The Role of Multinational Production in a Risky Environment*

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Abstract

The crucial difference between Foreign Direct Investment (FDI) and other international financial flows is that the former involves technology flows across countries. In the presence of country-specific shocks, these flows not only alter the distribution of output across countries, but also across different states of nature.

This paper introduces FDI simultaneously as a portfolio and technology flow in a risky environment. We find that multinational activities improve the scope for international risk diversification even in world with complete international financial markets. Multinational firms have incentives to locate affiliates in countries with business cycles least correlated with world risk. In doing so, they reshape the patterns of world risk and improve the scope for international risk diversification. A calibration exercise for OECD countries suggests that multinational activities reduces the consumption risk premium by 5% beyond the diversification opportunities provided by complete financial markets.

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

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1 Introduction

One of the most notable features of economic globalization has been the increasing importance of multinational firms: by 2004, total sales of foreign affiliates of multinational firms represented 51% of world GDP, almost double the share of world exports.¹ These firms have become crucial not only in international goods' and factors' markets, but more importantly, as a channel through which countries exchange capital, ideas, and technologies.² The increase in Foreign Direct Investment (FDI) flows across countries is the manifestation on the financial side of the rising importance of multinational production (MP) activities.³

In this paper, we argue that FDI is fundamentally different from other international financial flows regarding its effects on the opportunities for risk diversification available to consumers. Precisely because it entails technology transfers across countries, the activity of multinational firms reshape international goods' and factors' markets not only by changing the allocation of production across countries, but also across states of nature. In this way, MP activities can reduce consumption risk beyond the diversification opportunities given by complete markets for state-contingent claims.

The economic literature has emphasized the benefits of international risk diversification. Holding shares of multinational corporations has been identified as a channel through which risk averse consumers can attain such diversification.⁴ However, the literature on international risk sharing and portfolio composition has not distinguished between FDI and other financial flows, such as equity holding of foreign firms, in regard of their consequences for risk sharing

¹World Investment Report 2006, UNCTAD.

²The 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).

³MP refers to the activities of foreign affiliates of multinational plants (e.g. sales, employment). Foreign Direct Investment (FDI) is a financial category of the Balance of Payment of a country. MP does not always take the form of FDI flows; FDI is just one of the sources through which multinational firms fund their foreign activities.

⁴This has been extensively analyzed in the context of "home bias" in equity holdings (See the survey in Lewis, 1999).

opportunities. By introducing MP activities simultaneously as a portfolio and technology flow in a risky environment with country-specific shocks, this paper uncovers a number of novel implications.

First, when 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-specific 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 output available in each of these states.

Second, with complete financial markets, firms fully internalize the impact of their location decisions on consumers' risk-sharing opportunities; the resulting geographical pattern of multinational activities is efficient. Hence, the existence of MP activities reduces the consumption risk premium precisely because firms have incentives to locate 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-specific shocks, in the spirit of Backus, Kehoe, and Kydland (1992). 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. Yet, there is undiversifiable risk; that is, the world experiences states of (relative) scarcity and abundance.

On the production side, the model builds on Melitz (2003). Firms are heterogenous in their technologies and compete monopolistically. They can serve foreign markets by opening affiliates

there after paying a fixed entry cost. We treat firms as technology entities in the sense that the same technology parameter characterizes the parent company and its affiliates.⁵ Crucially, we assume that affiliates face host country risk. This country-specific shock equally affects the unit cost of production of all firms located in a market regardless of being domestic or foreign. In this way, 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. That is, firms' decisions to open affiliates abroad alter the pattern of aggregate risk faced by all agents in the world.

Of course, 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 paper, we restrict the analysis to location-specific shocks that affect the unit labor cost of all productive units located in the country. As long as there are shocks of this type, MP, and more generally, any other form of technology flows across countries, will affect the pattern of international risk.

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-specific shock to productivity affects 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, given by the realization of world output, i.e. 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

⁵See Domes 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.

correlated with world output. By modeling the location decision of firms, this transfer occurs endogenously: affiliates of multinational firms endogenously reshape the geographical pattern of production, increasing the production capacity of countries least correlated with world risk, and consequently, increasing their weight on world output.

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 of 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 efficient.

Our model also builds on Grossman and Razin (1984, 1985) and, more generally, the literature on trade and international risk sharing.⁶ Grossman and Razin 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 in different (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 in a similar risky environment.

The analysis of the role of MP in a risky environment modeled simultaneously as a portfolio and technology flow is novel in the literature.⁷ On the one hand, the international trade literature has focused on the role of MP as a way of serving foreign consumers by replicating production facilities abroad (horizontal FDI), or splitting the production chain to take advantage of cheap

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

⁷Aizenman and Marion (2004), and Goldberg and Kolstad (1995) study the location of MP activities under uncertainty. Both frameworks and motivations are very different from ours. They consider firms with imperfect access to financial market. In such framework, doing MP provides hedging within the boundaries of the corporation. They do not address the change in aggregate risk that results from reallocation of production.

input costs (vertical FDI).⁸ This literature emphasizes the role of MP in the exchange of goods but does not address its implications in terms of international risk sharing. On the other hand, the international business cycle literature has mainly treated MP as a portfolio flow abstracting from the technology transfers across countries that this flow entails.⁹ Connecting the macro literature on international risk sharing with trade and FDI models of heterogeneous firms results in relevant and novel interactions.

In sum, our paper has two distinct contributions. First, the theory provides an extremely simple and tractable framework to model international technology flows in risky environments that can be used for many purposes. We see as an advantage that results are obtained with no need to assume incomplete financial markets. Second, by modeling the dual role of FDI as a technology and financial flow in a risky environment, we uncover an additional through which the activities of multinational firms can be beneficial: the reduction in the consumption risk premium. Our calibration exercise suggests that, among a group of OECD countries, the consumption risk premium would increase by 5% if there were no MP activities but still complete markets for state-contingent claims. Indeed, the location decisions of firms improve international risk sharing opportunities.

