Size, Geography, and Multinational Production*

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(JOB MARKET PAPER)

January 12, 2006

Abstract

This paper analyzes the cross-country allocation and volume of multinational production, quantifies its barriers, and assesses its impact on welfare. From the patterns of multinational production across countries, three facts stand out: a small fraction of country-pairs engages in multinational activities with each other; geography remains a significant impediment to the expansion of such activities; and country size matters. I introduce multinational production in a competitive, multi-country, general equilibrium model with bilateral fixed costs that qualitatively reproduces these facts. The model delivers an equation for sales of foreign affiliates that predicts zero as well as positive volumes between country-pairs, and where positive flows are related to technology, size, and barriers. Using data on bilateral sales of affiliates, for OECD and non-OECD countries, I estimate barriers to multinational activities using an indirect inference procedure. Estimates suggest that distance remains a significant impediment, with countries twice as distant facing a 50% higher cost; policy variables, such as preferential treaties and taxes, have small effects. Finally, welfare calculations show that there are large, unrealized gains of removing *bilateral* barriers to multinational production.

*I would like to thank Fernando Alvarez, Christian Broda, Thomas Chaney, William Fuchs, Hugo Hopenhayn, Robert Lucas, Alejandro Rodriguez, Robert Shimer, Nancy Stokey, and Balazs Szentes for their comments and discussions. I benefited from comments of participants at seminars at the University of Chicago, Universidad T. Di Tella, and Chicago Federal Reserve Bank. All remaining errors are mine.

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1. INTRODUCTION

One of the most notable features of economic globalization has been the increasing importance of multinational production around the world. In fact, international firms have become one of the most important mechanisms through which countries exchange goods, capital, and technologies[1]. By 2001, total sales of foreign affiliates of multinational firms represented almost 60% of world GDP, more than double the share of world exports. Furthermore, over the past two decades, while exports have almost quadrupled, sales of affiliates have increased by a factor of more than seven[2]. Despite the importance of multinational production as a mechanism through which firms serve foreign buyers, little work has been done that describes, explains, and quantifies its cross-country patterns and impact on welfare. This paper tries to fill that gap by analyzing the determinants of the cross-country allocation of affiliate plants of multinational firms and the volume of their activities, and quantifying the effects on welfare of changes in barriers to international production.

Three facts stand out from the observed patterns of multinational production across countries. First, only 25% of all possible country-pairs engages in multinational activities with each other. Second, geography remains an important impediment to the expansion of such activities; remote country-pairs have substantially less, and mostly non-existent, multinational activities with each other. Third, country size (in terms of income) seems to be an important factor determining both the allocation and volume of multinational production; in fact, the bulk of multinational activities takes place between large economies, while the lack of them is mostly observed between small economies. These stylized facts emerge from a new data set on bilateral activities of foreign affiliates of multinational firms

[1] Multinational activities involve activities of foreign affiliates of multinational plants in a host country, and not always take the form of Foreign Direct Investment (FDI). FDI is a capital account category in the Balance of Payment of a country, and one of the mechanisms through which multinational firms fund their affiliate plants (e.g. if they fund investment through local or international banks, then no FDI would be observed). Throughout this paper, I use indistinctly the term multinational activities, international production, and FDI to refer to the activity of affiliate plants of multinational firms.

[2] See Table 1 in the paper.

that I assemble using various information sources[3].

I introduce multinational production in a competitive, general equilibrium model with bilateral fixed costs, heterogeneous countries, and decreasing returns to scale at the plant level, that qualitatively reproduces the stylized facts above. Firms have to decide whether to open affiliate plants abroad, and how to allocate them across countries. Regardless of the country of destination, affiliate plants inherit the productivity levels of their parent firm. However, to transfer such technology, firms face a bilateral fixed cost. This cost is proxied by variables such as geography, regulations, and cultural factors that are specific to the pair of trading countries, and some of which are observable while others are not. Additionally, as in Eaton and Kortum (2002), countries are heterogeneous in their productivity distribution, and size. Given countries' productivity levels and fixed costs, a firm opens an affiliate in another country as long as its profits are high enough to cover the bilateral cost, and the price charged is lower than that of potential competitors of any other origin. Once established in the host market, affiliate plants produce using local labor, sell output exclusively in the host market, and eventually, repatriate profits to the home economy[4].

The model delivers a set of implications regarding the allocation and volume of activities of affiliate plants of firms from country j in country i. First, similar to the model in Helpman, Melitz, and Rubinstein (2004) for international trade, this model allows for each firm in country j to choose not to produce in country i, since no firm from j may have a productivity level such that it can set the lowest price in market i and break-even. Therefore, the model is consistent with zero two-way multinational activities between some country-pairs, as well as only one-way activities for other country-pairs. Second, the model predicts positive two-ways multinational activities for some country-pairs, which is also observed in the data. Finally, as suggested by the stylized facts, the model generates a gravity equation

[3] UNCTAD, published and unpublished data; and OECD, International Direct Investment and Globalization databases.

[4] I focus on "horizontal FDI" by contrast to "vertical FDI". Horizontal FDI refers to foreign facilities which are set up to serve consumers in a host market. Vertical FDI involves the fragmentation of the production process among different locations in order to take advantage of lower inputs' prices (see Helpman (1984); Helpman and Antras (2003)).

for sales of affiliate plants of firms from country j in i, according to which positive volumes are proportional to countries' technology and size, dampened by bilateral barriers[5].

Although similar to the structural equation derived in Eaton-Kortum (2002) for trade patterns, the equation for bilateral sales' volumes derived in this paper differs fundamentally from theirs. My model highlights the role of absolute rather than comparative advantages in determining the allocation of bilateral multinational production: since production in affiliate plants is done by employing inputs from the host economy, and prices are uniform across plants of any origin, input costs do not matter in determining which plants produce in the host market; productivity levels and bilateral fixed costs are the only relevant variables determining the cross-country allocation of multinational production. Moreover, the introduction of bilateral fixed costs allows for the possibility of zero bilateral flows which prevail in the data.

I then use detailed data on bilateral sales volumes and the predictions of the model to quantify the magnitude of barriers to international production. The data include variables such as bilateral sales of affiliate plants, which I concentrate on, and other measures of bilateral multinational activities and FDI, for OECD and non-OECD countries, from 1990 to 2002[6]. Finally, using the theory and estimates, I present welfare calculations of liberalizing and lowering barriers to multinational activities, both world-wide and for selected economies.

The presence of bilateral fixed costs and zero volumes does not allow one to apply traditional linear regression methods to consistently estimate the barriers' parameters. The empirical framework to estimate these barriers uses an indirect inference procedure derived from the theory that deals with biases typically present in linear estimates of gravity equations. The indirect inference estimator is the one that minimizes the distance between a vector of moments computed from the actual and simulated data. These moments are cho-

[5]In this model, employment, assets, and number of affiliate plants of firms from country j in i are all proportional to sales.

[6]The data set includes FDI stocks and flows, as computed in the balance of payment of countries, and sales, assets, employment, and number of affiliate plants of foreign firms.

sen to properly capture the empirical patterns of the allocation and volume of multinational production across countries. It turns out that bilateral distance remains the most important impediment to international activities of multinational firms: country-pairs twice as distant face an almost 50% higher bilateral fixed cost. This estimate translates into a 45% lower share of sales of affiliates from country j on income of country i. Policy variables such as preferential taxation treaties or bilateral corporate tax rates have a small impact on the bilateral cost of multinational activities.

Regarding welfare calculations, I calculate real income gains for each country under various regime changes: (i) moving to autarky; (ii) removing *bilateral* barriers and lowering them to a uniform level; and (iii) moving the United States to autarky. Additionally, I calculate real income changes when barriers are lowered within NAFTA and the EU, respectively. Preliminary results suggest that average real income losses of going to world-wide autarky would be more than 50%, but unevenly spread across countries, ranging from 20% for the United States to 90% for Philippines. Conversely, average real income gains of "balancing the field" across firms of different origins in each country would be more than 60%. Moreover, if the EU further liberalized multinational activities among its members, it would experience an increase in real income of around 30%, while further liberalization within NAFTA would increase real income in the United States by 10%, with very small effects on Mexico.

Previous literature has typically examined the determinants of trade volumes across countries using mostly a gravity approach[7]. This approach has been very successful in fitting bilateral trade flows, with increasingly accurate estimates of the size of trade barriers, and their impact on welfare.

However, to my knowledge, there is no study that performs a similar exercise for bilateral sales of affiliates of multinational firms by incorporating them into a model that is then quantified and used to perform welfare calculations. Even though I abstract from issues related to international trade in goods, which certainly should be incorporated in future work, a benchmark that analyzes multinational production as opposite to only international

[7] See Anderson and Van Wincoop (2003).

trade, gives new and interesting insights into the importance of impediments to multinational activities, and their effects on welfare[8]. Indeed, the work of Burstein and Monge (2005) is similar in spirit to the one in this paper in that they quantify a general equilibrium model of cross-country allocation of managerial ability, and they use it to draw welfare implications of barriers reductions. Even though they study a similar question to the one in this paper, they use a different theoretical framework, concentrate in North-South flows, consider policy barriers, and use FDI stocks.

In particular, the theory in my paper is closer to Eaton and Kortum (2002), and Alvarez and Lucas (2004) in that it keeps the probabilistic formulation of technology, modifying it to plants' rather than goods' mobility, and adding bilateral fixed costs at the country-pair level.

Additionally, this paper complements the results in Helpman, Melitz and Yeaple (2004): while their paper studies the competing forces between exports and "horizontal" FDI at the firm-level in a single country across industries, mine analyzes the competing forces that determine why affiliates of multinational firms from certain countries are located in some countries and not others, at the aggregate (bilateral) country level[9].

Regarding the empirical framework, studies which incorporate countries that do not trade with each other are almost non-existent in the international trade and FDI literature, with

[8] Besides, in most service sectors, the only way of serving foreign markets is by setting up local operations through FDI or licensing. In fact, FDI in services sectors has grown more rapidly than FDI in other sectors, representing in some countries, 80% of total FDI stocks. However, as the World Investment Report (2004) points out, "given the non-tradability of many services, one would expect services to be delivered to foreign markets mainly via FDI, and goods mainly via trade". Data for the United States and other European countries show that the ratio of sales of foreign affiliates to total export at the end of the 90's was 2.5 for goods and almost 2 for services. Still, international transactions in goods rely on FDI much more than on trade, and much more so than international transactions in services.

[9] Moreover, while in their model variables such as geographic distance decrease the *ratio* of bilateral sales of foreign affiliates to exports, in mine, they decrease the *level* of bilateral sales. This does not exclude the fact that both variables might decrease with distance. In fact, in the data, both bilateral exports and bilateral sales of affiliates are positive correlated, with distance decreasing both exports and sales of affiliates between two countries, but proportionally more the former.

the notable exception of Helpman, Melitz and Rubinstein (2004), and Razin, Rubinstein and Sadka (2003). Both papers incorporate zero bilateral trade and FDI flows, respectively, in a two-step estimation procedure that corrects for biases present in linear estimates of gravity equations[10]. The empirical part of my paper addresses similar concerns to those in the two papers above, but it deals with them in a different way. Even though the theory I present could potentially be used to derive a two-step estimation procedure, the nature of the selection term, which is different from the one derived using Melitz's framework, makes it intractable. Apart from being computationally simpler, the estimation method I propose allows me to estimate other important parameters, necessary to carry out welfare analysis.

