Finally, net wealth for the representative consumer in country i in (6) is given by the value

presented in the Appendix.

¹¹Foreign 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.

¹²From (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 \bar{z}_{ij} such that $V_{ij}(\bar{z}_{ij}) - f_{ij}p_k = 0$. For all firms with productivity z above that cut-off, the condition $V_{ij}(z) > f_{ij}p_k$ is satisfied and entering market j is optimal.

of the initial endowment of the investment good net of total costs of opening affiliates in each country j ,

$$B_i^0 = p_k \left[K_i - \sum_{j=1}^I f_{ij} [1 - G_i(\bar{z}_{ij})] \right]. \quad (11)$$

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.

3.1 National Equilibrium

Definition 1. *Given the matrix $\{\bar{z}_{ji}\}_{j=1}^I$, an equilibrium in country i and state s is defined by the vectors of output, labor demands, and prices for intermediate goods, $\{\langle q_{ji}(z, s) \rangle_{z \in Z}, \langle l_{ji}(z, s) \rangle_{z \in Z}, \langle p_{ji}(z, s) \rangle_{z \in Z}\}_{j=1}^I$ 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,*

$$x_{ij}(z, s) = q_{ij}(z, s)p_{ij}(z, s); \quad (12)$$

3. *Labor market clears,*

$$L_i = L_i^f(s) + \sum_{j=1}^I L_{ji}(s), \quad (13)$$

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

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

Define $Z_{ji} \equiv \int_{\bar{z}_{ji}}^{\infty} z^{\eta-1} dG_j(z)$, 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 \bar{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

$$A_i(s) = \phi_0 W_i(s)^\alpha P_i(s)^{1-\alpha}, \quad (14)$$

where ϕ_0 is a positive constant.¹³ Using (3) and (14), the wage and price index for the composite intermediate good in country i and state s are, respectively,

$$W_i(s) = \phi_1 \cdot A_i(s) \cdot Z_i^{\frac{1-\alpha}{\eta-1}}, \quad (15)$$

$$P_i(s) = \phi_2 \cdot A_i(s) \cdot Z_i^{\frac{\alpha}{1-\eta}}, \quad (16)$$

where ϕ_1 and ϕ_2 are positive constants.¹⁴ As expected, wages depend positively on aggregate productivity, both in the intermediate good sector Z_i and final good sector $A_i(s)$. Moreover, the effect of country shocks $A_i(s)$ on wages translate one-to-one into the price of the intermediate good $P_i(s)$ which is larger in states with higher realizations of $A_i(s)$.

¹³ $\phi_0 \equiv \alpha^{-\alpha} (1-\alpha)^{-(1-\alpha)}$.

¹⁴ $\phi_1 \equiv \phi_0^{-1} \left(\frac{\eta-1}{\eta}\right)^\alpha$ and $\phi_2 \equiv \phi_0^{-1} \left(\frac{\eta-1}{\eta}\right)^{1-\alpha}$.

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

$$P_i(s)Q_i(s) = (1 - \alpha)Y_i(s), \quad (17)$$

$$W_i(s)L_i^f(s) = \alpha Y_i(s). \quad (18)$$

Labor market equilibrium in (13) implies that total output in the final good sector in country i , state s , is:¹⁵

$$Y_i(s) = \phi_3 \cdot L_i \cdot Z_i^{\frac{1-\alpha}{\eta-1}} \cdot A_i(s), \quad (19)$$

where ϕ_3 is a positive constant.¹⁶ $Y_i(s)$ 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 (16), profits for a firm with productivity z from country j operating in country i are

$$\pi_{ji}(z, s) = \frac{1 - \alpha}{\eta} \cdot \frac{z^{\eta-1}}{Z_i} \cdot Y_i(s) = \phi_3 \frac{1 - \alpha}{\eta} \cdot z^{\eta-1} \cdot L_i \cdot Z_i^{\frac{1-\alpha}{\eta-1}-1} \cdot A_i(s). \quad (20)$$

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).

¹⁵Using the market clearing condition for good z in (12), and (17), 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 (18) and (13), we obtain $Y_i(s) = \frac{\eta}{\eta-1+\alpha} W_i(s) L_i$, which leads to expression (19).

¹⁶ $\phi_3 \equiv \phi_1 \frac{\eta}{\eta-1+\alpha}$.

3.2 International Equilibrium

Definition 2. For a given vector of initial endowments, $\{K_i\}_{i=1}^I$, the international equilibrium is defined by the matrix $\{\bar{z}_{ij}\}_{i,j}$, the price of the investment good p_k , the vector of prices for Arrow-Debreu securities $\{\varphi(s)\}_{s \in S}$, the vector of consumption and holdings of Arrow-Debreu securities $\{C_i(s)\}_{i=1}^I$ and $\{B_i(s)\}_{i=1}^I$, respectively, for each $s \in S$, such that¹⁷

1. The Euler equation in (8) is satisfied, for all countries $i = 1, \dots, I$;
2. The budget constraint in (6) is satisfied, for all countries $i = 1, \dots, I$;
3. The productivity cutoffs $\{\bar{z}_{ij}\}_{i,j}$ satisfy the zero profit conditions in (10), for all country pairs $i, j = 1, \dots, I$;
4. Arrow-Debreu securities are in zero net supply, for each $s \in S$, $\sum_{i=1}^I B_i(s) = 0$;
5. The world resource constraint for the investment good (at time zero) is satisfied,

$$\sum_{i=1}^I K_i = \sum_{i=1}^I \sum_{j=1}^I [1 - G_i(\bar{z}_{ij})] f_{ij}; \quad (21)$$

and

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

$$\sum_{i=1}^I C_i(s) = \sum_{i=1}^I Y_i(s). \quad (22)$$

The world described in this paper is analogous to a Lucas-type endowment economy with output in country i given by (19), $Y_i(s) = \phi_3 Z_i^{\frac{1-\alpha}{\eta-1}} L_i A_i(s)$. We can interpret $\phi_3 L_i Z_i^{\frac{1-\alpha}{\eta-1}}$ as the number of efficiency units of trees, and $A_i(s)$ as the amount of fruits delivered in state s

¹⁷This equilibrium is efficient. See the Appendix for the formulation of the corresponding social planner problem.

by each tree located in i . Thus, world output in each state s is the world amount of fruits, $Y_W(s) = \sum_{i=1}^I Y_i(s)$.