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 extends the model to introduce physical capital. Section 6 concludes.

⁸See Markusen (1984); Brainard (1997); Markusen and Venables (1998); Carr, Markusen, and Maskus (2001); Helpman, Melitz, and Yeaple (2004); Ramondo (2005), Burstein and Monge (2007), McGrattan and Prescott (2007), for horizontal FDI. See Helpman (1984), Antras (2003), Antras and Helpman (2004), for vertical FDI.

⁹See for example Backus and Smith (1993), Baxter and Jermann (1997), Perri and Heathcote (2004), and Mendoza, Quadrini, and Rios-Rull (2006).

2 Model

We present a multi-country, stochastic model with a complete set of state-contingent claims. There is a freely-tradable homogenous final consumption good and a continuum of non-tradable 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, compete monopolistically, and can serve a foreign market by opening affiliates there. Affiliates inherit their parent specific productivity.

Our analysis distinguishes between two assets: shares of firms, some of which are multinationals; and a portfolio of other risky and risk-free assets, that we interpret as contingent claims, i.e. 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* country-shocks are realized in which trade in Arrow-Debreu securities and FDI (i.e. 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, $E \{A_i(s)\} = 1$, for all i .¹⁰ Assume that there is a finite number

¹⁰In this economy, all asymmetries in $E(A_i(s))$ across countries can be equivalently expressed as differences in labor size L_i .

of states, $S = \{s_1; s_2; \dots; s_N\}$, 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. The final consumption good is produced under perfect competition with a constant returns to scale technology that combines labor and the composite intermediate good,

$$Y_i(s) = A_i(s) L_i^f(s)^\alpha Q_i(s)^{1-\alpha}, \quad (2)$$

$0 < \alpha < 1$, and $A_i(s)$ is country- i productivity shock, and $Q_i(s)$ is a CES composite intermediate input that combines a continuum of varieties ω

$$Q(s) = \left[\int_{\omega \in \Omega} q(\omega, s)^{\frac{\eta-1}{\eta}} d\omega \right]^{\frac{\eta}{\eta-1}},$$

The parameter $\eta > 1$ is the elasticity of substitution among intermediate goods, and the associated price index for $Q(s)$ is:

$$P(s) = \left[\int_{\omega \in \Omega} p(\omega, s)^{1-\eta} d\omega \right]^{\frac{1}{1-\eta}},$$

Total expenditure in the composite intermediate good is then $P(s)Q(s)$.

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

The intermediate goods sector has a continuum of firms of measure one. 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 affiliate plants abroad with the same productivity parameter $z(\omega)$ as the one they have at home. Production functions for a firm from country i producing good ω in country j is:

$$q_{ij}(\omega, s) = z(\omega) \cdot l_{ij}(\omega, s). \quad (3)$$

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.¹¹

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,

$$p_{ij}(z, s) = \frac{\eta}{\eta - 1} \cdot W_j(s) \cdot \frac{1}{z}, \quad (4)$$

where $W_j(s)$ denotes the wage in country j , state s .

Profits for a firm with productivity z that supplies market j are

$$\pi_{ij}(z, s) = \frac{x_{ij}(\omega, s)}{\eta}, \quad (5)$$

where total expenditure in each intermediate good is given by:

$$x_{ij}(z, s) = \left[\frac{p_{ij}(z, s)}{P_j(s)} \right]^{1-\eta} Q_j(s) P_j(s). \quad (6)$$

Assets Structure. The representative consumer in each country holds two types of assets:

¹¹Since 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 .

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 $j \neq i$.¹² With complete financial markets, the budget constraint for the representative consumer in country i is given by

$$\sum_{s \in S} \varphi(s) C_i(s) = B_i^0 + \sum_{s \in S} \varphi(s) \left\{ L_i W_i(s) + \int_{z \in Z} \pi_i(z, s) dG_i(z) \right\}, \quad (7)$$

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 , as defined in (8).

Total profits for a firm with productivity z from country i are given by:

$$\pi_i(z, s) = \sum_{j=1}^I \iota_{ij}(z) \pi_{ij}(z, s), \quad (8)$$

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

The Euler equation from the consumer's optimization problem is:

$$\varphi(s) = \frac{\beta \Pr(s)}{\lambda_i} u' [C_i(s)], \quad (9)$$

where $u' [C_i(s)] = C_i(s)^{-\sigma}$ is the marginal utility of consumption and λ_i is the multiplier on the consumer's budget constraint in country i .¹³

*Foreign Direct Investment (FDI).*¹⁴ Before the realization of country shocks, firms decide

¹²Results are unchanged if national firms are initially owned by national consumers and sold in the international market.

¹³The multiplier λ_i is also the inverse of the welfare weights of the corresponding planner's problem, which is presented in the Appendix.

¹⁴Foreign Direct Investment (FDI) refers to the Balance of Payment flow; in our model occurs only once, i.e.

whether to serve a market. If a firm from country i decides to enter the foreign 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,

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

where $\varphi(s)$ correspond to the price of a security that pays a unit of the consumption good in state s , and satisfies the Euler equation (9).

Countries are initially endowed with a stock of an investment tradable good, K_i . Entry costs to foreign markets are paid in units of this good, which international price is denoted by p_k .