The paper is organized as follows. Section 2 presents the stylized facts on bilateral multinational activities. Section 3 develops the theory and its implications. Section 4 presents the empirical framework. Section 5 shows estimates of the model's parameters, and welfare calculations. Section 6 concludes.

2. CROSS-COUNTRY FACTS ON MULTINATIONAL PRODUCTION

International production has become increasingly important in the last decades of the twentieth century, as the mechanism through which countries exchange goods, capital and technologies.

Table 1 shows world totals for GDP, sales of foreign affiliates of multinational firms, and exports, for the period 1982-2001. While world exports have represented between 19% and 23% of world GDP during these period, total sales of foreign affiliates of multinational firms have increased from 24% of world GDP in 1982, to 58% in 2001. Moreover, over the period 1982-2001, while GDP and exports grew at an average annual rate of around 5% and 6%, respectively, sales of foreign affiliates did it at more than 10% per year. Meanwhile, the share of world exports of affiliates in world sales of affiliates, has been decreasing in the last two decades, reaching 14%, in 2001. These magnitudes suggest that not only multinational

[10] Razin *et al.* use information on bilateral FDI stocks, for OECD countries. However, their theory does not deliver gravity.

	Value at Current Prices (Billions of dollars)				Annual Growth Rate (Per cent)
	1982	1990	1996	2001	82-01
World GDP	11,758	22,610	29,024	31,900	**5.3**
World sales of foreign affiliates of MNEs	2,765	5,727	9,372	18,517	**10.0**
as % of world GDP	**24%**	**25%**	**32%**	**58%**	
World export of goods and non-factor services	2,247	4,261	6,523	7,430	**6.3**
as % of world GDP	**19%**	**19%**	**22%**	**23%**	
World exports of foreign affiliates of MNEs	730	1,498	1,841	2,600	**6.7**
as % of world exports	**32%**	**35%**	**28%**	**35%**	
as % of sales of affiliates	**26%**	**26%**	**20%**	**14%**	
FDI stocks*	628	1,769	3,238	6,846	**12.6**
as % of world GDP	**5%**	**8%**	**11%**	**21%**	

(*): Inward FDI stocks computed from the Balance of Payment of countries
"MNE" = multinational enterprise
Source: UNCTAD, WIR 2004

Table 1: World International Production and Trade

production is the most important mode through which firms serve foreign consumers, as opposite to exports, but also that "horizontal FDI" remains much more important than "vertical FDI".

The data set that I introduce in this paper includes six bilateral measures of FDI and international production. In particular, I record FDI stocks and flows from country j in country i, as measured in the balance of payment of countries, and, more importantly, variables related to the activity of affiliates of firms from country j in country i: sales, number of plants, employment, and assets. Additionally, OECD and non-OECD countries with population over one million are included. Observations are averages over the period 1990-2002. The main information source is published and unpublished data from UNCTAD. (The Appendix reports data details).

In what follows, let country-pairs be classify according to their multinational production status: country-pairs with some multinational activity in both directions, country-pairs with activities in only one direction, and country-pairs that do not have any multinational

	Country-pairs with Xij> 0 and Xji > 0	Country-pairs with Xij > 0 and Xji= 0	Country-pairs with Xij = 0 and Xji = 0	All possible country-pairs *
Means (millions of current U$):				
Sales of foreign affiliates	8,015	16	0	289
Assets of foreign affiliates	18,490	13	0	369
FDI stocks	1,531	44	0	146
FDI flows	223	8	0	22
Mean number of foreign affiliates	119	2	0	4
Number of country-pairs	2,404	2,812	17,434	0
% of country-pairs	0.11	0.12	0.77	1

(*) For country-pairs with zero bilateral FDI, missing values are replaced by zeros
Xij= multinational production of firms from country j in country i

Table 2: Bilateral Multinational Production and FDI

relationship with each other. I consider that country j has multinational production activities in country i if at least one of the six variables recorded in the database is positive. On the contrary, a country j is considered to have zero production activity in country i, if *all* six measures are missing values or zeros.

Table 2 shows that among the 151 countries in the sample, there are 22,650 possible bilateral country-pairs of which only 3,810 have an FDI relationship. In particular, 77% of all possible country-pairs do not engage in any FDI activity, during the 90s'; the comparable figure for international trade is around 50% for the mid-nineties[11]. Since engaging in a FDI relationship implies to have a significant participation in the ownership of either a preexistent or new plant abroad, unlike international trade flows, the nature of the FDI relationship makes implausible to attribute such a high fraction of zeros to an statistical problem, that either bunches small flows in an "other" category, or does not compute them at all.

Table 2 also shows that, on average, the bulk of multinational activities occurs among country-pairs that have positive volumes in both direction; they are much smaller for country-pairs with positive volumes in only one direction, according to any of the mea-

[11] See Helpman, Melitz and Rubinstein (2004).

sures shown.

Barriers' measures:	Country-pairs with Xij > 0 and Xji > 0	Country-pairs with Xij > 0 and Xji = 0	Country-pairs with Xij = 0 and Xji = 0
mean distance between country-pairs (in km)	5862	7028	7504
% of country-pairs with common language	0.143	0.133	0.141
% of country-pairs with common border	0.08	0.03	0.02
% of country-pairs ever in colonial relationship	0.05	0.02	0.01
% of country-pairs with double taxation treaty	0.67	0.27	0.04
mean corporate tax rate between country-pairs	16.8	26.3	34.1

Barriers values for country-pairs in column 1 and 3 are significantly different for all variables but common language
Xij= multinational production of firms from country j in country i

Table 3: Bilateral barriers to Multinational Production

The gravity approach suggests that the bilateral volumes of multinational production is a multiplicative function of trading partners' sizes in terms of income, dampened by barriers. One widely used variable for barriers is geography. Table 3 shows that the average distance among the group of country-pairs with no FDI is much higher than among country-pairs with positive flows. The table also shows that the fraction of country-pairs with a common border and a common colonial past is higher among pairs with positive than for pairs with no FDI. Unexpectedly, sharing a language does not seem to be a factor that promotes international production. The last two variables are related to taxation of foreign firms: the average bilateral tax rate for firms from country j in country i, and the average fraction of country-pairs that share a double-taxation treaty that reduces taxes for foreign companies in the host country. Bilateral corporate taxes are substantially lower among country-pairs with positive flows than among the ones with zero multinational production activities (16% against 34%), while the fraction of country-pairs sharing a treaty is much higher among the first than the second group, respectively (67% and 4%).

Lastly, Table 4 suggests that multinational production mainly takes place among large countries in terms of GNP, and from large to small countries. The lack of this kind of flows

Gross National Product	Country-pairs with Xij> 0 and Xji > 0	Country-pairs with Xij > 0 and Xji= 0			Country-pairs with Xij = 0 and Xji = 0
		all	country j (source)	country i (host)	
Mean					
(in millions of current U$)	728,764	355,894	614,778	95,688	82,890
(as % of world mean)	3.7	1.9	3.3	0.5	0.4
Std. Dev. (as % of mean)	1.6	2.1	2.4	4.3	2.9
# of country-pairs	1,292	1,407			8,717

Xij= multinational production of firms from country j in country i

Table 4: Size distribution of country-pairs. Summary statistics

is mainly observed among small economies, and from small to large economies. In fact, country-pairs with positive volumes in both directions involve countries almost four times larger than the world average, and fairly similar in terms of size (the standard deviation of GNP as percentage of the mean is 1.6). Among country-pairs with FDI in only one direction, source countries are more than three times larger than the world average, while host countries are half the size of the world average. Country-pairs with zero FDI in both directions are mostly small countries with an average size less than half the world average.

Indeed, the evidence summarized in the previous tables suggests that size in terms of income and geography are important factors in explaining the existence, allocation and volumes of international production activities across countries. Moreover, a theory that tries to explain the cross-country patterns of such flows has to be able to predict zero flows between some country-pairs.

3. MODEL

I introduce the decision to replicate production abroad in a competitive, multi-country model with bilateral fixed costs to multinational activities. The model delivers a structural equation for bilateral sales of affiliates that relates bilateral volumes to the size and technology of trading partners and costs of access a market, allowing for zero volumes between some country-pairs. I present the basic set up of the model, the closed economy, and the open economy where multinational activities are allowed.

There are N countries which produce goods using only labor. Country i has L_i consumers that supply one unit of labor each. Each country i has two types of goods. One is a homogeneous consumption good, that can be freely traded, produced under a constant returns to scale technology that uses $1/w_i$ units of labor per unit of output. Provided that each country produces it, the homogeneous good is the numeraire, and its price normalized to one, such that the wage rate in country i is w_i.

The other good is a composite good, made of a continuum of goods indexed by $\omega \in [0,1]$, produced with the technology described below, under perfect competition. Multinational production is allowed in this sector so that firms from country j can replicate production of good ω in country i, by opening affiliate plants. In particular, affiliate plants from country j in country i inherit the productivity level of their parent company, carry production hiring local labor, sell output exclusively in the host market, and repatriate (all or part of) their profits to the home economy (in units of the homogenous consumption good).

Technology. There is a continuum of plants in the production of each good ω that behaves competitively. Each plant operates under an only-labor decreasing returns to scale production technology that is assumed to be:

$$q_{ij}(\omega) = x_j(\omega)^{-\theta} s_{ij}(\omega)^{\alpha}, \tag{1}$$

where $\alpha < 1$, $q_{ij}(\omega)$ is output of a plant from country j in country i, $s_{ij}(\omega)$ is labor required by a plant from country j to produce good ω in country i, and $x_j(\omega)$ is stochastic, specific to plants from country j that produce good ω, and amplified in percentage terms by the parameter θ. In each country i, the productivity parameter $x_i(\omega)$ is randomly drawn across symmetric goods from an exponential function with *bounded* support:

$$\phi_i(x_i) = \frac{\lambda_i e^{-\lambda_i x_i}}{e^{-\lambda_i \underline{x}} - e^{-\lambda_i \bar{x}}}$$

where $x_i \in [\underline{x}, \bar{x}]$. Moreover, since productivity is independently distributed across countries, the density function for the vector $x(\omega) = [x_1(\omega), x_2(\omega), ..., x_n(\omega)]$ is:

$$\phi(x) = \prod_{i=1}^{n} \phi_i(x_i). \tag{2}$$

where $x \in \mathbf{X} = [\underline{x}, \bar{x}]^n$. This configuration of productivity draws is similar to Eaton-Kortum (2002) and Alvarez and Lucas (2004), except for the bounded productivity support.

Preferences. Consumers have preferences given by:

$$u(c_i, Q_i) = c_i^{1-\mu} Q_i^{\mu} \tag{3}$$

where c is the homogenous good, and Q is a symmetric CES aggregate over the continuum of goods ω, given by:

$$Q_i = [\int_{\omega \in [0,1]} q_i(\omega)^{\frac{\eta-1}{\eta}} d\omega]^{\frac{\eta}{\eta-1}} \tag{4}$$

These goods are substitute, with elasticity of substitution $\eta > 1$. The parameter μ is the exogenous fraction of income spent on the composite good Q. The demand function for good ω, in country i, is:

$$(\frac{p_i(\omega)}{P_i})^{-\eta} Q_i L_i \tag{5}$$

where $p_i(\omega)$ is the price of good ω in country i, and P_i is the price index associated with the aggregate good Q_i, given by:

$$P_i = [\int_{\omega \in [0,1]} p_i(\omega)^{1-\eta} d\omega]^{\frac{1}{1-\eta}} \tag{6}$$

The aggregate demand for Q_i is given by the expenditure condition:

$$L_i P_i Q_i = \mu Y_i. \tag{7}$$

National income in country i, denoted by Y_i, is given by labor income plus profits, and is fixed (in units of the numeraire good).