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

$$A_W(s) \equiv \sum_{i=1}^I \varpi_i A_i(s) \quad (23)$$

with

$$\varpi_i \equiv \frac{L_i Z_i^{\frac{1-\alpha}{\eta-1}}}{\sum_{i=1}^N L_i Z_i^{\frac{1-\alpha}{\eta-1}}}. \quad (24)$$

World output can then be expressed as

$$Y_W(s) = \sum_{i=1}^I Y_i(s) = \phi_3 \cdot A_W(s) \cdot L_W Z_W, \quad (25)$$

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 , $d^2 Y_W/dA_i d\varpi_i > 0$. 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. That is, from (8), the ratio of consumptions between any country pair is constant across states of nature, $C_i(s)/C_j(s) = \lambda_j/\lambda_i$. Combining this expression with the world feasibility constraint for the final good in (22), consumption in country i is a constant share of the world output of the final good,

$$C_i(s) = \mu_i Y_W(s), \quad (26)$$

where $\mu_i \equiv \lambda_i^{1/\sigma} / \sum_{k=1}^I \lambda_k^{1/\sigma}$ and $\sum_{i=1}^I \mu_i = 1$. It is clear from (26), that even though consumers perfectly share country-specific risks, consumption fluctuates with world output across states of nature. The existence of aggregate risk is the obvious limitation of international trade and financial flows to diversify country risks. That is, 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.¹⁸ 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. *Define $\Psi_i \equiv \text{cov}(A_W^{-\sigma}; A_i)$, and let ρ_i be the consumption risk premium defined by $u[E(C_i)(1 - \rho_i)] = E[u(C_i)]$. Consider two countries i 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_i decreases (increases) for all i .*

Proof: See Appendix. □

¹⁸In 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.

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 (9) and (20), the value of doing MP for a firm with productivity z from country i in country j , net of entry costs is

$$\frac{1 - \alpha}{\eta} \cdot \frac{z^{\eta-1}}{Z_j} \cdot \sum_{s \in S} \varphi(s) Y_j(s) - p_k f_{ij}, \quad (27)$$

where $Y_j(s) = \phi_3 \cdot L_j \cdot Z_j^{\frac{1-\alpha}{\eta-1}} \cdot A_j(s)$, as specified in (19). From (27), 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 (27) decreases with aggregate productivity of firms Z_i .¹⁹ 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 (26) in (8), the price of an Arrow-Debreu security in state s is

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

where ϕ_4 is a positive constant, and $Y_W(s)$ world output in 25.²⁰ Further combining (27) and (29), the value of doing MP in country j can be expressed as $V_{ij}(z) = \phi_5 \cdot \frac{z^{\eta-1}}{Z_j} \cdot E[Y_W^{-\sigma} \cdot Y_j]$, where ϕ_5 is a positive constant.²¹ Crucially, the discounted flow of profits depends on the correlation between the marginal utility of consumption, $Y_W^{-\sigma}(s)$, and output in the host country, $Y_j(s)$.

¹⁹

$$\frac{dV_{ij}(z)}{dZ_j} = \sum_{s \in S} \varphi(s) \left\{ \frac{\partial \pi_{ij}(z, s)}{\partial Z_j(s)} + \frac{\partial \pi_{ij}(z, s)}{\partial Y_j(s)} \frac{\partial Y_j(s)}{\partial Z_j} \right\} = - \left(1 - \frac{1 - \alpha}{\eta - 1} \right) \frac{V_{ij}(z)}{Z_j} < 0. \quad (28)$$

²⁰ $\phi_4 \equiv \beta \left(\sum_k \lambda_k^{-1/\sigma} \right)^{-\sigma}$.

²¹ $\phi_5 \equiv \phi_3 \phi_4 \frac{1 - \alpha}{\eta}$.

Clearly, 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 (19) and (25), 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 ,

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

where ϕ_6 is a positive constant, and $A_W(s)$ is defined in (23).²² The stochastic properties of $A_j(s)$ determine the value of a foreign affiliate located in j . As suggested by (30), it is more profitable to locate affiliates in economies with shocks less correlated with world risk $A_W(s)$. By opening foreign affiliates and changing the amount of output across states of nature, firms can have relatively higher profits when world output is more scarce. This is the intuition behind the following proposition.

Proposition 1. *Let $\Psi_i \equiv \text{cov}(A_W^{-\sigma}; A_i)$. 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 $\bar{z}_{ji} < \bar{z}_{jh}$, 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.

²² $\phi_6 \equiv \phi_5 \phi_3^{1-\sigma} \left[\sum_{i=1}^I L_i Z_i^{\frac{1-\alpha}{\eta-1}} \right]^{1-\sigma}$.