Only those firms with productivity z such that the value of doing MP in market j , $V_{ij}(z)$, is larger than the value of the entry cost, $f_{ij}p_k$, will open an affiliate in that market. The entry decision is characterized by a cut-off rule defined by the following zero profit condition:¹⁵

$$V_{ij}(\bar{z}_{ij}) = f_{ij} \cdot p_k. \quad (11)$$

Firms from country i with z above $\bar{z}_{ij}$ open affiliates in country j . That is, $\iota_{ij}(z) = 1$ for all $z \geq \bar{z}_{ij}$ and $\iota_{ij}(z) = 0$ for all $z < \bar{z}_{ij}$. National firms face zero entry cost, $f_{jj} = 0$, which guarantees that $\bar{z}_{jj} = z_{\min}$.

the initial set-up of affiliates abroad. MP refers to the productive activities of affiliates abroad; in our model occurs in the second period.

¹⁵Notice from (4) that $p_{ij}(z, s)$ is inversely related to the firms's productivity z . Thus, with elastic demand function ($\eta > 1$), profits in expressions (5) increase in z :

$$\sum_{s \in S} \varphi(s) \frac{\partial}{\partial z} \pi_{ij}(z, s) > 0.$$

Hence, the optimal entry decision into market j for firms from country i is characterized by a cut-off 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 the market j is optimal.

Finally, net wealth in the budget constraint (7), for consumers in country i , is given by

$$B_i^0 = p_k \left[K_i - \sum_{j=1}^I f_{ij} [1 - G_i(\bar{z}_{ij})] \right], \quad (12)$$

that is, the value of the initial endowment of the investment good net of the total costs of opening affiliate plants.

3 Equilibrium

We define the equilibrium in two steps. First, we characterize *national* equilibrium prices and quantities in a given country and state of nature, as functions of the number of firms doing MP in each country. In the second step, we define the *international* equilibrium, characterize the MP decisions of firms and consumption across countries and states of nature.

3.1 National Equilibrium

Definition 1. *Given the cut-off rules $\{\bar{z}_{ji}\}_{j=1}^I$, the National Equilibrium in country i and state s is defined by the vector of output of across sectors $\{\langle q_{ji}(z, s) \rangle_{z \in Z}\}_{j=1}^I, Y_i(s)$, wage $W_i(s)$, prices $\{\langle p_{ji}(z, s) \rangle_{z \in Z}\}_{j=1}^I$, and labor demands across sectors $\{\langle l_{ji}(z, s) \rangle_{z \in Z}\}_{j=1}^I, L_i^f(s)$, such that:*

1. *Firms producing intermediate and final goods maximize profits;*
2. *For each good z , market clears:*

$$q_{ij}(z, s) \cdot p_{ij}(z, s) = x_{ij}(z, s); \quad (13)$$

3. *Labor market clears:*

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

where $L_{ji}(s)$ is aggregate labor demand by firms from country j located in country i in the intermediate good sector, $L_{ji}(s) = \int_{\bar{z}_{ji}}^{\infty} l_{ji}(z, s) dG_j(z)$; and

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

Define the following aggregate productivity index for firms from country j located in i :

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

The index Z_i aggregates the productivity in the intermediate good sector for firms from all countries located in i , $Z_i = \sum_{j=1}^I Z_{ji}$. Since investment decisions are taken at date zero before uncertainty is resolved, the productivity of the marginal firm from country j entering the market i , $\bar{z}_{ji}$, does not vary across states s . Thus, aggregate productivity indices, Z_i and Z_{ji} , are constant.

The law of one price in the final good sector implies that unit costs of production are equalized across countries. With Cobb-Douglas production functions (equation 2) and perfect competition, this implies that

$$\alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)}W_i(s)^\alpha P_i(s)^{1-\alpha} = A_i(s). \quad (15)$$

Using (4) and (15), the wage level and the price index for the intermediate aggregate good, in country i and state s are given by:

$$W_i(s) = \phi_1 \cdot A_i(s) \cdot Z_i^{\frac{1-\alpha}{\eta-1}}, \quad (16)$$

$$P_i(s) = \phi_2 \cdot A_i(s) \cdot Z_i^{\frac{\alpha}{1-\eta}}, \quad (17)$$

where ϕ_1 and ϕ_2 are positive constants.¹⁶ 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 the productivity shock $A_i(s)$ on wages translates one-to-one into the price of the intermediate good, $P_i(s)$, which is larger in states with higher realizations of $A_i(s)$.

From equation (2), the final good is produced with constant shares of labor and the intermediate good,

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

$$P_i(s)Q_i(s) = (1 - \alpha)Y_i(s). \quad (19)$$

The labor clearing condition in equation (14) implies that total output in the final good sector, in state s , is:¹⁷

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

where ϕ_3 is a positive constant.¹⁸ Output in the final good sector is proportional to the country-wide productivity shock, $A_i(s)$, and the proportionality factor increases with the size of the economy, L_i , and the overall productivity of firms located in i , Z_i .

Finally, using (4), (5), and the price index in (17), profits for a firm from country j with productivity z , operating in country i are:

$$\pi_{ji}(z, s) = \frac{1 - \alpha}{\eta} \cdot \frac{z^{\eta-1}}{Z_i} \cdot Y_i(s), \quad (21)$$

¹⁶ $\phi_1 \equiv \alpha^\alpha (1 - \alpha)^{1-\alpha} \left(\frac{\eta-1}{\eta}\right)^\alpha$ and $\phi_2 \equiv \alpha^\alpha (1 - \alpha)^{1-\alpha} \left(\frac{\eta-1}{\eta}\right)^{1-\alpha}$.

¹⁷ Using the market clearing condition for good z in (13), and (19), 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 (14), we obtain $Y_i(s) = \frac{\eta}{\alpha-1+\alpha} W_i(s) L_i$, which leads to expression (20).

¹⁸ $\phi_3 \equiv \alpha^\alpha (1 - \alpha)^{1-\alpha} \left(\frac{\eta-1}{\eta}\right)^\alpha \frac{\eta}{\eta-1+\alpha}$.

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 $Y_i(s)$, given by equation (20). Market share is constant across states of nature. It is larger for firms with better productivity –i.e. higher z – and lowers in the degree of competition by other firms in market i , given by their productivity index Z_i .