Since the only parameter that varies across goods is productivity, and goods enter symmetrically the aggregate in equation (4), it is convenient to rename each good ω by its productivity x. From now on, I refer to “good x” instead of “good ω”, where x is the vector of productivity draws across countries $(x_1, x_2, ..., x_n)$. The aggregate good in equation (4) and the price index in (6) is rewritten as:

$$Q_i = [\int_{\mathbf{X}} q_i(x)^{\frac{\eta-1}{\eta}} \phi(x) dx]^{\frac{\eta}{\eta-1}}, \tag{8}$$

$$P_i = [\int_{\mathbf{X}} p_i(x)^{1-\eta} \phi(x) dx]^{\frac{1}{1-\eta}} \tag{9}$$

and the production function in equation (1) as:

$$q_{ij}(x) = x_j^{-\theta} s_{ij}(x)^{\alpha} \tag{10}$$

where x_j is the productivity draw specific to plants from country j that produce good x in country i.

Bilateral fixed cost. There is an unbounded pool of potential entrants into the production of good x. A subsidiary plant that enters the production of good x in country i at the same technology level as the one of its parent company in country j, has to pay a fixed cost, t_{ij} (in units of the homogenous consumption good). This cost is specific to the pair of "trading" countries, and can be thought as the costs of forming subsidiaries and distribution networks, adapting the technology to the local environment, as well as any information, transaction, and legal costs related to market access. This fixed cost is also borne by domestic plants, denoted by t_{ii}, and might include any overhead cost of production.

Given the vector x, potential entrants decide whether to enter the production of good x, in country i, pay the fixed cost, and start production hiring local labor. There is free entry into the industry, and the mass of plants from country j in country i, in sector x, is denoted by $m_{ij}(x)$.

3.1. Closed economy

The closed economy is such that $t_{ij} \to \infty$, for all $j \neq i$. As a result, FDI is not possible, and only local plants carry on production. "Good x" in country i is just given by country i's productivity draw, x_i. For notational simplicity, in what follows, I drop the subscript i.

A potential firm with productivity x enters the industry as long as profits are as high as the fixed cost:

$$\pi(x) \geq t \tag{11}$$

where $\pi(x)$ is the profit function:

$$\pi(x) = \max_{s(x)} \{p(x)x^{-\theta}s(x)^{\alpha} - ws(x)\}. \tag{12}$$

In any equilibrium where entry is unrestricted, the value of entering the industry could not be positive since the mass of prospective entrants is unbounded. Further, if this value were negative, no firm would enter. Thus, in equilibrium, firms enter the production of good x until equation (11) holds with equality. Condition (11) pins down the equilibrium price for *each* good x; the price $p(x)$ adjusts such that (11) is satisfied. Consequently, all goods x are produced in equilibrium. Under perfect competition, the maximization problem in (12) yields:

$$\pi[p(x)] = (1-\alpha)(\frac{\alpha}{w})^{\frac{\alpha}{1-\alpha}}[x^{-\theta}p(x)]^{\frac{1}{1-\alpha}}, \tag{13}$$

Replacing (13) in (11), and solving for $p(x)$ yields:

$$p(x) = \gamma_0 \cdot w^{\alpha} \cdot t^{1-\alpha} \cdot x^{\theta}, \tag{14}$$

where

$$\gamma_0 \equiv (\frac{\alpha}{1-\alpha})^{1-\alpha}\frac{1}{\alpha} \tag{15}$$

Prices are fully determined by the supply side of the economy; productivity x, costs t, and wages w determine the position of the long run supply curve. The size of the industry is determined by the demand side of the economy, $\mu(p(x)/P)^{-\eta}(Y/P)$, where P is the aggregate price index:

$$P^{1-\eta} = (\gamma_0 w^{\alpha})^{1-\eta} t^{(1-\alpha)(1-\eta)} \lambda\Gamma, \tag{16}$$

where

$$\lambda\Gamma \equiv \int_{\underline{x}}^{\bar{x}} x^{\theta(1-\eta)}\phi(x)dx,$$

and Y is total income.

3.2. Open economy

Each country i has the structure described in the set up, with preferences and technology parameters, ρ, η, μ, θ, and α, common across countries. Given the vector x, a producer from country j opens a plant in country i as long as the value of opening such plant is non-negative:

$$-t_{ij} + \pi_{ij}(x) \geq 0 \tag{17}$$

where

$$\pi_{ij}(x) = \max_{s_{ij}(x)} \{p_i(x)x_j^{-\theta} s_{ij}(x)^{\alpha} - w_i s_{ij}(x)\}, \tag{18}$$

for all i, j. x_j is the productivity draw for good x specific to firms from country j, and $p_i(x)$ is the price for good x in country i. Since there is an unbounded pool of potential entrants and free entry, in equilibrium, (17) holds with equality. The price for good x at which new plants from country j break even in country i is given by:

$$p_{ij}(x) = \gamma_0 \cdot w_i^{\alpha} \cdot t_{ij}^{1-\alpha} \cdot x_j^{\theta} \tag{19}$$

for all i, j, and γ_0 is a constant given by (15). There are n source countries of potential suppliers of good x, but consumers buy from the cheapest one. Hence, the prevailing price for good x in country i is the minimum price among all potential sources that satisfies (19):

$$p_i(x) = \gamma_0 \cdot w_i^{\alpha} \cdot \min_j \{t_{ij}^{1-\alpha} \cdot x_j^{\theta}\}_{j=1}^{n}. \tag{20}$$

Likewise the closed economy, equation (20) determines the position of the long run supply curve, at lowest minimum average cost point.

Next, I introduce the conditions under which the model generates zero multinational production flows. Let B_{ij} be the set of goods x produced in country i by affiliate plants of firms from country j, i.e., goods for which plants from country j are able to charge the minimum price in country i, defined by:

$$B_{ij} = \{x \in \mathbf{X} : p_{ij}(x) < p_{ik}(x) \text{ for all } k \neq j\}, \tag{21}$$

where $\mathbf{X} = [\underline{x}, \bar{x}]^n$. Equivalently, B_{ij} can be defined in terms of productivity draws:

$$B_{ij} = \{x \in \mathbf{X} : x_j < (\frac{t_{ik}}{t_{ij}})^{\frac{1-\alpha}{\theta}} x_k \text{ for all } k \neq j\}. \quad (22)$$

However, B_{ij} might be empty because there could be no good x for which (i) $x_j \in [\underline{x}, \bar{x}]$, and (ii) $p_{ij}(x) < p_{ik}(x)$ for all k, simultaneously. The following condition is needed for B_{ij} to be non-empty:

$$\underline{x} < (\frac{t_{ik}}{t_{ij}})^{\frac{1-\alpha}{\theta}} \bar{x} \quad (23)$$

for *all* $k \neq j$. When the support condition in (23) is not satisfied, no firm from country j produces in i. The following assumption assures that there is always some production done by domestic plants (i.e., B_{ii} is never empty).

Assumption 1. For all $k \neq i$,

$$\underline{x} < (\frac{t_{ik}}{t_{ii}})^{\frac{1-\alpha}{\theta}} \bar{x}.$$

In each country i, goods are supplied by either foreign or domestic plants, but not both, and all available goods are produced (i.e. $\cup_j B_{ij} = \mathbf{X}$). However, due to country-pair specific costs, not necessarily, goods are produced by plants from the country with the best technology; plants from more than one country produce the same good in different parts of the world. Moreover, some countries might not produce any good in some other countries, generating zero bilateral multinational activities. However, note that the condition in (22) does not involve the cost of inputs, as standard trade models do. Since production in affiliate plants is done employing local inputs, and input prices are uniform across plants of any origin, the cost of inputs does not matter in determining which plants produce in country i; the only thing that matters is relative productivities compared with relative fixed costs. In this sense, the model with international production is driven by absolute instead of comparative advantages.

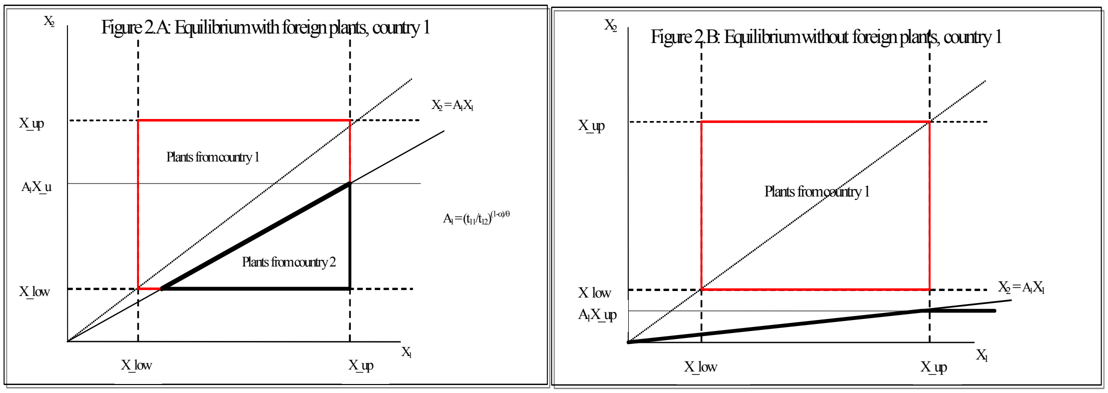

Figure 2: Two-country world equilibrium foreign (A) and no foreign (B) plants

Figure 2 shows a two-country world example. Productivity for country 1 (x_1) is in the x-axis, and productivity for country 2 (x_2) in the y-axis. Situation in country 1 is depicted. Goods for which $x_2 < (t_{11}/t_{12})^{\frac{1-\alpha}{\theta}} x_1$ are produced by plants from country 2. Figure 2.A shows the case in which there is plants from country 2 in 1. Figure 2.B shows the case in which the relative cost t_{11}/t_{12} is so low that the support condition (23) is not satisfied. Hence, there is no plants from country 2 in 1.