Hence, the equilibrium location of production across countries is efficient.²³ 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 (23), $\varpi_i = L_i Z_i^{\frac{1-\alpha}{\eta-1}} / \sum_{i=1}^I L_i Z_i^{\frac{1-\alpha}{\eta-1}}$. 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 $\Psi_i \equiv \text{cov}(A_W^{-\sigma}; A_i)$. 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

²³The 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 $E(A_W^{-\sigma}; A_i)$. 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_i be the consumption risk premium defined by $u[E(C_i)(1 - \rho_i)] = E[u(C_i)]$. 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 determines the location pattern of affiliates. In turn, these patterns dictates 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 GDP per capita, for a set of OECD countries.²⁴ We first simulate the gains of moving from autarky —that is, a world without MP— to a world with the calibrated levels of MP entry costs. We use this framework to perform counterfactual exercises that highlight the effects of the location patterns of affiliates on consumption risk.

²⁴We 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.

Parameters are chosen in the following way. Bilateral fixed costs are calibrated to match gross value of production of affiliates from country i in j , as share of country j 's GDP, for an average over the nineties.²⁵ 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.²⁶ Finally, given the pattern of MP across countries and the size of countries, the stochastic process for country shocks is set to match the time series properties of real GDP per capita observed in the data, for the period 1970-2004, among OECD countries.²⁷ We assume that these shocks follow a log normal distribution.²⁸ The procedure and data used in the calibration is presented in Appendix. The remaining parameters are taken from the literature, as shown in the following table.

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

Table 1: Parameters from literature.

A summary of model simulated variables is presented in Table 2. The United States is the largest economy, and its weight on world risk, given by the variable ϖ_i in the model, is 0.46. However, since there is a lot of heterogeneity in the stochastic process of shocks across countries, a large country size (a high ϖ) does not uniformly translate into a stronger covariance between the country's shock and the stochastic discount factor (given by $\Psi_i \equiv cov(A_W^{-\sigma}; A_i)$).

The calibrated entry cost for foreign affiliates is summarized in Table 2, columns III and

²⁵Source: UNCTAD

²⁶Source: Klenow and Rodriguez-Clare (2005).

²⁷Source: Penn World Tables de-trended using a Hodrick-Prescott filter.

²⁸We draw 500,000 vectors ($I \times 1$) of country shocks to simulate the model.

IV. The median cost for foreign affiliates is presented relative to the calibrated cost for national firms. Those countries with low MP flows in the data are characterized by high entry costs, while those countries with low entry costs have relative high MP flows.

Finally, the model provides a measure of technology transfer embedded in MP flows, that is, the productivity index for foreign affiliates, $Z_{ij} \equiv \int_{\bar{z}_{ij}}^{\infty} z^{\eta-1} L_i dG_i(z)$. Table 2 presents the calibrated outflows and inflows of “firm-embedded” productivities. Large countries show both large inflows and outflows of MP flows, but tend to be net exporters of technologies.

Country	ϖ_i	Ψ_i	(median) MP Costs [†]		Technology Transfers [‡]		
			outward	inward	outward	inward	net
Australia	0.015	-0.50	730	198	1	4	-3
Austria	0.004	-0.55	473	521	1	2	-1
Belgium	0.006	-0.64	367	664	2	3	-2
Canada	0.032	-0.67	1150	170	3	11	-8
Denmark	0.003	-0.63	115	1951	1	0.1	0.1
Spain	0.021	-0.58	1443	184	1	3	-3
Finland	0.003	-0.37	57	1268	1	1	1
France	0.047	-0.64	72	61	6	6	0.1
United Kingdom	0.051	-0.82	125	48	9	11	-2
Germany	0.093	-0.62	32	29	14	13	1
Greece	0.004	-0.53	5418	1414	0.0	0.3	-0.3
Italy	0.037	-0.64	349	168	2	3	-1
Japan	0.198	-0.60	231	335	14	4	10
Netherlands	0.011	-0.71	62	105	8	6	3
Norway	0.003	-0.19	197	1185	1	1	0.1
New Zealand	0.002	-0.01	2089	4033	0.1	1	-0.4
Portugal	0.004	-0.59	4677	86	0.1	3	-3
Sweden	0.006	-0.47	62	346	2	2	0.0
United States	0.461	-0.89	66	11	34	26	8

[†]: outward = $\sum_{j;i \neq j} f_{ij}/f_{jj}$; inward = $\sum_{j;j \neq i} f_{ij}/f_{jj}$. [‡]: outward = $100 \times \sum_{i;i \neq j} Z_{ij} / \sum_{i,j;i \neq j} Z_{ij}$; inward = $100 \times \sum_{j;i \neq j} Z_{ij} / \sum_{i,j;i \neq j} Z_{ij}$; net = outward - inward.

Table 2: Calibrated Model. OECD countries.

In Table 3, columns I and II, we present a comparison between the calibrated version of the model and a world without MP ($f_{ij} = \infty$ for all $i \neq j$). According to this exercise, the observed location of MP activities across countries reduces the consumption risk premium in only 0.5%, beyond the diversification opportunities given by a world with complete financial markets but no endogenous reallocation of production.

	Benchmark	No MP	frictionless MP from the US	frictionless MP into the US
% Change in risk premium	-0.5%	-	-7%	5%
Correlation between Y_i and Y_W				:
Australia	0.50	0.50	0.46	0.53
Austria	0.55	0.55	0.60	0.51
Belgium	0.64	0.64	0.70	0.60
Canada	0.68	0.67	0.66	0.69
Denmark	0.63	0.63	0.59	0.66
Spain	0.58	0.58	0.64	0.55
Finland	0.37	0.36	0.39	0.37
France	0.64	0.64	0.70	0.61
United Kingdom	0.82	0.81	0.82	0.82
Germany	0.62	0.63	0.66	0.59
Greece	0.53	0.53	0.56	0.51
Italy	0.64	0.64	0.69	0.62
Japan	0.60	0.61	0.64	0.56
Netherlands	0.71	0.70	0.73	0.69
Norway	0.19	0.19	0.15	0.22
New Zealand	0.01	0.01	0.00	0.03
Portugal	0.59	0.59	0.66	0.55
Sweden	0.47	0.47	0.49	0.47
United States	0.89	0.89	0.84	0.92

Table 3: The effects of MP on world risk. OECD countries.