3.2 International Equilibrium

Definition 2. *For a given vector of initial endowments, $\{K_i\}_{i=1}^I$, the international equilibrium is defined by a matrix of cut-off rules $\{\bar{z}_{ij}\}_{i,j}$, the price of the investment good p_k , prices of Arrow-Debreu securities $\{\varphi(s)\}_{s \in S}$, consumption and holdings of Arrow-Debreu securities, in each $s \in S$, $\{C_i(s), B_i(s)\}_{i=1}^I$, such that:¹⁹*

1. *The Euler equation (9) is satisfied, for all countries $i = 1, \dots, I$;*
2. *The budget constraint in (7) is satisfied, for all countries $i = 1, \dots, I$;*
3. *The productivity cutoffs $\{\bar{z}_{ij}\}_{i,j}$ satisfy the zero profit conditions in (11), 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:*

$$\sum_{i=1}^I K_i = \sum_{i=1}^I \sum_{j=1}^I [1 - G_i(\bar{z}_{ij})] f_{ij}; \quad (22)$$

¹⁹This equilibrium is efficient. See the Appendix for the corresponding Social Planner problem.

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

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

The world described in this paper is analogous to a Lucas-type endowment economy where $\phi_3 Z_i^{\frac{1-\alpha}{\eta-1}} L_i$ is the number of (efficiency-adjusted) trees in country i , and $A_i(s)$ the stochastic amount of fruits delivered in state s by trees located in country i . Output in country i is therefore $Y_i(s) = \phi_3 Z_i^{\frac{1-\alpha}{\eta-1}} L_i A_i(s)$, the same expression as the equilibrium output in (20). World output in each state s is simply the world output 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:

$$A_W(s) \equiv \sum_{i=1}^I \varpi_i A_i(s) \quad \text{and} \quad \varpi_i \equiv \frac{L_i Z_i^{\frac{1-\alpha}{\eta-1}}}{\sum_{i=1}^I L_i Z_i^{\frac{1-\alpha}{\eta-1}}}. \quad (24)$$

World output can then be expressed as

$$Y_W(s) = \phi_3 \cdot A_W(s) \cdot \sum_{i=1}^I L_i Z_i^{\frac{1-\alpha}{\eta-1}}, \quad (25)$$

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

With frictionless trade and complete financial markets, perfect international risk sharing is attained. That is, from the Euler equation (9), 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 (23), 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 $\sum_{i=1}^I \mu_i = 1$.

Even though consumers perfectly share country-specific risk, as long as there is some non-diversifiable risk, world output and consumption in each country fluctuate across states of nature. The existence of aggregate risk is the obvious limitation of international trade and financial flows in diversifying 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 overall amount of goods produced in each state: they act by altering the patterns of production across countries. Examples are migration flows and, as stressed in this paper, international technology flows. We emphasize a specific form of technology flow across countries: the one embedded in the productive activities of foreign affiliates of multinational firms.

We treat multinational firms as technology entities, in the sense that the same technology z characterizes the parent company and its affiliates. Then, 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. That is, by affecting the fixed component of country-wide productivity, Z_i , and hence ϖ_i , MP changes the allocation of “trees” across countries, and the resulting impact of country-specific shocks on world aggregate fluctuations. Moreover, as shown in Proposition 1, consumption risk is reduced when affiliates (or “trees”) locate in economies with shocks (or “fruits”) least correlated with aggregate risk.

Proposition 1. Define $\Psi_i \equiv \text{cov}(A_W^{-\sigma}; A_j)$, 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 h and j such that $\Psi_j > \Psi_h$. Technology flows such that $d\varpi_j = -d\varpi_h > 0$ decrease the consumption risk premium ρ_i , for all i .

Proof: See Appendix □

A crucial assumption for this result is that affiliates (or new “trees”) bear the shock specific to the host country. In this paper, country shocks only affect affiliates through their impact on the unit labor cost. Thus, it is natural to assume that shocks to the unit labor cost affect all firms located in the country, irrespectively of their origin. Different shock specifications could add other considerations to the result in Proposition 1.²⁰ Yet, as long as there are shocks that affect all production located in a country, the results in this paper hold.

We show in the next section that indeed the direction of multinational production in a model where decentralized firms choose the location of their affiliates is as the one stated in Proposition 1.

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.²¹ The existence of

²⁰For instance, we could add productivity shocks specific to the multinational firm regardless of where its affiliates are located.

²¹The determinants of MP in a risk-less environment have been previously analyzed in Markusen (1984), Helpman, Melitz, Yeaple (2004), Ramondo (2005), Burstein and Monge (2007), McGrattan and Prescott (2007), among others.

aggregate risk introduces an additional factor: 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

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

where $Y_j(s) = \phi_3 \cdot L_j \cdot Z_j^{\frac{1-\alpha}{\eta-1}} \cdot A_j(s)$, as specified by equation (20). From the expression in (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 $Y_j(s)$ in the host market, increases profits in all states s , and hence increases the value of doing MP there. 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 output, $Y_j(s)$, 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 .²² Finally, as pointed out in previous literature, higher entry costs, f_{ij} , also reduce the net value of doing MP into market j .

²²

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

4.1 MP and the Patterns of Aggregate Risk

Crucially, in a risky environment, the stochastic properties of the shock in the host country is a new factor that also determines the value of doing MP for a firm with productivity z from country i in j is.

Replacing (26) in the Euler equation (9), Arrow-Debreu prices are:

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

where ϕ_4 is a positive constant.²³

Combining (29) and (27), the value of doing MP in country j can be expressed as follows:

$$V_{ij}(z) = \phi_5 \cdot \frac{z^{\eta-1}}{Z_j} \cdot E(Y_W^{-\sigma} \cdot Y_j),$$

where ϕ_5 is a positive constant.²⁴ Crucially, the discounted flow of profits depends on the correlation between the marginal utility of consumption, given by $Y_W^{-\sigma}(s)$, and output in the host country, $Y_j(s)$. 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 in those states.