Bilateral sales of affiliate plants. The total value of sales of affiliate plants of firms from country j in country i, is given, in equilibrium, by:

$$X_{ij} = \begin{cases} \mu \cdot \int_{B_{ij}} (\frac{p_i(x)}{P_i})^{1-\eta} \cdot Y_i \cdot \phi(x) \cdot dx \text{ if } B_{ij} \neq \varnothing \\ \\ 0 \text{ if } B_{ij} = \varnothing \end{cases} \tag{24}$$

where P_i is the price index for the composite good Q_i, given by:

$$P_i^{1-\eta} = (\gamma_0 w_i^{\alpha})^{1-\eta} \sum_j \int_{B_{ij}} t_{ij}^{(1-\alpha)(1-\eta)} \cdot x_j^{\theta(1-\eta)} \cdot \phi(x) \cdot dx \tag{25}$$

where γ_0 is given by (15). Replacing $p_i(x)$ by equation (20) and P_i by (25) in equation (24), yields:

$$X_{ij} = \mu \cdot \varsigma_{ij} \cdot Y_i \tag{26}$$

where ς_{ij} is the effective market share of plants from country j in i:

$$\varsigma_{ij} \equiv \frac{t_{ij}^{(1-\alpha)(1-\eta)}\lambda_j\Gamma_{ij}}{\sum_k t_{ik}^{(1-\alpha)(1-\eta)}\lambda_k\Gamma_{ik}},$$

$\sum_j \varsigma_{ij} = 1$, and $\varsigma_{ij} = 0$ for $B_{ij} = \varnothing$. The expression $\lambda_j\Gamma_{ij}$ is defined by[12]:

$$\lambda_j\Gamma_{ij} \equiv \int_{B_{ij}} x_j^{\theta(1-\eta)}\phi(x)dx.$$

The variable Γ_{ij} mirrors the one in Helpman, Melitz and Rubinstein (2004). The main difference is that Γ_{ij} depends on the whole vector of (relative) bilateral fixed costs in country i, $\{t_{ij}/t_{ik}\}_{k\neq j}$, as well as the vector of country average productivities, $(\lambda_1, ..., \lambda_n)$, and the support bounds, $\underline{x}$ and $\bar{x}$. All these parameters determine the cross-country *allocation* of multinational production. First, the set B_{ij} may be empty for some (or all) $j \neq i$, so that Γ_{ij} equals zero, and sales from country j into i are zero. Hence, the model is able to generate zero volumes between some country-pairs, $X_{ij} = 0$. However, firms from country j may have affiliate plants in other destinations, and country i may host plants from other sources. Since Γ_{ij} is different from Γ_{ji}, even with symmetric costs (i.e. $t_{ij} = t_{ji}$), the theory allows for asymmetric bilateral flows, which may be zero in one direction, with $X_{ij} = 0$ and $X_{ji} > 0$, or $X_{ij} > 0$ and $X_{ji} = 0$, zero in both directions, $X_{ij} = X_{ji} = 0$, or positive in both directions but of different magnitude, $X_{ij} \neq X_{ji} > 0$. Such asymmetric FDI relationships are widely spread in the data, as shown in Section 2. Second, for the group of country-pairs with positive flows, gravity regulates their magnitude; in fact, expression (26) relates the bilateral volume of sales of plants from country j in i to the "importer" size, Y_i, "exporter" technology, λ_j, and bilateral costs to access the importer's market, t_{ij}. The higher Y_i or λ_j, the larger X_{ij}, and the higher t_{ij}, the lower X_{ij}.

[12]

$$\lambda_j\Gamma_{ij} \equiv \lambda_j \int_{\underline{x}}^{\bar{x}} x_j^{\theta(1-\eta)} e^{-\lambda_j x_j} \prod_{k\neq j} [e^{-x_j\lambda_k(\frac{t_{ij}}{t_{ik}})^{\frac{1-\alpha}{\theta}}} - e^{-\lambda_k\bar{x}}]dx_j$$

Besides bilateral sales of affiliate plants, employment, assets and number of affiliates plants of firms from country j in i, could also be considered as measures for international production. Since all of them are proportional to sales, the previous analysis still holds, and it is sufficient to analyze sales[13].

Symmetric example. Let $t_{ij} = t_i$, for all j. Then, $\Gamma_{ij} = \Gamma_j$, for all i, and strictly positive. Assume that the ratio of productivity to size, λ_i/L_i, is uniform across countries. For the rest, countries are identical. All possible country-pairs have an FDI relationship, and volumes follow a basic gravity equation[14]:

$$X_{ij} = \mu \cdot \frac{(\Gamma_j/w_j)}{\sum_k (\Gamma_k/w_k) Y_k} \cdot Y_j \cdot Y_i. \tag{27}$$

The volume of bilateral sales is a function of the product of the trading partners' size, given by total income, Y_i and Y_j. Notice that the fixed costs to access the market do not affect equation (27). Indeed, the stock of *plants* from country j in i depends on the

[13] Bilateral employment from country j in i is:

$$S_{ij} = \frac{\alpha}{w_i} X_{ij};$$

the bilateral number of affiliate plants is:

$$m_{ij} = \frac{1-\alpha}{t_{ij}} X_{ij};$$

and the bilateral value of assets is given by the value of installed plants from country j in i:

$$a_{ij} = t_{ij} m_{ij} = (1-\alpha) X_{ij}.$$

[14] I use the fact that the "numeraire" sector has all of its income going to labor, and the remaining sector only the fraction α. Since the expenditure share of each sector is given by the parameter μ in (3), total labor costs are given by:

$$w_i L_i = [1 - \mu(1-\alpha)] Y_i.$$

magnitude of the bilateral fixed cost, and is given by:

$$m_{ij} = \mu(1-\alpha) \cdot \frac{(\Gamma_j/w_j)}{\sum_k (\Gamma_k/w_k) Y_k} \cdot \frac{1}{t_i} \cdot Y_j \cdot Y_i.$$

Lastly, the theory can be used to analyze the effects of foreign plants on the performance of a small open economy. In fact, it delivers a set of predictions about the behavior of prices, productivity, size and turnover of plants in a host industry when foreign entry occurs, that matches some widely documented empirical evidence about foreign plants in host economies. In the Appendix, I present the implications of the theory for a host economy, and characterize the transition path from the closed to the open economy for a small country.

4. EMPIRICAL FRAMEWORK

Equation (26) relates the volume of bilateral sales of foreign affiliates to characteristics of the source country, host country, and the cost of accessing the host country from a given source country. When condition (23) is not satisfied, no firm from country j is productive enough to open an affiliate in country i, inducing zero FDI from j to i. For positive FDI, equation (26) governs the volume of bilateral sales of affiliates from country j in i. Rearranging terms, equation (26) can be expressed in log-linear form as

$$\ln \frac{X_{ij}}{Y_i} = \ln \mu + \ln \lambda_j - \ln[\sum_k \lambda_k t_{ik}^{(1-\alpha)(1-\eta)} \Gamma_{ik}] - \ln t_{ij}^{(1-\alpha)(\eta-1)} + \ln \Gamma_{ij} \tag{28}$$

if $\Gamma_{ij} > 0$.

The term capturing the cost of accessing country i for plants from country j, t_{ij}, has observable and unobservable components. Following the gravity literature on international trade, I relate it to observable variables such as geography, language, colonial past, and policy variables related to corporate taxation. I further assume that these costs are stochastic due to unobservable frictions that are country-pair specific, and denoted by ϵ_{ij}. In particular, for $i \neq j$, let t_{ij} have the following form:

$$\ln t_{ij}^{(1-\alpha)(\eta-1)} = \delta_d \ln d_{ij} - \epsilon_{ij} \tag{29}$$

where d_{ij} is an observable measure of bilateral costs, and it is easily extended to be a vector, and ϵ_{ij} is unobservable. Particularly, I assume that:

$$\epsilon_{ij} = u_i + v_{ij}, \tag{30}$$

so that $\epsilon'_{ij}s$ are not independent across $j's$, for a given i. The term u_i is country i' fixed effect, independently and normally distributed across countries, with mean zero and variance σ_u^2, and v_{ij} is i.i.d. across country-pairs, normally distributed with mean zero and variance σ_v^2[15].

Notice that t_{ii} cannot be approximated by observable variables. Hence, I set t_{ii} to be a fraction τ of the minimum fixed cost faced by firms from any other country j in i:

$$t_{ii} = \tau \cdot \min_{j \neq i}\{t_{ij}\}. \tag{31}$$

where τ must satisfy Assumption 1[16]. Replacing (29) in (28), for $j \neq i$, yields:

$$\ln \frac{X_{ij}}{Y_i} = \ln \mu + S_j - H_i - \delta_d \ln d_{ij} + \ln \Gamma_{ij} - \epsilon_{ij} \tag{32}$$

[15] ϵ_{ij} are normally distributed, with zero mean and variance-covariance matrix given by:

$$V = \begin{bmatrix} \Sigma & 0 & ... & 0 \\ 0 & \Sigma & ... & 0 \\ ... & ... & ... & ... \\ 0 & ... & 0 & \Sigma \end{bmatrix}$$

where Σ is an (nxn) matrix equal to:

$$\Sigma = \begin{bmatrix} \sigma_u^2 + \sigma_v^2 & \sigma_u^2 & ... & \sigma_u^2 \\ \sigma_u^2 & \sigma_u^2 + \sigma_v^2 & ... & \sigma_u^2 \\ ... & ... & ... & ... \\ \sigma_u^2 & ... & ... & \sigma_u^2 + \sigma_v^2 \end{bmatrix}.$$

[16]

$$\tau < (\frac{\bar{x}}{\underline{x}})^{\frac{\theta}{1-\alpha}}.$$

if $\Gamma_{ij} > 0$, where $S_j \equiv \ln \lambda_j$, and $H_i \equiv \ln[\sum_k \lambda_k t_{ik}^{(1-\alpha)(1-\eta)} \Gamma_{ik}]$. Equation (32) looks much as the gravity equation that is traditionally estimated through OLS using only positive bilateral flows, and two sets of country fixed effects. The first important difference that equation (32) bears with traditional gravity equations is the new variable $\ln \Gamma_{ij}$. This variable mirrors the one in Helpman, Melitz and Rubinstein (2004), and depends on the vector of (relative) barriers in country i, $\{t_{ij}/t_{ik}\}_{k \neq j}$,, among other parameters, transforming equation (32) in a non-linear function of the coefficient δ_d and the error terms ϵ_{ij}. When $\ln \Gamma_{ij}$ is not included as a regressor, there is an omitted variable bias, and the OLS estimate of the coefficient on d_{ij}, can no longer be interpreted as an estimate of δ_d. The second important difference is the bias arising from the fact that, considering positive flows only, the error term of the OLS regression is no longer independent of the regressors. This selection effect induces a positive correlation between the unobservable term ϵ_{ij}, and the observable barriers d_{ij}: country-pairs with large observable barriers (high d_{ij}) that have positive FDI are likely to have low unobservable barriers (high ϵ_{ij}), inducing a downward bias in the OLS coefficient on d_{ij}.

4.1. Estimation procedure

The goal is to get consistent estimates of the parameters corresponding to barriers, to calculate bilateral costs of multinational activities, and explore some counterfactual exercises. As shown in the previous subsection, when information on zero volumes is disregarded, and there is fixed costs of entry along with a bounded productivity support, OLS estimates of the gravity equation are biased because of a selection and omitted variable bias, respectively.

I use an indirect inference procedure derived from the theory to estimate the parameters of interest of the model. The indirect inference estimator is the one that minimizes the distance between a vector of moments (so called "auxiliary" parameters) computed from the actual and simulated data. These moments are chosen to properly capture the empirical patterns of the allocation and volume of multinational production across countries.

The estimation procedure works as follows. Let Δ be the $(qx1)$ vector of parameters of the model. Let ρ denote the $(px1)$ vector of moments. I first calculate ρ with the actual data. I then simulate the model for H realizations of the matrix $\{\epsilon_{ij}^h\}_{i,j}$, for each vector Δ. With the simulated data, for each h and Δ, I calculate again the vector of moments ρ. The indirect inference estimator Δ^* is the solution to the following minimization problem[17]:

$$\Delta^* = \arg\min_{\Delta} \, [\rho_d - \frac{1}{H}\sum_{h=1}^{H}\rho_s^h(\Delta)]'\hat{\Omega}[\rho_d - \frac{1}{H}\sum_{h=1}^{H}\rho_s^h(\Delta)] \tag{33}$$

where ρ_d is the vector of moments from the actual data, and $\rho_s^h(\Delta)$ is the one from simulation h of the model evaluated at the set of parameters Δ. The (pxp) matrix $\hat{\Omega}$ is the weighting matrix that, for now, is set to be the identity matrix.