Two off-setting 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 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 off-sets the size effects of MP on risk patterns.

To highlight this point, Table 4 decomposes the overall impact of MP on the consumption risk premium into two effects. First, we isolate the “size” effect: We calculate the change in the consumption risk premium assuming that country shocks are i.i.d. with variance given by the sample mean. 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%. Second, Table 4 presents the “risk” effect, which shows the effect of MP flows on the consumption risk premium assuming that the risk pattern across countries is as calibrated from the data, but countries are symmetric in size ($L_i = L$). Our calculations suggest that the consumption risk premium increases by 1.75% due to this risk effect, off-setting the size effect.

	Overall Effect	Size Effect [†]	Risk Effect [‡]
% Change in risk premium (from autarky to benchmark)	-0.5%	-2%	1.75%

[†]: parameters calibrated as in benchmark but assuming that $cov(A_i, A_j) = 0$, for $i \neq j$, and $cov(A_i, A_j) = \sigma_{median}^2$. [‡]: parameters calibrated as in benchmark but assuming that $L_i = 1$ for all i .

Table 4: Size and Risk Effects. OECD countries.

Going back to Table 3, columns III and IV, we present a counterfactual exercise aimed to highlight how the direction of MP flows affects the consumption risk premium. The United States, being the largest country in the sample, co-move the most with world risk (the calibrated parameters governing the stochastic process of shocks across countries are presented in the Appendix). We calculate the change in the consumption risk premium from a situation with no MP to one where the US is the only source of MP activities, and another one where the

US is the only destination, respectively. That is, column III presents results for $f_{US,j} = 0$, for all destination countries j and $f_{ij} = \infty$ for all $i \neq j$ and $i \neq US$; 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 $j \neq US$. As suggested by Proposition 2, when the US is the only source of MP flows, the risk premium is reduced by 7% with respect to autarky. In this case, the co-movement between the US's GDP and world's fluctuations drops by 5.5% relative to autarky, as the US-specific shock affects a lower share of world production. Correspondingly, when the US is the sole recipient of affiliates from the remaining eighteen OECD countries, the correlation between the US's GDP and world fluctuations rises by almost 3.5%. In this case, the rest of the world reduces its capacity to provide insurance against US specific shocks and the consumption risk premium increases by 5%.

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 entailed by the foreign 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.

Our paper provides a very simple model of costly international technology transfers in risky environments that is a good point of departure for future research on international decisions of firms in risky environments.

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6 Appendix I: Proofs

6.1 Proof of Lemma 1

Combining the utility function in (1), world output in (19), and consumption in (26), the risk premium ρ_i is constant across countries $i = 1, \dots, I$:

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

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

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

6.2 Proof of Proposition 1

By contradiction. Consider a country j^* such that the marginal multinational firm from country j^* into country i and h satisfies $\bar{z}_{j^*i} \geq \bar{z}_{j^*h}$. Countries h and i are symmetric except for $\Psi_i > \Psi_h$. Since $f_{j^*i} = f_{j^*h}$, the zero profit condition in (10) implies that $V(\bar{z}_{j^*i}) = V(\bar{z}_{j^*h})$, which can be expressed as follows:

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

From (29) and (19), we know that

$$\frac{\sum_{s \in S} \varphi(s) Y_h(s)}{\sum_{s \in S} \varphi(s) Y_i(s)} = \frac{Z_h^{\frac{1-\alpha}{\eta-1}} (1 + \Psi_h)}{Z_i^{\frac{1-\alpha}{\eta-1}} (1 + \Psi_i)}.$$

Rearranging terms, condition $V(\bar{z}_{j^*i}) = V(\bar{z}_{j^*h})$, with $\bar{z}_{j^*i} \geq \bar{z}_{j^*h}$, can be expressed as follows

$$\frac{\bar{z}_{j^*i}^{\eta-1}}{\bar{z}_{j^*h}^{\eta-1}} = \left(\frac{Z_i}{Z_h} \right)^{\frac{\eta-2+\alpha}{\eta-1}} \cdot \frac{(1 + \Psi_h)}{(1 + \Psi_i)} \geq 1.$$

Then, under Assumption (1) and $\Psi_i > \Psi_h$, it has to be that $Z_i > Z_h$. However, if the above condition holds, then for all $j \neq i, h$ the zero profit condition implies $\bar{z}_{ji}^{\eta-1} \geq \bar{z}_{ji}^{\eta-1}$ and therefore

$Z_i < Z_h$, which is a contradiction. Then, it must be that for all $j \neq i, h$: $\bar{z}_{ji} < \bar{z}_{jh}$. \square

6.3 Proof of Lemma 2

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

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

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 $E(A_W^{-\sigma} A_j) < E(A_W^{-\sigma} A_h)$. Or, equivalently,

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

Since $E(A_j) = E(A_h)$, it follows that $\text{cov}(A_W^{-\sigma}; A_j) < \text{cov}(A_W^{-\sigma}; A_h)$. \square

6.4 Proof of Proposition 2

Applying the same logic as in the proof of Proposition 1, the inequality $\text{cov}(A_W^{-\sigma}; A_j) < \text{cov}(A_W^{-\sigma}; A_h)$ 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 $\text{cov}(A_W^{-\sigma}; A_j) < \text{cov}(A_W^{-\sigma}; A_h)$. \square