Further replacing $Y_W(s)$ and $Y_j(s)$ with expressions (20) and (25), 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 :

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

²³ $\phi_4 \equiv \beta \left(\sum_k \lambda_k^{-1/\sigma} \right)^{-\sigma}$.

²⁴ $\phi_5 \equiv \phi_3 \phi_4^{\frac{1-\alpha}{\eta}}$.

where ϕ_6 is a positive constant, and the world average shock $A_W(s)$ is defined in (24).²⁵

The stochastic properties of the process governing the host country shock $A_j(s)$, crucially determine the value of a foreign affiliate. As suggested by (30), it is more profitable to locate affiliates in economies with shocks less correlated with world risk $A_W(s)$. In this way, by opening foreign affiliates and changing the amount of output across states of nature, firms can have relatively higher (MP) profits when world output is more scarce. This is the intuition behind the following proposition:

Proposition 2. *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 : $\Psi_i > \Psi_h$ iff $\bar{z}_{ji} < \bar{z}_{jh}$, for all $j \neq i, h$.*

Proof: See Appendix □

The number of foreign affiliates and, therefore, production, is largest in those economies with shocks least correlated with world shocks. This is because, with frictionless financial markets, the price of financial assets reflects consumers risk aversion, and firms use such prices to discount profits. Hence, the equilibrium location of production across countries is efficient and reduces consumption risk.²⁶ Indeed, in line with proposition 1, consumption risk, measured as the difference between certainty equivalent and expected consumption, is lower in a world with MP flows than in a world without MP. We refer to a world without MP (i.e. where the number of firms in each country is exogenously given) as *autarky*, and denote variables in this equilibrium with the superscript a . The following proposition formalizes this intuition.

Proposition 3. *Let ρ_i be the consumption risk premium defined by $u[E(C_i)(1 - \rho_i)] = E[u(C_i)]$.*

The risk premium is lower in a world with MP flows relative to a world without MP flows. That

²⁵ $\phi_6 \equiv \phi_5 \phi_3^{1-\sigma} \left[\sum_{i=1}^I L_i Z_i^{\frac{1-\alpha}{\eta-1}} \right]^{-\sigma}$.

²⁶ The corresponding social planner problem is presented in the Appendix.

is, $\rho_i^\alpha > \rho_i$, for all $i = 1, \dots, I$.

Proof: See Appendix □

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. Propositions 2 and 3 assumed that countries were symmetric except for the covariance between country and aggregate shocks, $\text{cov}(A_W^{-\sigma}; A_i)$. Now, we focus on asymmetries in the economic size of countries, L_i .

The economic size of a country is given by the size of its labor force L_i , and the aggregate productivity of firms located in the country, the index Z_i . Notice that the economic size of a country also determines the effect of its specific shock on overall world output fluctuations in expression (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 and, as a result, world output tends to follow fluctuations in the larger economy rather than the ones in the smaller economy. The following proposition formalizes this intuition.

Proposition 4. *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. In this case, consumption risk lowers if small economies are net recipients of MP flows. That is, again, technologies flow towards economies with shocks least correlated with world risk. The following is a Corollary to Proposition 4.

Corollary 1. *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 ρ . If $L_h = \min\{L_i\}_{i=1}^I$, then technology flows of the form $dZ_{jh} > 0$ decrease the consumption risk premium ρ .*

4.3 The effects of MP liberalization on consumption risk

Lowering barriers to entry of foreign firms, i.e. lower f_{ij} , has a different impact on consumption risk premium depending on country size and the correlation of country shocks with world risk. In the following calibration exercise, we simulate the effects of liberalizing MP among OECD countries.²⁷ Parameters are chosen in the following way. Parameters related to the stochastic process of country shocks, $\{E(A_i), Var(A_i), Cov(A_i, A_j)\}_{i \neq j=1}^I$, are chosen to match the stochastic process for real GDP per capita observed in the data, for the period 1960-2000, among the set of OECD countries.²⁸ We assume that these shocks follow a multivariate (truncated) normal distribution.²⁹ Bilateral fixed costs are calibrated to match gross value of production of affiliates from country i in j , as share of host country GDP, for an average over the nineties.³⁰ Finally, we calibrate the variable L_i using a measure of labor, for an average over the nineties, in which employment is adjusted to account for human and physical capital available per worker. In this way, this variable captures the total number of “equipped-efficiency” units available for production.³¹

The summary of the data is presented in the Appendix.

²⁷We 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.

²⁸Source: Penn World Tables.

²⁹We draw 500,000 vectors to simulate the model.

³⁰Source: UNCTAD.

³¹Source: Klenow and Rodriguez-Clare (2005).

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 Weinstein (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
β	0.98	match interest rate of 2%	discount factor

Table 1: Parameters from literature.