I restrict the vector Δ to be a subset of the structural parameters of the model:

$$\Delta = [\delta_d, \sigma_u^2, \sigma_v^2, \tau, \bar{x}, \kappa]$$

where δ_d is the coefficient of the observable component of costs in equation (29); σ_u^2 and σ_v^2 are the variances of u_i and v_{ij}, respectively, in equation (30); τ is defined by equation (31); $\bar{x}$ is the upper bound of the productivity support; and κ is a scale parameter defined below. Besides dimensionality problems in the numerical computations, I choose these parameters to be in Δ because they are the ones that mostly govern the magnitude of barriers, and the allocation and volume of multinational production across countries.

I set the remaining parameters needed to simulate the model at the values summarized in Table 5. The vector of technology parameters $(\lambda_1, ..., \lambda_n)$ is not observable. Using data on countries' GNPs, I calibrate it to capture the idea that larger countries have on average more technology draws than smaller countries, relative to the United States. The parameter κ gives the proportionality factor:

$$\lambda_i = \kappa \frac{Y_i}{Y_{us}}$$

The parameter μ is the expenditure share of goods from the sector where international production is allowed (i.e. the CES sector). Since I calibrate it to the observed average sales

[17] The indirect inference estimator Δ^* is consistent under the assumptions in Gourieroux, Monfort and Renault (1993). The minimized value of (33) is distributed as a $\chi^2(p-q)$.

Parameter	Value	Definition	Source
θ	0.25	variability of productivity draws	Eaton-Kortum
μ	0.5	share of CES sector in total expenditure	avg. sales of foreign affiliates in a host economy, as share of GDP^
η	3.1	elasticity of substitution	from Broda-Weinstein
$\underline{x}$	1	lower bound of productivity support	normalization
Y_i	GNP_i	National income or GNP for country i	Data on GNP
H	1	Number of simulations of the model at each Δ	
α	0.55	effective equipped labor share in production	from Alvarez-Lucas
1-μ(1-α)	0.78	share of labor costs in income	implied from α and μ

^ Countries for which data in all sectors are available (UNCTAD): United States, Ireland, Czech Rep., Finland, Germany, Hungary, Sweden, Netherlands, Poland, Slovenia, Canada

Table 5: Calibrated parameters of the model

of foreign affiliates (as share of host country's GDP), for selected developed economies, it can be thought as a lower bound.

The data I use to compute the vector of moments from the data, ρ_d, are aggregate sales of affiliates from country j in i, measures of observable barriers between country-pairs, and GNPs, for the 151 countries in the sample.

In particular, ρ_d contains the following statistics: fraction of country-pairs with $X_{ij} > 0$ and $X_{ji} > 0$; fraction of country-pairs with $X_{ij} = 0$ and $X_{ji} = 0$; mean value of observable barriers among country-pairs with (i) $X_{ij} > 0$ and $X_{ji} > 0$, (ii) $X_{ij} = 0$ and $X_{ji} > 0$, and (iii) $X_{ij} = 0$ and $X_{ji} = 0$; mean value of bilateral sales of foreign affiliates for country-pairs with (i) $X_{ij} > 0$ and $X_{ji} > 0$, and (ii) $X_{ij} > 0$ and $X_{ji} = 0$; mean value of GNP for country-pairs with (i) $X_{ij} > 0$ and $X_{ji} > 0$, (ii) $X_{ij} = 0$ and $X_{ji} > 0$, and (iii) $X_{ij} = 0$ and $X_{ji} = 0$; mean value of GNP for source countries (countries j) and host countries (countries i), for country-pairs with $X_{ij} > 0$ and $X_{ji} = 0$; lastly, the OLS coefficients of the following regression:

$$\ln \frac{X_{ij}}{Y_i} = a + a_d \ln d_{ij} + C_i + C_j + e_{ij}, \tag{34}$$

for all observations with $X_{ij} > 0$, where C_i and C_j are host and source country fixed effects, respectively, and the error term e_{ij} has variance σ_e^2. The regression in (34) is a traditional estimate of the gravity equation using data on positive bilateral sales of affiliate plants.

The vector ρ_s has the same moments as in ρ_d, except that they are computed with simulated data. In particular, the outcome of each simulation h, for a given set Δ, is the matrix of sales of affiliate plants from country j in i, $\{\tilde{X}_{ij}^h(\Delta)\}_{i,j}$. Creating this simulated data set requires data on observable bilateral barriers, $\{d_{ij}\}_{j\neq i}$, and on GNPs to calibrate the vector of countries' income, $(Y_1, ..., Y_n)$, and technology parameters $(\lambda_1, ..., \lambda_n)$, for the 151 countries in the sample.

(Tables A.3.7 and A.3.8 in the appendix summarize the moments calculated from the actual data, ρ_d, and simulated data at the optimal model parameters' value, $\rho_s(\Delta^*)$; a description of each parameter is also included. In the tables in Section 2, statistics in ρ_d are highlighted in red).

The indirect inference method focuses on some moments of the data, rather than on the whole joint distribution. Since (32) is non-linear in the parameters of interest, an alternative to indirect inference is maximum likelihood that requires to write down the likelihood function from the set of conditional probabilities that the model dictates. Similarly, a two-step procedure that corrects for the selection of country-pairs into FDI partners would be adequate. However, the complex structure of the variable Γ_{ij}, a multivariate truncated distribution that depends on the entire vector of bilateral barriers in country i, $\{t_{ij}\}_{\forall j}$, that includes both $\{d_{ij}\}_{\forall j\neq i}$ and $\{\epsilon_{ij}\}_{\forall j\neq i}$, makes both methods very hard to apply.

5. ESTIMATES

I use the following variables as the observable components of the cost of accessing country i for firms from country j: bilateral distance d_{ij}, common border δ_{ij}^c, common language δ_{ij}^l, colonial ties δ_{ij}^{col}, and the presence of a double taxation treaty δ_{ij}^{dtt}, between country-pairs. $\delta_{ij}'s$ are all dummy variables. Equation (29) ends up being:

$$\ln t_{ij}^{(1-\alpha)(\eta-1)} = \delta_d \ln d_{ij} - \sum_{s=c,l,\text{col},dtt} \delta_{ij}^s \ln b_s - \epsilon_{ij}.$$

Alternatively to the double taxation treaty dummy, I use corporate tax rates applied to firms from country j in i[18].

[18] I am very grateful to Ernesto Stein and Christian Daude for providing me with data on corporate tax

(Details on variables are provided in the appendix).

The first two columns in Tables 6.1 show OLS estimates of equation (34), for country-pairs with $X_{ij} > 0$, and different sets of observable barriers, for the all countries in the sample. Each observation is an average over the period 1990-2002[19].

	OLS				Probit [1]	
Dependent variable:	sales of affiliates from country j in i (in logs, as % of country i' s GNP)				1 for positive FDI from country j to i	
	Country-pairs with positive FDI		All possible country-pairs [1,2]			
	I	II	III	IV	V	VI
log of bilateral distance (thousands of km)	-1.137	-1.144	-0.512	-0.576	-0.699	-0.717
	[0.099]**	[0.099]**	[0.027]**	[0.028]**	[0.031]**	[0.031]**
1 for pairs with common official language or >20% pop. same language	0.497	0.49	-0.178	-0.168	0.342	0.344
	[0.224]*	[0.224]*	[0.050]**	[0.051]**	[0.066]**	[0.066]**
1 for pairs with a common border	-0.065	-0.09	0.619	0.608	0.358	0.356
	[0.261]	[0.259]	[0.117]**	[0.120]**	[0.110]**	[0.110]**
1 for pairs with double taxation treaty	0.108		2.76		0.648	
	[0.199]		[0.062]**		[0.050]**	
1 for pairs ever in colonial relationship	0.85	0.848	-0.905	-0.745	0.052	0.086
	[0.283]**	[0.284]**	[0.160]**	[0.163]**	[0.117]	[0.117]
bilateral corporate tax rates		0.001		-0.066		-0.019
		[0.007]		[0.002]**		[0.002]**
Observations	846	846	19684	19684	21906	21906
R-squared	0.86	0.86	0.63	0.62		

Standard errors in brackets. * significant at 5%; ** significant at 1%
All specifications with constant, and source and host country fixed effects
(1): FDI=0 if all measures of FDI are zero or missing values
(2): for country-pairs with no FDI, sales are replaced by one dollar

Table 6.1: Traditional gravity for FDI and participation equation. All countries.

From the first two columns, it clearly emerges that affiliates from country j have more sales in country i, as share of country i's GNP, when the two countries are closer to each other, share a language, and have colonial ties. Even if insignificant, sharing a border seems to have the opposite effect than expected on the dependent variable. The presence of a bilateral double taxation treaty has a positive but insignificant effect, while bilateral tax

rates.

[19] Considering 3-year average observations yields similar results.

rate seems to have the wrong sign but still insignificant[20].

Among the 151 countries considered in the sample, there are 22,801 possible pairs; only 3,810 of these pairs have non-zero FDI relationships[21]. Columns III and IV show estimates in which all possible country pairs are included and the ones with zero FDI are assigned a one-dollar value of sales. Estimates change drastically; the coefficient on bilateral distance drops by half, and the one on common language turns negative, while coefficients on common border and having a double taxation treaty increase substantially. The effects of bilateral tax rate on sales of affiliates is negative and significant: a 10% increase in the tax rate of country i for firms from country j decreases sales of affiliates of that country, as share of country i's income, by 0.6%. The last two columns show Probit estimates for the presence of FDI from country j into i, using the same explanatory variables as for the OLS regressions. The dependent variable is one if country j has positive FDI in country i, and zero otherwise. Results show that the same variables that impact sales' volumes of plants from country j in i also impact the probability that j engages in an FDI relationship with i. Moreover, all variables have the expected sign, even bilateral taxes, even though the dummy for colonial ties looses significance.

Table 6.2 shows the same estimates as Table 6.1. restricting the sample to OECD countries, among which the presence of zero bilateral FDI is very small.

(Estimates using other measures of FDI and international production are shown in the appendix).

Tables 7.1 and 7.2 summarize the vector of model parameters' estimates, Δ^*. While Table 7.1 shows estimates which include as observable barriers double taxation treaties, Table 7.2 includes bilateral corporate tax rates. Results for the 151 countries in the sample, and only OECD countries, among which the fraction of zero FDI is small, are shown. According to these estimates, bilateral distance is the most important barrier to international production:

[20] See Stein and Daude (2001) for an estimate of a gravity equation for bilateral FDI stocks, for OECD countries.

[21] A country j has no FDI relationships with country i for the period 1990-2002, if *all the six measures* of FDI and international production recoeded in the database are missing values or zeros.