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 $\Gamma = \left\{ \langle C(s) \rangle_{i=1}^I, \langle \bar{z}_{ji} \rangle_{i,j} \right\}$ that satisfies the

following program:

$$\begin{aligned}
& \max_{\Gamma} \sum_{s \in S} \beta \Pr(s) \sum_{i=1}^I \lambda_i u(C_i(s)) \\
& \text{s.t.} \\
\mu(s) & : \sum_{i=1}^I C_i(s) = Y_W(s) = \phi_3 \cdot A_W(s) \cdot \sum_{i=1}^I L_i Z_i^{\frac{1-\alpha}{\eta-1}} \quad (s \in S) \\
\mu_0 & : \sum_{i=1}^I \sum_{j=1}^I [1 - G(\bar{z}_{ji})] f_{ji} = \sum_{i=1}^I K_i,
\end{aligned}$$

where $\mu(s)$ and μ_0 are the multipliers on the corresponding constraints, and the world shock is defined as in the paper, $A_W(s) \equiv \sum_{i=1}^I \varpi_i A_i(s)$, with $\varpi_i \equiv L_i Z_i^{\frac{1-\alpha}{\eta-1}} / \sum_{i=1}^I L_i Z_i^{\frac{1-\alpha}{\eta-1}}$. As in the decentralized economy presented in the paper, the optimal allocation involves perfect international risk sharing, $\lambda_i/\lambda_j = u'(C_j(s))/u'(C_i(s))$, that, with CRRA preferences, implies $C_i(s) = \left\{ \lambda_i^{1/\sigma} \left[\sum_{j=1}^I \lambda_j^{1/\sigma} \right]^{-1} \right\} \cdot Y_W(s)$. The efficient entry decision for a firm from country j into country i is given by a cut-off productivity level \bar{z}_{ji} that satisfies the following first order condition:

$$\phi_3 \left(\frac{1-\alpha}{\eta-1} \right) \frac{\bar{z}_{ji}^{\eta-1}}{Z_i} L_i Z_i^{\frac{1-\alpha}{\eta-1}} E(\mu A_i) - \mu_0 f_{ji} = 0.$$

The multiplier $\mu(s)$ on the world resource constraint is the marginal utility of world output in state s , i.e. $\mu(s) = \beta \Pr(s) \lambda_i u'(C_i(s))$. Thus,

$$\phi_6 \cdot \frac{\bar{z}_{ji}^{\eta-1}}{Z_i} \cdot L_i Z_i^{\frac{1-\alpha}{\eta-1}} \cdot E(A_W^{-\sigma} \cdot A_i) = \mu_0 f_{ji}.$$

This condition is equivalent to the zero profit condition in (30) for the decentralized problem where the market price p_k corresponds to the social valuation of capital μ_0 .

7 Appendix II: Adding 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.²⁹ 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 physical capital is used to set-up foreign affiliates in period zero, before country shocks are realized. In period one, after country shocks are realized, capital is used in production. We denote by K_i^0 the initial endowment of capital for country i , and its price at time zero as p_k^0 . In period one, we drop the time superscript, and index variables by s , $K_i(s)$ and $p_k(s)$, respectively.

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

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

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

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

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 , $\left\{ \langle k_{ji}(z, s) \rangle_z, K_i^f(s) \right\}$, given the world price of capital, $p_k(s)$. In each country, the marginal product of capital across goods in state s , is equalized,

$$\frac{q_{ji}(z, s)}{k_{ji}(z, s)} = (1 - \alpha) \frac{Y_i(s)}{K_i^f(s)},$$

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

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

$$K_i^f(s) = (1 - \alpha) \cdot K_i(s), \quad (34)$$

where $K_i(s)$ is total capital available in country i and state s , $K_i(s) = K_i^f(s) + \sum_{j=1}^I K_{ji}(s)$

²⁹This difference is also highlighted by McGrattan and Prescott (2007) in the context of a neoclassical growth model that incorporates both physical and technology capital.

with $K_{ji}(s) = \int_{\bar{z}_{ji}}^{\infty} k_{ji}(z, s) dG(z)$. Combining (32), (33), and (34), the capital stock in country i , state s , is:

$$K_i(s) = (1 - \nu) \cdot \frac{Y_i(s)}{p_k(s)}. \quad (35)$$

Alternatively, we can write this condition as $p_k(s) = (1 - \nu) Y_i(s) / K_i(s)$.

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:

$$Y_i(s) = \tilde{\phi}_3^{1/\nu} \left[A_i(s) \cdot \tilde{L}_i^\nu \cdot p_k(s)^{-(1-\nu)} \right]^{1/\nu}, \quad (36)$$

$$\text{where } : \quad \tilde{L}_i \equiv \left[Z_i^{\frac{1-\alpha}{\eta-1}} L_i^\nu \right]^{1/\nu}, \quad (37)$$

and $\tilde{\phi}_3$ is a positive constant.³⁰ Output fluctuates with country shocks $A_i(s)$. Adding physical capital introduces another source of fluctuation.

We add to Definition 2 of the international equilibrium, the vector of price of capital across states, $\{p_k(s)\}_{s \in S}$. At time zero, capital is used for setting-up foreign affiliates which requires f_{ij} units. However, some of the initial world endowment of capital, $K_W^0 \equiv \sum_{i=1}^I K_i^0$ needs to be left for production in period one. For each s , the feasibility condition for capital is

$$K_W(s) = K_W^0 - \sum_{i=1}^I \sum_{j=1}^I f_{ij} [1 - G(\bar{z}_{ij})], \quad (38)$$

where $K_W(s) \equiv \sum_{i=1}^I K_i(s)$. Notice that the world capital stock available in period one is constant across states, $K_W(s) = K_W^1$. Combining (35) and (38), the equilibrium international price of capital is

$$p_k(s) = (1 - \nu) \cdot \frac{Y_W(s)}{K_W^1}, \quad (39)$$

and fluctuates with world output $Y_W(s)$. Additionally, the intertemporal equilibrium allocation of capital requires that the return to MP activities for the marginal firm be equal to the discounted marginal product of capital in production. That is, the following arbitrage condition must be satisfied:

$$p_k^0 = \sum_{s \in S} \varphi(s) p_k(s). \quad (40)$$

The marginal multinational firm from country i opening an affiliate in country j is defined by

³⁰ $\tilde{\phi}_3 \equiv \phi_3 (1 - \nu)^{(1-\nu)}$.