We calculate the consumption risk premium under four scenarios: the benchmark (i.e. the calibrated baseline model); no MP ($f_{ij} = \infty$ for all $i \neq j$); no MP but frictionless MP *from* the United States into any market j (i.e. $\bar{z}_{US,j} = z_{min}$ for all j , and $\bar{z}_{jj} = z_{min}$ and $\bar{z}_{ji} = \infty$ for all $i \neq j, j \neq US$); and no MP but frictionless MP *into* the United States from any market j (i.e. $\bar{z}_{j,US} = z_{min}$ for all j , and $\bar{z}_{jj} = z_{min}$ and $\bar{z}_{ji} = \infty$ for all $i \neq j, i \neq US$). We also report the correlation coefficient between country shocks (A_i) and world risk (A_W). Table 2 shows that the consumption risk premium decreases by almost 5% when we move to the calibrated benchmark with MP from a world with complete financial markets but no MP. The risk premium would also decrease by 5% (column III) if all American firms were able to become multinationals and open affiliates in the remaining 19 OECD countries, while the remaining firms in the world were just domestic, suggesting that the calibrated economy is indistinguishable from this scenario. However, the correlation between shocks specific to the United States and the average world shock would decrease from 0.48 to 0.34, while the one for the remaining countries would mostly increase (column I/II versus III). However, as suggested by Corollary 1, if all firms in OECD countries were able to open affiliates in the United States (column IV), the largest economy in the world, and the most correlated with aggregate risk, the consumption risk premium would increase by more than 80%. At the same time, the correlation between the United States and world risk would rise to almost 0.9. Indeed, the location decisions of firms affect the pattern of

	benchmark	no MP	frictionless MP from the US	frictionless MP into the US
% Change in risk premium (from no MP)	-4.8%	-	-4.8%	83%
Correlation between Y_i and Y_W				
Australia	-0.30	-0.29	-0.28	-0.28
Austria	-0.35	-0.36	-0.22	-0.76
Belgium	-0.31	-0.32	-0.18	-0.73
Canada	0.16	0.18	0.10	0.36
Denmark	-0.38	-0.39	-0.25	-0.79
Spain	0.28	0.29	0.16	0.67
Finland	-0.28	-0.27	-0.16	-0.65
France	0.05	0.07	0.11	-0.13
United Kingdom	-0.27	-0.27	-0.14	-0.68
Germany	0.05	0.08	0.09	-0.02
Greece	-0.54	-0.53	-0.45	-0.70
Italy	0.00	0.03	0.09	-0.25
Japan	0.44	0.41	0.53	-0.05
Netherlands	-0.29	-0.29	-0.17	-0.67
Norway	-0.28	-0.25	-0.23	-0.35
New Zealand	-0.14	-0.14	-0.08	-0.33
Portugal	-0.33	-0.33	-0.22	-0.67
Sweden	-0.15	-0.13	-0.04	-0.47
United States	0.48	0.49	0.34	0.89

Table 2: The effects of MP on world risk (OECD countries).

world risk and thus, the consumption risk premium.

5 Extension: 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 basic 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.³² 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 into a market, which reinforces the location patterns of production analyzed in the basic model.

In the model, physical capital is used in period zero, before country shocks are realized, to set-up foreign affiliates. 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 the mentioned 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:

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

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

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

where $0 < \nu < 1$.

Since capital is freely mobile, equilibrium allocations entail equalization of its marginal product 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).

The *national equilibrium* adds to Definition 1 the allocation of physical capital across sectors,

³²This difference is also highlighted by McGrattan and Prescott (2007) in a growth model that incorporates technology capital.

in 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 equilibrium, the marginal product of capital across goods, in country i , 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 (6), 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 , $K_i(s) = K_i^f(s) + \sum_{j=1}^I K_{ji}(s)$ with $K_{ji}(s) = \int_{\tilde{z}_{ji}}^{\infty} k_{ji}(z, s) dG(z)$. 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 $p_k(s) = (1 - \nu) \cdot (Y_i(s) / K_i(s))$, that shows that the marginal product of capital is equalized across countries, in each 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:

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

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

and $\tilde{\phi}_3$ is a positive constant.³³ Output fluctuates with country shocks $A_i(s)$. The introduction of capital introduces another source of fluctuation given by the international price of capital.

³³ $\tilde{\phi}_3 \equiv \phi_3 (1 - \nu)^{(1-\nu)}$.

The *international equilibrium* adds to Definition 2 the international price of capital in state s , $\{p_k(s)\}_{s \in S}$. At time zero, capital is used for setting-up foreign affiliates which requires f_{ij} units. However, some of the initial 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, $K_W(s) = K_W^1$, for all s . Combining conditions (35) and (38), the equilibrium international price of capital is:

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

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:

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

Replacing p_k^0 by the zero profit condition in (11), and $p_k(s)$ by (39), the marginal firm from country i opening an affiliate in country j is defined by:

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

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 $\tilde{\omega}_i \equiv \frac{\tilde{L}_i}{\tilde{L}_W}$. As in the basic framework, the weight of a country shock in aggregate fluctuations is given by the size of a country's productive capacity: the size of the labor force, L_i , and aggregate productivity of firms located in market i , Z_i .

Qualitatively, results are identical to those for the basic model. Thus, Propositions 2 and 3 still hold. 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.³⁴ However, this extension not only highlights the difference between capital and MP flows, but also reinforces the results in the previous sections. From (35), (39), and (41), the allocation of capital across countries is given by:

$$K_i(s) = \tilde{\omega}_i \cdot \left[\frac{A_i(s)}{A_W(s)} \right]^{1/\nu} \cdot K_W.$$

This expression implies 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.³⁵

³⁴The parameter Ψ_i in proposition 2 is now defined as $\Psi_i \equiv \text{cov} \left(A_W^{-\sigma-(1-\nu)/\nu}; A_i^{1/\nu} \right)$.

³⁵For documentation on this fact see, for example, Lipsey (2001), Albuquerque (2003), and Bachetta and Van Wincoop (2000).

Second, the capital stock for country i , in any state, is higher the larger the weight $\tilde{\omega}_i$, that is, when more productive firms are located there (i.e. higher Z_i). This result is particularly relevant for our analysis. Opening foreign affiliates involves technology transfers to the host economy, and therefore it affects the marginal product of all productive 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 and, therefore, the larger the capital inflows. 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 2.