Dependent variable:	sales of affiliates from country j in i (in logs, as % of country i's GNP)			
	Country-pairs with positive FDI		All possible country-pairs [1,2]	
	I	II	III	IV
log of bilateral distance	-0.83	-0.84	-1.19	-1.19
(thousands of km)	[0.129]**	[0.129]**	[0.280]**	[0.281]**
1 for pairs with common official language or	0.26	0.25	0.84	0.84
>20% pop. same language	[0.270]	[0.271]	[0.584]	[0.584]
1 for pairs with a common border	0.60	0.62	0.42	0.39
	[0.270]*	[0.271]*	[0.597]	[0.596]
1 for pairs ever in colonial relationship	0.41	0.47	0.63	0.61
	[0.306]	[0.306]	[0.680]	[0.678]
1 for pairs with double taxation treaty	-0.8		0.3	
	[0.359]*		[0.675]	
bilateral corporate tax rates		0.014		0.005
		[0.010]		[0.020]
Observations	396	396	432	432
R-squared	0.82	0.82	0.74	0.74

Standard errors in brackets. * significant at 5%; ** significant at 1%
All specifications with constant, and source and host country fixed effects
(1): FDI=0 if all measures of FDI are zero or missing values
(2): for country-pairs with no FDI, sales are replaced by one dollar

Table 6.2: Traditional gravity for FDI. OECD countries. OLS.

countries that are twice as distant have a 46% higher cost. This magnitude translates into a 43% lower share of bilateral sales of affiliates of firms from country j in i, in country i's income. Sharing a border or a language decreases the bilateral cost of international production by 0.16% and 0.14%, respectively, while sharing a colonial past does it by 0.30%. Country-pairs with a double taxation treaty have only 0.0003% lower barriers. The standard errors σ_u and σ_v are 0.08 and 0.17.

Table 7.2. shows estimates with corporate tax rates as an observable measure of barriers. The effect of distance is even stronger than in Table 7.1: countries twice as distant have 53% higher costs. Common colonial past decreases fixed costs by 0.37%. Similarly to results in Table 7.1, tax rates have a very small effect on total costs.

Parameters	*Estimates*				*Effect of barriers on Xij/Yi*		*Definition*
	All countries		*OECD countries*				
	I	***OLS (I)***	***II***	***OLS (II)***	***I***	***II***	
δ_d	**0.46**	**0.63**	**0.46**	**0.46**	**-0.43**	**-0.43**	*bilateral distance*
$\ln(b_c)$	**0.16**	**-0.04**	**0.13**	**0.33**	**0.152**	**0.13**	*common border*
$\ln(b_l)$	**0.14**	**0.28**	**0.14**	**0.15**	**0.136**	**0.13**	*common language*
$\ln(b_{col})$	**0.30**	**0.47**	**0.24**	**0.23**	**0.281**	**0.22**	*common colonial ties*
$\ln(b_{dtt})$	**0.0003**	**0.06**	**0.0003**	**-0.4**	**0.0003**	**0.0003**	*bilateral double taxation treaty*
σ_v	**0.17**	**0.64**	**0.16**	**0.61**			*std. error of v_{ij}*
σ_u	**0.08**		**0.10**				*std. error of u_{ij}*
τ	**0.66**		**0.48**				*parameter on barriers for domestic plants*
κ	**2.60**		**2.68**				*scale parameter*
$\bar{x}$	**16.1**		**43.9**				*upper bound of the productivity support*
chi-square	**45**		**32**				
p-value	0.995		0.95				
correlation between actual and simulated data for:							
bilateral sales of affiliates from country j in i	**0.19**		**0.30**				
total sales of foreign plants *in* country i	**0.87**		**0.88**				
total sales of affiliates abroad *from* country i	**0.26**		**0.07**				

Table 7.1: Parameters' Estimates I

Regarding the remaining estimates for the model's parameters, estimates in Table 7.1 suggest that domestic plants face barriers to entry that are two third the magnitude of the ones faced by the most favoured foreign plants (i.e. the parameter τ in equation (31)). This means that foreign plants that face the lowest value of barriers have to be at least twice as productive as domestic plants in the same sector. Conversely, estimates in Table 7.2 suggest that domestic plants are more productive than the most favoured foreign plant (i.e. $\tau > 1$).

Which are the differences with the OLS estimates for barriers to international production? A model without zero volumes that generates a "traditional" gravity equation as the one in (34), would allow us to calculate the parameter δ_d in equation (29) from the OLS coefficient a_d in equation (34)[22]. Using OLS estimates in Table 6.1 (column I), and calibrating the remaining parameters at the values in Table 5, doubling distance between country-pairs

[22] The model generates a "traditional" gravity equation as long as $\underline{x} = 0$ and $\bar{x} \to \infty$. Bilateral sales of

Parameters	Estimates				Effect of barriers on Xij/Yi		Definition
	All countries		OECD countries				
	I	OLS (I)	II	OLS (II)	I	II	
δ_d	0.53	0.63	0.70	0.47**	-0.50	-0.66	bilateral distance
$\ln(b_c)$	0.12	-0.33	0.13	0.35*	0.11	0.12	common border
$\ln(b_l)$	0.16	0.03	0.14	0.14	0.15	0.13	common language
$\ln(b_{col})$	0.37	0.16	0.32	0.26	0.35	0.30	common colonial ties
δ_t	0.007	0.63	0.001	-0.62	-0.01	0.001	1- bilateral corporate tax rate
σ_v	0.135	0.64	0.124				standard error of v_{ij}
σ_u	0.067		0.081				standard error of u_{ij}
σ_ε	0.15		0.15				standard error of ε_{ij}
τ	1.05		0.41				parameter on barriers for domestic plants
κ	3.06		3.59				scale parameter
$\bar{x}$	8.10		77.73				upper bound of the productivity support
chi-square	39		26				
p-value	0.95		0.80				
correlation between actual and simulated data for:							
bilateral sales of affiliates from country j in i	0.19		0.21				
total sales of foreign plants *in* country i	0.87		0.89				
total sales of affiliates abroad *from* country i	0.24		0.33				

Table 7.2: Parameters' Estimates II

increases barriers by 63%, while sharing a language decreases them by 0.28% and having

affiliates from country j in i, as share of country i's GNP, are given by (in logs):

$$\ln \frac{X_{ij}}{Y_i} = \ln \mu + \hat{C}_j - \hat{C}_i + a_d \ln d_{ij} + e_{ij}$$

where $\hat{C}_j$ and $\hat{C}_i$ are source and host country fixed effects:

$$\hat{C}_j \equiv \ln \lambda_j$$

$$\hat{C}_i \equiv \ln \sum_k \lambda_k t_{ik}^{-\frac{1-\alpha}{\theta}} - \frac{1-\alpha}{\theta} u_i$$

$$a_d \equiv \frac{1-\alpha}{\theta} \delta_d$$

$$e_{ij} \equiv \frac{1-\alpha}{\theta} v_{ij}.$$

colonial ties by 0.47%. The existence of a double taxation treaty decreases barriers by 0.06%. Analogous calculations for OLS estimates in Table 6.1. (column II) are shown in Table 7.2.

The indirect inference estimator is different from the OLS estimator. In particular, this comparison suggests that OLS estimates are upward biased, since the impact of distance and common border on the cost of multinational production are smaller when they are calculated with the indirect inference estimator.

How well does the model reproduce the data? A chi-square test on the optimality criterion in equation (33) leads us to accept that, overall, the actual data are generated by a model with parameter Δ^*. Additionally, the correlation coefficient between simulated and actual data on sales of affiliates from country j in i is 0.19, while the one for (log of) total sales of foreign affiliates *into* country i is 0.87, and the one for (log of) total sales of affiliates abroad *from* country i is around 0.25. The fit for the sample of OECD countries ranges from 0.21 to 0.3 for bilateral sales of affiliates, is similar to the one for all the sample for total sales of foreign affiliates into a host country (0.89), and very different depending on whether estimates in Table 7.1 or 7.2 are considered, for total sales of affiliates abroad (0.07 and 0.33, respectively).

Tables A.3.7 and A.3.8 in the appendix show the moments calculated with the actual and simulated data at the optimal Δ^*, for estimates in Table 7.1 and 7.2, respectively. Even though the model captures fairly well the fraction of country-pairs with zero and positive FDI relationships, as well as the mean values of barriers for country-pairs with positive, zero, and one-way multinational production activities, it fails to pick features related to size in terms of income.

5.1. Welfare gains of multinational production

The estimation above provides parameters' values to quantify the model, and pursue the analysis of counterfactuals, in the same spirit as the experiments studied by Eaton and Kortum (2002 and 2003), Alvarez and Lucas (2004) for international trade, and Burstein and Monge (2005) for international production. The criteria to examine counterfactuals is overall welfare in country i, measured by real income[23]:

$$W_i = Y_i / P_i^{\mu}$$

The change in welfare decomposes into income and price effects:

$$\ln \frac{W_i'}{W_i} = \ln \frac{Y_i'}{Y_i} - \mu \ln \frac{P_i'}{P_i} \tag{35}$$

where z_i' denotes the counterfactual value of a variable z_i, and the price index is given by (25). Equation (26) for bilateral sales of affiliates from country j in i, along with (25) comprise the general equilibrium for the open economy. Notice that since labor supply L_i and wages w_i are fixed, income Y_i, in terms of the numeraire good, is also fixed.

Proposition 1 *For each country i, the aggregate price index for the open economy, P_i^{fdi}, is lower than (or equal to) the one for the closed economy, P_i^c.*

I first consider the effects of raising barriers to multinational production to their autarky level ($t_{ij} \to \infty, i \neq j$) in each country simultaneously. I then present the effects of removing bilateral barriers and set them to a uniform level, equal to t_{ii}, for plants from any origin, in each country i ("zero-gravity").

	World Average (1)		World Average (2)	
	(I)	(II)	(I)	(II)
Avg. value of barriers*	7.00	5.11	9.21	10.25
Avg. sales of foreign affiliates (model):				
baseline	76,440	78,742	82,783	81,083
zero-gravity	91,962	91,962	91,962	91,961.70
US in autarky	60,283	60,260	61,729	61,236
Avg. sales of foreign affiliates (data):	40,461 54,797	(in) (out)		

[23] Since the homogeneous good is the numeraire, the price level in country i is P_i^{μ}.

		welfare (% change in real income)	
		(I)	(II)
Effects of moving from baseline to:			
autarky			
	all countries (1)	-70%	-70%
	all countries (2)	-81%	
"zero-gravity"			
	all countries (1)	70%	65%
	all countries (2)	68%	
US in autarky			
	all countries (1)	-1.3%	-0.33%
	all countries (2)	-0.5%	

(1): parameters' estimates using all the sample of countries (151)
(2): parameters' estimates using the sample of OECD countries (28)
(I): Estimates from Table 7.1. include bilateral double taxation treaties
(II): Estimates from Table 7.2. include bilateral corporate tax rates
baseline: estimated bilateral barriers; autarky: tij? 8 , for all j?i. "zero-gravity": tij=tii, for all j
(*) tij/tii: ratio of barriers faced by plants from country j in i, to barriers for plants from country i

Table 8: Welfare gains of changing barriers to international production, world average

Table 8 shows world averages for the bilateral cost of international production, sales of foreign affiliates into country i and from country i, as well as world average welfare gains of changing bilateral costs, from estimates in Tables 7.1. (I) and 7.2 (II), for both parameters' estimates calculated using the whole sample of countries (1) and OECD countries (2). Average world real income would decrease by 70% if each of the 151 countries in the sample moved to autarky from the baseline case. Going to a "zero-gravity" world, in which *bilateral* barriers would be removed, would increase average real income by 65-70%; unrealized gains of removing bilateral barriers seem quite large. Conversely, the effects on average welfare if the United States moved to autarchy would be rather small.