$V_{ij} = f_{ij}p_k^0$. Replacing p_k^0 by 40, and $p_k(s)$ by (39), we get

$$\sum_s \varphi(s) \frac{\pi_{ij}(\bar{z}_{ij}, s)}{f_{ij}} = (1 - \nu) \sum_{s \in S} \varphi(s) \frac{Y_W(s)}{K_W^1}.$$

Solving for world output, we get

$$Y_W(s) = \tilde{\phi}_3 \cdot K_W^{1-\nu} \cdot \tilde{L}_W^\nu \cdot A_W(s), \quad (41)$$

where $\tilde{L}_W \equiv \sum_{i=1}^I \tilde{L}_i$, and the average world shock is now $A_W(s) \equiv \sum_{i=1}^I \tilde{\omega}_i A_i(s)^{1/\nu}$, with $\tilde{\omega}_i \equiv \tilde{L}_i / \tilde{L}_W$. 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. Foreign affiliates locate in economies with shocks least correlated with world shocks and, as a result, the existence of MP flows reduces the consumption risk premium in all countries.³¹ The inclusion of physical capital reinforces the results in the previous sections. From (35), (39), and (41), the allocation of capital across countries is given by $K_i(s) = \tilde{\omega}_i [A_i(s) / A_W(s)]^{1/\nu} K_W$. This expression entails two features of international capital flows that are worth emphasizing. First, while capital flows fluctuate with the (relative) magnitude of country shocks, the weight $\tilde{\omega}_i$ 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.³² 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 $\tilde{\omega}_i$). 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 strengthens the result in Proposition 1.

³¹The parameter Ψ_i in Proposition 1 is now defined as $\Psi_i \equiv \text{cov} \left(A_W^{-\sigma-(1-\nu)/\nu}; A_i^{1/\nu} \right)$.

³²For documentation on this fact see, for example, Lipsey (2001), Albuquerque (2003), and Bachetta and Van Wincoop (2000).

8 Appendix III: Data and Calibration

Firm-imbedded productivities in each country follows a Pareto distribution, characterized by the same parameters z_{\min} and γ , but scaled by the size of domestic labor force L . The aggregate productivity of firms operating in their own country is:

$$Z_{jj} = L_j \frac{\gamma}{\gamma + 1 - \eta} z_{\min}^{\eta-1}$$

We calibrate MP flows to match gross production of affiliates from country i in host market j , as share of j 's GDP, for the nineties: $sh_{ij} = E \left\{ \frac{X_{ij}}{Y_j} \right\}$ (in Appendix, Table 8):

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

We obtain the aggregate and cut-off productivities Z_{ij} and \bar{z}_{ij} in the following way:

$$\begin{aligned} Z_{ij} &= L_j \frac{sh_{ij}}{sh_{jj}} \cdot \frac{\gamma}{\gamma + 1 - \eta} z_{\min}^{\eta-1} \\ \bar{z}_{ij} &= \left(\frac{L_j sh_{ij}}{L_i sh_{jj}} \right)^{-\frac{1}{(\gamma+1-\eta)}} \cdot z_{\min} \end{aligned}$$

We combined the calibrated $\{z_{ij}\}_{i,j=1}^I$ and $F \left(\{A_{ij}\}_{i,j=1}^I \right)$ to derive the implied bilateral entry costs. The price of the capital good is normalized so that $p_k \cdot f_{US,US} = 1$:

$$\begin{aligned} p_k &= \phi_6 \cdot \frac{\bar{z}_{\min}^{\eta-1}}{Z_{US}} \cdot \varpi_{US} \cdot cov \{ A_W^{-\sigma}; A_{US} \} \\ f_{ij} &= \left(\frac{\bar{z}_{ij}}{z_{\min}} \right)^{\eta-1} \cdot \frac{\varpi_j}{\varpi_{US}} \cdot \frac{cov \{ A_W^{-\sigma}; A_j \}}{cov \{ A_W^{-\sigma}; A_{US} \}} \end{aligned}$$

Table 2 presents the barriers to multinational firms, understood as the entry cost for a foreign affiliate relative to entry cost for a national firm: f_{ij}/f_{jj}

8.0.1 Data

Country	equipped-labor [†] (as share of US)	STD. DEV. real GDP pc [‡]
Australia	0.06	0.015
Austria	0.02	0.018
Belgium	0.03	0.019
Canada	0.11	0.027
Denmark	0.02	0.020
Spain	0.08	0.032
Finland	0.02	0.046
France	0.16	0.017
United Kingdom	0.16	0.023
Germany	0.27	0.019
Greece	0.02	0.035
Italy	0.13	0.016
Japan	0.52	0.024
Netherlands	0.04	0.022
Norway	0.02	0.022
New Zealand	0.01	0.028
Portugal	0.02	0.039
Sweden	0.03	0.026
United States	1.00	0.022

[†]: Klenow and Rodriguez-Clare (2005), average over the nineties. [‡]: log real GDP per capita (at constant prices) from PWT (6.2). 1970-2004. HP Filtered.

Table 5: Summary statistics. OECD countries.