6 Conclusions

This paper emphasizes the connection between technology flows and the pattern of international risk. In particular, the scope for international risk diversification is improved when more productive technologies are used in economies with business cycles less correlated with the world risk pattern. Technology flows towards such economies may take different forms. In this paper, we analyzed the effects of a very natural form of technology transfer across countries, in a risky environment: 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 can benefit consumers in a risky environment with country-specific shocks. By altering host country's productivity, multinational production (MP) affects the patterns of world risk even under complete financial markets. The impact of country-specific shocks on international goods and assets markets is changed in such way that the scope for international risk diversification is improved.

A calibration exercise for nineteen OECD countries shows that a world with MP has a consumption risk premium 5% lower than a world without MP but complete financial markets. Indeed, the location decisions of firms affect the pattern of world risk and thus, the consumption risk premium.

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7 Appendix

7.1 Proof of Proposition 1

Combining the utility function in (1), world output in (20), 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 $d\varpi_j = -d\varpi_h > 0$:

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

7.2 Proof of Proposition 2

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 (11) 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 (20), 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 $\bar{z}_{ji}^{\eta-1} \geq \bar{z}_{jh}^{\eta-1}$ and therefore $Z_i < Z_h$, which is a contradiction. Then, it must be that for all $j \neq i, h$: $\bar{z}_{ji} < \bar{z}_{jh}$. $\square$

7.3 Proof of Proposition 3

Let $\{\bar{z}_{ji}^*\}_{j,i=1}^I$ be the efficient equilibrium allocation of affiliates that maximizes expected utility.

Then, $\{\bar{z}_{ji}^*\}_{j,i=1}^I$ satisfies:

$$E \left\{ \left[Y_W | \{\bar{z}_{ji}^*\}_{j,i=1}^I \right]^{1-\sigma} \right\} \geq E \left\{ \left[Y_W | \{\bar{z}_{ji}\}_{j,i=1}^I \right]^{1-\sigma} \right\},$$

for any $\{\bar{z}_{ji}\}_{j,i=1}^I$ that satisfies the feasibility condition (22). This condition can be expressed in terms of the risk premium ρ :

$$\frac{E \left\{ Y_W | \{\bar{z}_{ji}^*\}_{j,i=1}^I \right\}}{E \left\{ Y_W | \{\bar{z}_{ji}\}_{j,i=1}^I \right\}} \geq \frac{1 - \rho \left(\{\bar{z}\}_{j,i=1}^I \right)}{1 - \rho \left(\{\bar{z}_{ji}^*\}_{j,i=1}^I \right)}.$$

Let $\{\bar{z}_{ij}^m\}_{j,i=1}^I$ be the cut-off rule that maximizes expected output $E \{Y_W(s)\}$. Since $E(A_i) = 1$ for all $i = 1, \dots, I$, expected output is just:

$$E(Y_W) = \phi_3 \cdot L \sum_{i=1}^I Z_i^{\frac{1-\alpha}{\eta-1}},$$

which is maximized when firms with the highest productivity z open affiliates. Since $G_i(z) = G(z)$, for all i , the location of affiliates that maximizes world aggregate productivity is such that $\bar{z}_{ij}^m = \bar{z}$ for all $i, j = 1, \dots, I$. This allocation implies equal weights for country-specific shocks on world risk in equation (24), $\varpi_i^m = I^{-1}$, for all $i = 1, \dots, I$. Notice that, if countries are symmetric and there is no MP flows, equal weights also characterize the autarky solution: $\varpi_i^a = \varpi_i^m$. It follows that world risk under autarky, $A_W^a(s)$, is equal to world risk under the output maximizer technologies' allocation, $A_W^m(s)$. Correspondingly, risk premia are also equal: $\rho \left(\{\bar{z}_{ji}^m\}_{j,i=1}^I \right) = \rho^m = \rho^a$.

However, as long as the feasibility condition (22) is binding, Proposition (2) states that weights are not identical across countries, and therefore the output maximizer technologies' allocation does not coincide with the efficient allocation: $\{\bar{z}_{ij}^m\}_{j,i=1}^I \neq \{\bar{z}_{ij}^*\}_{j,i=1}^I$. Then: $E \left\{ Y_W | \{\bar{z}_{ji}^*\}_{j,i=1}^I \right\} < E \left\{ Y_W | \{\bar{z}_{ji}^m\}_{j,i=1}^I \right\}$.

For $\{\bar{z}_{ji}^*\}_{j,i=1}^I$ to be maximal, it has to be that $1 - \rho \left(\{\bar{z}_{ji}^*\}_{j,i=1}^I \right) > 1 - \rho \left(\{\bar{z}_{ji}^m\}_{j,i=1}^I \right)$. It

follows that $\rho^* < \rho^m = \rho^a$. $\square$

7.4 Proof of Proposition 4

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 $\varpi_j > \varpi_h$: $E(A_W^{-\sigma} A_j) < E(A_W^{-\sigma} A_h)$. 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 $\text{cov}(A_W^{-\sigma}; A_j) < \text{cov}(A_W^{-\sigma}; A_h)$.

Applying the same logic as in the proof of proposition 2, 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 $\text{cov}(A_W^{-\sigma}; A_j) < \text{cov}(A_W^{-\sigma}; A_h)$. $\square$

7.5 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 $\Gamma = \{\langle C(s) \rangle_{i=1}^I, \langle \bar{z}_{ji} \rangle_{i,j}\}$ 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 $\varpi_i \equiv \frac{L_i Z_i^{\frac{1-\alpha}{\eta-1}}}{\sum_{i=1}^I L_i Z_i^{\frac{1-\alpha}{\eta-1}}}$. As in the decentralized economy presented in the paper, the optimal allocation involves perfect international risk sharing:

$$\frac{\lambda_i}{\lambda_j} = \frac{u'(C_j(s))}{u'(C_i(s))},$$

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 .