Table 9 shows counterfactual exercises for the United States, Mexico and Canada, and for the European Union (25), calculated from estimates in Table 7.1 (I) and 7.2 (II). As expected, income losses of moving to autarky would be smaller for the United States than for other countries, while gains of removing bilateral barriers world-wide ("zero-gravity") would be quite large for all the countries shown. The effect on neighbors' countries if United States moved to autarky are small, but larger than for countries in the EU. Further liberalizing NAFTA ("zero-gravity" among NAFTA members) would be beneficial for all three members, with the United States benefiting the most. Finally, there are large unrealized

	Welfare Changes (% change in real income)							
	US		Mexico		Canada		EU	
	(I)	(II)	(I)	(II)	(I)	(II)	(I)	(II)
Effects of moving from baseline to:								
autarky	-25%	-31%	-61%	-68%	-57%	-49%	-67%	-66%
zero-gravity	98%	91%	76%	65%	78%	83%	71%	68%
US in autarky	-	-	-2%	-1%	-1%	-4%	-0.1%	-0.1%
NAFTA (zero-gravity among members)	9%	9%	6%	4%	4%	8%	0%	0%
EU (zero-gravity among members)	0%	0%	0%	0%	0%	0%	28%	26%

(I): Estimates from Table 7.1. include bilateral double taxation traties
(II): Estimates from Table 7.2. include bilateral corporate tax rates
baseline: estimated bilateral barriers; autarky: tij? 8 , for all j?i. "zero-gravity": tij=tii, for all j

Table 9: Welfare gains of changing barriers to international production, selected economies

gains of further liberalizing multinational production among EU members ("zero-gravity" among EU members): real income would increase by more than 25%.

6. CONCLUSIONS

This paper analyzes the determinants of the cross-country allocation and volume of multinational production, quantifies the size of its barriers, and its impact on welfare. For that purpose, I introduce multinational production in a competitive, multi-country model with fixed costs, close to Eaton-Kortum's (2002) and Alvarez and Lucas (2004). The theory is able to capture some stylized facts on cross-country multinational activities: a very small fraction of country-pairs engages in multinational activities with each other; geography remains a significant impediment to these activities; country size in terms of income matters. Additionally, similarly to international trade theories, gravity governs the volumes of multinational activities. However, the driven forces behind it are fundamentally different to the ones for trade. In fact, this model highlights the role of absolute rather than comparative advantages in determining the cross-country allocation and volume of multinational activities.

To take the theory to the data, I first assemble a new data set that includes OECD and non-OECD countries, as well as several measures of international activities and FDI, at the country-pair level. I specifically concentrate on bilateral sales of affiliates. The availability of several bilateral measures allows me to accurately construct the sample of country-pairs with no FDI. I then use the theory to derive an estimation procedure that includes both information on country-pairs with zero as well as positive FDI, and corrects for biases present if linear methods were used. From preliminary estimates, it turns out that bilateral distance remains the most important impediment to multinational activities: country-pairs twice as distant face a 46% higher cost than otherwise. This estimate translates into a 43% lower share of sales of affiliates from country j on income of country i. Policy variables such as tax treaties or bilateral corporate tax rates have very small effects on the total costs of multinational activities.

Finally, I explore welfare gains of moving to autarky, and removing *bilateral* barriers to international production, world-wide and for selected economies. Even though there would be much to loose if each country reverted to autarchy (a world average drop in real income of 70%), there are large unrealized gains of removing *bilateral* barriers, and lowering them to a uniform level across firms of any origin (more than 60% increase in real income). Conversely, if the United States closed to foreign firms, losses would be rather small for neighbors' countries. Additionally, preliminary results suggest that if the EU further liberalized multinational production among its members, it would experience an increase in real income of more than 25%, while further liberalization within NAFTA members would increase real income in the United States by 9%, and around 5% in Mexico and Canada.

Indeed, a theory with both international production and trade is needed. While this paper presents a benchmark for thinking about the determinants/impediments of international production across countries, using a structural model that can easily be taken to the data, it might be a useful point of departure for a theory on the interaction between international trade and production, and their different determinants/impediments. Such a theory should address questions such as: how are trade and FDI related; are these flows substitute or complement; is there substantial trade when there is no FDI; how comparative and absolute advantages interact when both flows are combined; how do policies that liberalize and/or restraint one of these flows affect the other. Therefore, the challenge for future research is twofold: (i) building a theoretical model that incorporates both FDI and trade flows, and delivers a positive aggregate correlation between both flows, as preliminary empirical evidence suggests[24]; and (ii) designing an empirical strategy able to deal with the potential simultaneity problem arising from the fact that FDI might enhance trade in goods, and vice versa.

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[24] The empirical evidence shown in Table 1 suggests that foreign affiliates are an important channel for international trade: their exports represent one third of world exports; this figure goes up to two third if international shipments from parents companies are also considered. Therefore, it seems that multinational firms play a key role in spreading international trade and its potential benefits. Moreover, the presence of an FDI relationship from country j to i seems to have a positive and significant impact on the probability of positive trade between the same country-pair; the unconditional correlation between the two variables is 0.305, for the period 1985-2003.

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APPENDIX 1. THE EFFECTS OF FOREIGN PLANTS IN THE HOST ECONOMY

The equilibrium presented in this paper can be interpreted as a long-run equilibrium in which plants disappear at the exogenous rate δ, and there is new entry such that the size of the industry is constant (i.e. $n_{ij}(x) = \delta m_{ij}(x)$), future is discounted at the rate ρ equal to the world interest rate, r. Hence, future flows of profits are discounted at the constant rate $(1-\delta)/(1+r)$.

I further assume that additionally to variable labor costs, a plant in country i bears a per-period fixed cost of production f_i. Let t_{ij} be modified to take into account this extra fixed cost:

$$t_{ij} \equiv F_{ij} + \frac{1-\delta}{r+\delta} f_i$$

where F_{ij} is the entry cost for a plant from country j in i.

In this appendix, I analyze the transition between a closed and open long-run equilibrium, for a small economy that opens up to foreign plants. I describe the industry "shake out" in the host economy when foreign plants enter: prices drop, relatively less productive domestic plants exit, and are replaced by more productive foreign plants, but, at the same time, new and incumbent domestic plants become on average more productive. In this way, the model matches some widely documented facts about foreign plants, namely that they are larger and more productive than domestic plants, and even if they represent a small fraction of the total number of plants in the host industry, they have a large share in the value of production[25].

I assume that the rest of the world is in its long-run open equilibrium. Interest rate is given for the small economy, and fixed over time.

[25] In Ramondo (2004), I used plant-level data from the Chilean manufacturing sector to document some salient facts about foreign plants, and found evidence supporting the model's implications.

A.1.1. Transition equilibrium

The main feature in which the transition differs from the long run is that, in some sectors, new foreign plants coexist with old incumbent domestic plants. In fact, by virtue of the decreasing returns to scale technology, some incumbent domestic plants are able to survive at a smaller scale; they are productive enough to cover the per period fixed costs of production and break-even. However, productivity of domestic plants in those sectors is not high enough for *new* domestic plants to enter the industry. Consequently, since plants die at the rate δ, and there is only foreign entry, in the long run, these sectors end up having only foreign plants. Simultaneously, during the transition, some other sectors host exclusively domestic plants, and others exclusively foreign plants. In this latter sector, foreign plants are so productive and able to charge such a low price, that incumbent domestic plants must exit; they are not able to cover the fixed cost of production and break-even at any scale.

Let superscripts d, f and fd, denote domestic, foreign and "mixed" sectors, respectively. Variables that change over time have the subscript t.

The problem of a new firm is analogous to the one in equation (17), corresponding to the long run equilibrium (see next subsection):

$$\frac{1-\delta}{r+\delta}[\pi_{ij}(x) - f_i] \geq F_{ij} \tag{36}$$

As long as the vector of productivity draws and the interest rate are fixed over time, so do prices and profits. New domestic plants break-even at the price given in equation (19) rewritten as:

$$p_{ii}^N(x) = \gamma_0 \cdot w_i^\alpha \cdot t_{ii}^{1-\alpha} \cdot x_i^\theta \tag{37}$$

The problem for an incumbent domestic plant is whether to stay or exit the industry. As long as current profits are large enough to cover the fixed cost of production, it stays:

$$\pi_{ii}(x) \geq f_i \tag{38}$$

By setting (38) to equality, and replacing $\pi_{ii}(x)$ by equation (18), the price at which an incumbent domestic plant breaks-even is:

$$p_{ii}^{I}(x) = \gamma_0 \cdot w_i^{\alpha} \cdot (\frac{1-\delta}{r+\delta} f_i)^{1-\alpha} \cdot x_i^{\theta}, \tag{39}$$

where $p_{ii}^{N}(x) > p_{ii}^{I}(x)$. Consumers buy from the cheapest producer, so that plants able to charge the lowest price get the market. The relationship between $p_{ii}^{I}(x)$ and $p_{ij}^{N}(x)$, for $j \neq i$, determines which goods are produced by only foreign plants, only domestic plants, and both.

i) Goods produced exclusively by foreign plants. Let B_{ij}^{f} be the set of goods in country i produced by exclusively plants from country j. Plants from country j have a productivity draw such that $p_{ij}^{N}(x) < p_{ii}^{I}(x)$, $j \neq i$, and $p_{ij}^{N}(x) < p_{ik}^{N}(x)$, for all $k \neq j$. In terms of productivity draws, B_{ij}^{f} is defined by:

$$B_{ij}^{f} = \{x \in \mathbf{X} : x_j < (\frac{1-\delta}{r+\delta} \frac{f_i}{t_{ij}})^{\frac{1-\alpha}{\theta}} x_i \text{ and } x_j < (\frac{t_{ik}}{t_{ij}})^{\frac{1-\alpha}{\theta}} x_k, \ \forall k \neq j\}$$

Additionally, the support condition in order to have B_{ij}^{f} non-empty is:

$$\underline{x} < \bar{x} \min[(\frac{1-\delta}{r+\delta} \frac{f_i}{t_{ij}})^{\frac{1-\alpha}{\theta}}; (\frac{t_{ik}}{t_{ij}})^{\frac{1-\alpha}{\theta}}]$$

for all $k \neq j$.

ii) Goods produced exclusively by domestic plants. Let B_i^{d} be the set of goods in country i produced by exclusively plants from country i. Domestic plants have a productivity draw such that $p_{ii}^{N}(x) < p_{ik}^{N}(x)$, for all $k \neq i$. In terms of productivity draws, B_i^{d} is defined by:

$$B_i^{d} = \{x \in \mathbf{X} : x_i < (\frac{t_{ik}}{t_{ii}})^{\frac{1-\alpha}{\theta}} x_k\}$$

where B_i^{d} is always non-empty.

iii) Goods produced by both foreign and domestic plants. Let B_{ij}^{fd} be the set of goods in country i produced by both plants from country j and i. The relationship between productivity draws are such that $p_{ii}^{I}(x) < p_{ij}^{N}(x) < p_{ik}^{N}(x)$, for all $k \neq j$, and $j \neq i$. In terms of productivity draws, B_{ij}^{fd} is defined by:

$$B_{ij}^{fd} = \{x \in \mathbf{X} : (\frac{1-\delta}{r+\delta} \frac{f_i}{t_{ij}})^{\frac{1-\alpha}{\theta}} x_i < x_j < (\frac{t_{ik}}{t_{ij}})^{\frac{1-\alpha}{\theta}} x_k\}$$

The support condition is:

$$\underline{x} < (\frac{t_{ik}}{t_{ij}})^{\frac{1-\alpha}{\theta}} \bar{x}$$

for all $k \neq j$.