	AUS	AUT	BEL	CAN	DNK	ESP	FIN	FRA	GBR	GER	GRC	ITA	JPN	NLD	NOR	NZL	PRT	SWE	USA
AUS	1.00	-0.11	0.04	0.75	0.58	0.03	0.53	0.13	0.56	-0.12	0.18	0.23	-0.11	0.20	0.46	0.38	0.04	0.41	0.69
AUT	-0.11	1.00	0.79	0.27	0.14	0.70	0.20	0.79	0.32	0.74	0.58	0.60	0.50	0.68	-0.03	-0.20	0.75	0.25	0.27
BEL	0.04	0.79	1.00	0.41	0.13	0.84	0.31	0.80	0.50	0.69	0.60	0.78	0.59	0.74	-0.02	-0.04	0.83	0.41	0.32
CAN	0.75	0.27	0.41	1.00	0.57	0.44	0.66	0.49	0.77	0.08	0.43	0.49	-0.05	0.51	0.38	0.40	0.21	0.75	0.77
DNK	0.58	0.14	0.13	0.57	1.00	0.16	0.26	0.21	0.61	0.16	0.15	0.25	0.04	0.40	0.61	0.32	0.11	0.38	0.77
ESP	0.03	0.70	0.84	0.44	0.16	1.00	0.34	0.71	0.62	0.45	0.50	0.54	0.47	0.69	-0.04	0.17	0.75	0.53	0.32
FIN	0.53	0.20	0.31	0.66	0.26	0.34	1.00	0.55	0.57	-0.17	0.16	0.49	-0.01	0.16	0.02	0.44	0.24	0.79	0.36
FRA	0.13	0.79	0.80	0.49	0.21	0.71	0.55	1.00	0.56	0.61	0.59	0.76	0.45	0.61	-0.21	-0.08	0.75	0.55	0.39
GBR	0.56	0.32	0.50	0.77	0.61	0.62	0.57	0.56	1.00	0.22	0.37	0.54	0.36	0.51	0.12	0.36	0.46	0.70	0.76
GER	-0.12	0.74	0.69	0.08	0.16	0.45	-0.17	0.61	0.22	1.00	0.54	0.60	0.71	0.68	-0.07	-0.55	0.67	-0.02	0.33
GRC	0.18	0.58	0.60	0.43	0.15	0.50	0.16	0.59	0.37	0.54	1.00	0.35	0.39	0.42	-0.01	-0.10	0.38	0.24	0.37
ITA	0.23	0.60	0.78	0.49	0.25	0.54	0.49	0.76	0.54	0.60	0.35	1.00	0.48	0.63	0.01	-0.11	0.66	0.54	0.40
JPN	-0.11	0.50	0.59	-0.05	0.04	0.47	-0.01	0.45	0.36	0.71	0.39	0.48	1.00	0.36	-0.28	-0.35	0.71	0.02	0.23
NLD	0.20	0.68	0.74	0.51	0.40	0.69	0.16	0.61	0.51	0.68	0.42	0.63	0.36	1.00	0.39	-0.20	0.62	0.37	0.57
NOR	0.46	-0.03	-0.02	0.38	0.61	-0.04	0.02	-0.21	0.12	-0.07	-0.01	0.01	-0.28	0.39	1.00	0.21	-0.13	0.08	0.40
NZL	0.38	-0.20	-0.04	0.40	0.32	0.17	0.44	-0.08	0.36	-0.55	-0.10	-0.11	-0.35	-0.20	0.21	1.00	-0.14	0.38	0.19
PRT	0.04	0.75	0.83	0.21	0.11	0.75	0.24	0.75	0.46	0.67	0.38	0.66	0.71	0.62	-0.13	-0.14	1.00	0.18	0.25
SWE	0.41	0.25	0.41	0.75	0.38	0.53	0.79	0.55	0.70	-0.02	0.24	0.54	0.02	0.37	0.08	0.38	0.18	1.00	0.45
USA	0.69	0.27	0.32	0.77	0.77	0.32	0.36	0.39	0.76	0.33	0.37	0.40	0.23	0.57	0.40	0.19	0.25	0.45	1.00

Table 6: Correlation of GDP per capita across countries. OECD.

Note: The moments for real GDP per capita are calculated after de-trending the logs of real GDP per capita at constant prices (RGDPL) from the Penn World Tables (6.2) with a Hodrick-Prescott filter, for the period 1970-2004

	AUS	AUT	BEL	CAN	DNK	ESP	FIN	FRA	GBR	GER	GRC	ITA	JPN	NLD	NOR	NZL	PRT	SWE	USA
AUS	0.4	283	198	180	85	725	33	189	65	64	3020	1021	28	33	128	50	1039	48	28
AUT	801	0.3	104	1032	77	972	34	245	121	12	3573	366	287	30	152	1698	1037	55	171
BEL	288	54	0.3	192	983	4495	896	16	8845	10	1236	68	46	2412	47	607	1030	20	27
CAN	81	136	222	0.4	162	387	20	43	20	21	2113	100	34	10	71	159	1130	22	6
DNK	2520	804	506	3042	0.4	3317	19	741	630	118	15382	826	874	227	253	5314	6975	102	367
ESP	370	175	35	944	176	1	38	15	227	17	2269	49	217	9	348	767	33	93	66
FIN	958	252	256	1581	23	1994	0.3	1069.2	232	278	6613	893	789	28	18	1795	3316	5	432
FRA	250	86	7	165	26	97	15	1	37	12	1456	24	138	15	46	526	72	19	35
GBR	43	506	21	31	26	135	7	17	1	14	914	53	17	12	33	176	36	17	11
GER	143	4	5	53	6	36	8	14	9	1	871	30	51	1	19	262	367	7	21
GRC	2531	1059	4637	3692	437	3726	370	478	592	183	0.4	217	955	164	743	1891	86425	271	586
ITA	2482	105	106	482	215	457	42	34	67	33	3968	1	386	19	101	1109	634	13	73
JPN	315	678	471	812	198	1802	198	485	75	80	7598	14088	1	49	291	695	3467	109	38
NLD	149	156	15	622	44	1699	7	13	26	11	1801	251	32	0.3	33	630	356	23	13
NOR	1633	2208	265	428	21	2356	19	1583	380	251	11322	1938	557	90	0.4	1912	3931	31	211
NZL	334	4052	2819	2238	1216	10141	123	2691	917	523	43098	197609	231	462	1810	0.3	42839	687	102
PRT	102	7	31	480	5	5	35	14	11	9	505	14	220	3	178	206	0.2	19	76
SWE	445	82	125	565	6	686	3	197	41	53	2981	922	607	10	4	939	12411	0.4	97
USA	14	56	9	5	26	222	10	11	4	9	257	54	8	2	13	35	1052	6	1