7.6 Data

The moments for GDP per capita in Tables 3 and 4 are calculated after de-trending the original series taken from the Penn World Tables with a Hodrick-Prescott filter, for the period 1960-2000 (for mean and standard deviation), and 1970-2004 (for cross country correlations). The measure for equipped-efficient labor is taken from Klenow and Rodriguez-Clare (2005), as an average over the nineties. Table 5 show 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.

The model's calibration to these moments is called "benchmark".

	L	GDP p.c.	STD GDP p.c.
	(as share of L_{US})		
Australia	0.06	0.67	0.025
Austria	0.02	0.83	0.032
Belgium	0.03	0.77	0.029
Canada	0.11	0.70	0.038
Denmark	0.02	1.01	0.019
Spain	0.08	0.48	0.027
Finland	0.02	0.78	0.050
France	0.16	0.77	0.026
United Kingdom	0.16	0.70	0.025
Germany	0.27	0.83	0.028
Greece	0.02	0.35	0.034
Italy	0.13	0.66	0.029
Japan	0.52	1.12	0.035
Netherlands	0.04	0.79	0.025
Norway	0.02	1.11	0.047
New Zealand	0.01	0.48	0.039
Portugal	0.02	0.34	0.045
Sweden	0.03	0.91	0.031
United States	1.00	1.00	0.025

Table 3: Statistics for equipped-labor and GDP per capita. OECD.

	AUS	AUT	BEL	CAN	DNK	ESP	FIN	FRA	GBR	GER	GRC	ITA	JPN	NDL	NOR	NZL	PRT	SWE	USA
AUS	1.00	0.06	0.01	0.48	-0.02	-0.31	0.19	0.41	0.08	0.04	0.33	0.11	-0.27	-0.02	0.42	0.59	0.20	0.21	-0.20
AUT	0.06	1.00	0.95	-0.44	0.98	-0.73	0.80	0.27	0.92	0.05	0.75	0.50	0.38	0.94	0.41	0.30	0.76	0.64	-0.89
BEL	0.01	0.95	1.00	-0.46	0.94	-0.70	0.83	0.29	0.93	0.12	0.74	0.45	0.39	0.96	0.43	0.19	0.74	0.71	-0.88
CAN	0.48	-0.44	-0.46	1.00	-0.56	0.12	-0.10	0.39	-0.37	-0.04	-0.24	0.07	-0.44	-0.46	0.28	-0.04	-0.20	0.05	0.42
DNK	-0.02	0.98	0.94	-0.56	1.00	-0.74	0.78	0.17	0.90	0.07	0.73	0.47	0.42	0.90	0.25	0.26	0.77	0.59	-0.91
ESP	-0.31	-0.73	-0.70	0.12	-0.74	1.00	-0.78	-0.24	-0.68	-0.03	-0.63	-0.49	-0.38	-0.63	-0.24	-0.35	-0.70	-0.54	0.81
FIN	0.19	0.80	0.83	-0.10	0.78	-0.78	1.00	0.54	0.88	0.38	0.73	0.75	0.13	0.78	0.51	0.17	0.83	0.86	-0.80
FRA	0.41	0.27	0.29	0.39	0.17	-0.24	0.54	1.00	0.43	0.36	0.20	0.61	-0.18	0.29	0.61	0.38	0.37	0.73	-0.26
GBR	0.08	0.92	0.93	-0.37	0.90	-0.68	0.88	0.43	1.00	0.32	0.75	0.66	0.25	0.90	0.50	0.30	0.77	0.79	-0.84
GER	0.04	0.05	0.12	-0.04	0.07	-0.03	0.38	0.36	0.32	1.00	0.28	0.63	-0.32	0.09	0.19	0.09	0.23	0.41	-0.10
GRC	0.33	0.75	0.74	-0.24	0.73	-0.63	0.73	0.20	0.75	0.28	1.00	0.45	-0.09	0.73	0.48	0.26	0.60	0.56	-0.67
ITA	0.11	0.50	0.45	0.07	0.47	-0.49	0.75	0.61	0.66	0.63	0.45	1.00	-0.09	0.40	0.38	0.25	0.58	0.78	-0.42
JPN	-0.27	0.38	0.39	-0.44	0.42	-0.38	0.13	-0.18	0.25	-0.32	-0.09	-0.09	1.00	0.35	-0.27	0.09	0.20	0.02	-0.39
NDL	-0.02	0.94	0.96	-0.46	0.90	-0.63	0.78	0.29	0.90	0.09	0.73	0.40	0.35	1.00	0.48	0.18	0.69	0.64	-0.81
NOR	0.42	0.41	0.43	0.28	0.25	-0.24	0.51	0.61	0.50	0.19	0.48	0.38	-0.27	0.48	1.00	0.27	0.36	0.62	-0.34
NZL	0.59	0.30	0.19	-0.04	0.26	-0.35	0.17	0.38	0.30	0.09	0.26	0.25	0.09	0.18	0.27	1.00	0.17	0.18	-0.39
PRT	0.20	0.76	0.74	-0.20	0.77	-0.70	0.83	0.37	0.77	0.23	0.60	0.58	0.20	0.69	0.36	0.17	1.00	0.72	-0.78
SWE	0.21	0.64	0.71	0.05	0.59	-0.54	0.86	0.73	0.79	0.41	0.56	0.78	0.02	0.64	0.62	0.18	0.72	1.00	-0.62
USA	-0.20	-0.89	-0.88	0.42	-0.91	0.81	-0.80	-0.26	-0.84	-0.10	-0.67	-0.42	-0.39	-0.81	-0.34	-0.39	-0.78	-0.62	1.00

Table 4: Correlation of GDP per capita across countries. OECD.

	AUS	AUT	BEL	CAN	DNK	ESP	FIN	FRA	GBR	GER	GRC	ITA	JPN	NDL	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
NDL	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 5: Bilateral MP (as share of host country's GDP). OECD.