Table 7: Bilateral entry cost. OECD.

Note: Calibrated variables. Normalized to the entry cost of national US firms to the domestic country

	AUS	AUT	BEL	CAN	DNK	ESP	FIN	FRA	GBR	GER	GRC	ITA	JPN	NLD	NOR	NZL	PRT	SWE	USA
AUS	68.23	0.04	0.07	0.29	0.10	0.06	0.24	0.41	1.23	2.03	0.00	0.06	8.96	0.67	0.07	0.11	0.01	0.31	17.11
AUT	0.07	65.77	0.25	0.10	0.22	0.08	0.46	0.61	1.27	21.61	0.01	0.34	1.70	1.40	0.11	0.01	0.02	0.52	5.46
BEL	0.11	0.23	52.02	0.30	0.01	0.01	0.01	5.47	0.01	13.83	0.01	1.06	6.12	0.01	0.20	0.01	0.01	0.84	19.73
CAN	0.16	0.04	0.03	54.30	0.02	0.05	0.18	0.77	1.72	2.72	0.00	0.28	3.27	0.93	0.05	0.02	0.00	0.29	35.17
DNK	0.04	0.05	0.10	0.06	86.01	0.05	1.54	0.38	0.47	4.05	0.00	0.29	1.06	0.35	0.12	0.00	0.00	0.54	4.86
ESP	0.07	0.06	0.36	0.05	0.05	75.27	0.20	4.84	0.33	6.95	0.00	1.24	1.09	2.23	0.02	0.01	0.26	0.15	6.81
FIN	0.10	0.14	0.17	0.11	1.25	0.07	76.77	0.23	1.12	1.52	0.01	0.24	1.04	2.48	1.50	0.01	0.01	9.61	3.63
FRA	0.07	0.08	1.22	0.19	0.21	0.25	0.32	77.29	1.31	6.48	0.00	1.62	1.11	0.86	0.11	0.01	0.08	0.47	8.32
GBR	0.29	0.01	0.28	0.74	0.15	0.13	0.51	1.94	64.91	4.13	0.01	0.53	6.47	0.79	0.11	0.01	0.11	0.38	18.48
GER	0.07	1.06	1.05	0.35	0.49	0.39	0.35	2.01	3.30	71.44	0.00	0.77	1.75	7.69	0.16	0.01	0.01	0.73	8.35
GRC	0.04	0.04	0.01	0.05	0.07	0.04	0.07	0.55	0.46	2.44	90.80	1.02	0.90	0.45	0.04	0.01	0.00	0.19	2.82
ITA	0.01	0.09	0.10	0.09	0.03	0.07	0.16	1.85	0.98	3.22	0.00	85.49	0.54	0.92	0.07	0.00	0.01	0.92	5.46
JPN	0.03	0.01	0.01	0.02	0.02	0.01	0.01	0.06	0.37	0.57	0.00	0.00	94.16	0.15	0.01	0.00	0.00	0.05	4.51
NLD	0.14	0.05	0.66	0.06	0.15	0.02	0.82	4.17	2.24	8.46	0.00	0.19	5.75	49.63	0.19	0.01	0.02	0.46	26.98
NOR	0.06	0.02	0.18	0.42	1.47	0.06	1.47	0.17	0.72	1.79	0.00	0.12	1.57	0.84	81.54	0.01	0.01	1.66	7.91
NZL	0.36	0.01	0.02	0.09	0.03	0.02	0.26	0.12	0.35	1.00	0.00	0.00	4.40	0.19	0.02	73.93	0.00	0.09	19.12
PRT	0.29	1.66	0.43	0.11	1.70	7.53	0.23	5.45	7.01	13.70	0.02	4.48	1.14	7.62	0.05	0.03	41.46	0.78	6.32
SWE	0.11	0.22	0.18	0.15	2.40	0.10	5.26	0.65	3.18	4.00	0.01	0.12	0.68	3.48	3.44	0.01	0.00	67.80	8.23
USA	0.35	0.03	0.25	1.77	0.06	0.03	0.14	1.23	3.35	2.60	0.01	0.21	5.17	1.74	0.11	0.03	0.00	0.43	82.48

Table 8: Bilateral Multinational Production. OECD.

Note: Bilateral gross value of production for affiliates from country i in country j , as share of country j 's GDP, as an average over the nineties, from UNCTAD. Our measure for MP flows is the gross value of production of affiliates from country i in j (see Ramondo, 2006). Missing values for this variable are estimated using a gravity equation of the form $\log(X_{ij}/Y_{ij}) = S_i + D_j + B_d \log(d_{ij}) + B_f F_{ij} + B_l L_{ij} + e_{ij}$, where S_i and D_j are source and destination country fixed effects, respectively, d_{ij} is distance between countries i and j (in kilometers), F_{ij} and L_{ij} are dummy variables equal to one if country-pair share a border and language respectively