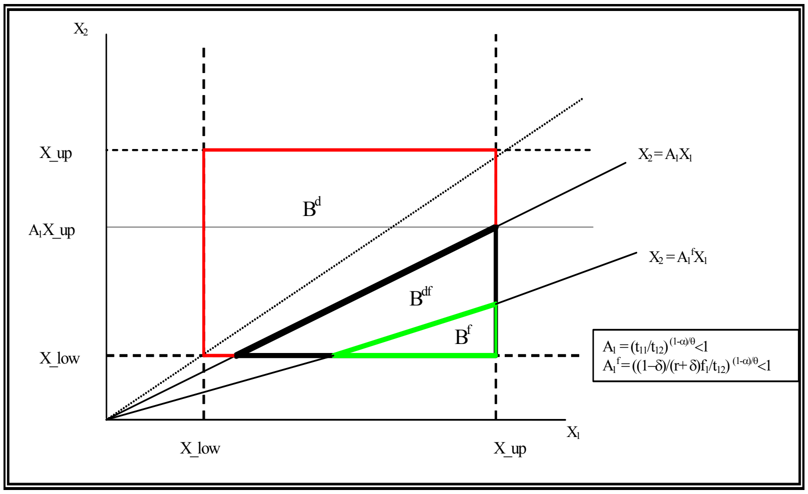

Figure 3: Transition equilibrium for country 1

Figure 3 presents a two-country world example. The productivity space is partitioned according to which type of plants carries production of good x in country 1; goods with "extreme" draws are produced by either plants from country 1 or 2 exclusively -i.e., the sets B^d and B^f, respectively; goods with "balanced" draws are produced by plants from both countries, i.e. the set B^{fd}.

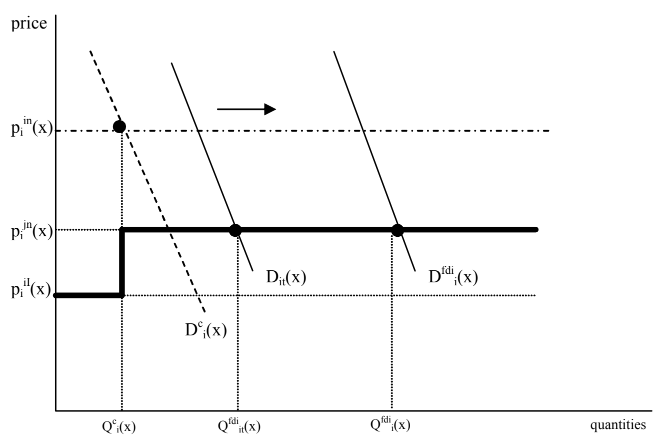

Figure 4: Equilibrium for good $x \in B_{ij}^{fd}$

Remark. Goods in the set B_{ij}^{fd} have a step supply curve (see Figure 4): the price $p_{ii}^{I}(x)$ prevails till the stock of shrinking inherited domestic plants is hit; then on, the price set by new foreign plants, $p_{ij}^{N}(x)$, is the relevant one. For the small economy, I conjecture that the equilibrium for good $x \in B_{ij}^{fd}$ is in the upper step of the supply curve, meaning that, at least, the demand for good x is as large as the one for the closed economy, for all $t > t_0$.

Even though prices do not change along the transition path, *aggregate* quantities do as the economy becomes wealthier, demand increases, and more plants enter the industry. The mass of plants producing goods in either B_{ij}^{f} or B_{i}^{d}, are pinned down from the market equilibrium condition, $\mu(p_i(x)/P_i)^{1-\eta}Y_i(t) = p_i(x)q_{ij}(x)m_{it}^{j}(x)$, where $q_{ij}(x)$ is individual output for a plant from country j operating in country i, and $m_{ijt}(x)$ is the mass of plants from country j operating in country i at time t , that evolves according to:

$$m_{ij,t+1}(x) = (1-\delta)m_{ij,t}(x) + n_{ij,t}(x).$$

The mass of foreign and domestic plants for $x \in B_{ij}^{fd}$ evolves, respectively:

$$m_{ij,t+1}(x) = (1-\delta)m_{ij,t}(x) + n_{ij,t}(x)$$

$$m_{i,t+1}^{ij}(x) = (1-\delta)m_{i,t}^{ij}(x)$$

where $m_{i,t}^{ij}(x)$ is the mass of plants from country i sharing production with plants from j, in country i, at time t. Note that the number of domestic plants is related to the number of plants in the closed economy. In particular, $m_{i,t}^{ij}(x) = (1-\delta)^{t-t_0}m_i^c(x)$, where t_0 is the period in which the economy opens to foreign plants. The mass of foreign plants $m_{ij,t}(x)$ is pinned down from the market clearing condition, $\mu(p_i(x)/P_i)^{1-\eta}Y_i(t) = p_i(x)[q_{ij}(x)m_{ij,t}(x)$ $+q_i^{ij}(x)m_{i,t}^{ij}(x)]$.

The recursive problem of a firm.—

I show that the recursive problem of a firm boils down into the problem in equation (36) for new plants, and equation (38) for incumbent plants. The value of opening a plant in country i for a potential producer from country j is:

$$V_{ij}(x, M_i) = \max[0, -F_{ij} + \frac{1-\delta}{1+r} W_{ij}(x, M_i')]$$

for all i, j. If the value of opening a new plant is non-negative, the producer pays the fixed cost F_{ij}, and start production next period, with a survival probability of $1 - \delta$. The vector $M_i = \{m_{ij}\}_{i,j}$ represents the state of the economy, given by the mass of foreign and domestic plants in country i. In equilibrium, the present value of opening a plant is equal to its cost, so that:

$$W_{ij}(x, M_i') = \frac{1+r}{1-\delta} F_{ij}; \tag{40}$$

$W_{ij}(x, M_i')$ is strictly positive in equilibrium. The value of an incumbent plant from country j operating in i is given by:

$$W_{ij}(x, M_i) = \max[0, \pi_{ij}(x, M_i) - f_i + \frac{1-\delta}{1+r} W_{ij}(x, M_i')] \tag{41}$$

for all i, j. Replacing $W_{ij}(x, M_i)$ by (40) yields:

$$\pi_{ij}(x, M_i) - f_i = \frac{r+\delta}{1-\delta} F_{ij}, \tag{42}$$

that is condition (36). Clearly, from (42), profits are constant over time.

A.1.2. Implications for the host economy

The arrival of foreign plants to a host economy affects its performance in various ways. The entry of more productive plants that displace less productive plants endogenously increases aggregate productivity in the host economy. With the entry of these more productive plants, competition gets tighter, and consequently, also domestic plants, new and incumbent, become more productive.

The model reproduces some stylized facts about foreign plants in a host economy, widely documented by the empirical literature on foreign plants. In particular, the model predicts that not only foreign plants are larger and more productive than domestic plants, they also contribute significantly to the value of production, in spite of being a very small fraction of the total number of plants. In Ramondo (2004), I exhaustively document these facts for the Chilean manufacturing sector, using plant-level data.

Assumption 1'. $F_{ij} > F_{ii}$, for all $j \neq i$

Proposition 2 *(foreign plants size advantage). Under Assumption 1', foreign plants are on average larger, in terms of sales and employment, than domestic plants.*

Proposition 3 *(foreign plants productivity advantage). Assume* $\lambda_i = \lambda$, $\underline{x} = 0$ *and* $\bar{x} \to \infty$, *for all* i. *Under Assumption 1', plants from country* j *have a productivity advantage with respect to plants from country* i, *in country* i.

Proposition 4 *Assume* $\underline{x} = 0$ *and* $\bar{x} \to \infty$, *for all* i. *the productivity distribution for domestic plants in the open economy first order stochastic dominates the one for the closed economy.*

Since domestic entry occurs in the set B_{ii}, *new* domestic plants are more productive in the open than in the closed economy. Exit of domestic plants occurs in the sets B_{ij}, meaning that foreign plants enter sectors in which domestic plants had relatively low productivity, relatively fewer plants, and higher prices.

Proposition 5 *Under Assumption 1', the share of foreign plants in the value of production is higher than the share in the total number of plants.*

Proposition 6 *For* $x \in B_{ij}^{fd}$, *a foreign plant has a size advantage over a domestic plant.*

Proposition 7 *For* $x \in B_{ij}^{fd}$, *a domestic plants shrinks with foreign entry.*

APPENDIX 2. PROOFS OF PROPOSITIONS

Proof of Proposition 1[26]. Let P_i^{fdi} be given by (25), and rewritten as:

$$(P_i^{fdi})^{1-\eta} = (\gamma_0 w_i^{\alpha})^{1-\eta} \int_{\mathbf{X}} [\min_j \{t_{ij}^{1-\alpha} \cdot x_j^{\theta}\}]^{1-\eta} \phi(x) dx \tag{43}$$

[26] I owe this proof to Constantino Hevia.

Let P_i^c be given by equation (16), and rewritten as:

$$(P_i^c)^{1-\eta} = (\gamma_0 w_i^\alpha)^{1-\eta} \int_{\mathbf{X}} \{t_{ii}^{1-\alpha} \cdot x_i^\theta\}^{1-\eta} \phi(x) dx \tag{44}$$

It follows that $t_{ii}^{1-\alpha} \cdot x_i^\theta \geq \min\{t_{ij}^{1-\alpha} \cdot x_j^\theta\}$. Comparing (43) and (44), $P_i^{fdi} \leq P_i^c$.■

Proof of Proposition 2. Sales and employment are given respectively by:

$$p_{ij}(x) q_{ij}(x) = \frac{r+\delta}{(1-\alpha)(1-\delta)} t_{ij} \tag{45}$$

$$s_{ij}(x) = \frac{r+\delta}{1-\delta} \frac{\alpha}{1-\alpha} \frac{t_{ij}}{w_i} \tag{46}$$

Under Assumption 1', $p_{ij}(x) q_{ij}(x) > p_{ii}(x) q_{ii}(x)$ and $s_{ij}(x) > s_{ii}(x)$.■

Proof of Proposition 3. Plants from country j that operate in country i have its productivity draw belonging to the set $B_{ij} = \{x \in R_+^n : x_j < (t_{ik}/t_{ij})^{\frac{1-\alpha}{\theta}} x_k \text{ for all } k \neq j\}$. Then, the cumulative distribution function for x_j in country i is given by:

$$G_i(x_j) = 1 - e^{-(\sum_k \lambda (\frac{t_{ij}}{t_{ik}})^{\frac{1-\alpha}{\theta}} x_j} \tag{47}$$

Average productivity for plants from country j is given by:

$$\int_0^\infty x_j^{\theta(1-\eta)} g_i(x_j) dx_j = \frac{\lambda \Gamma(\xi)}{[\sum_k \lambda (t_{ij}/t_{ik})^{\frac{1-\alpha}{\theta}}]^{\theta(1-\eta)}} \tag{48}$$

where $g_i(x_j) = \partial G_i(x_j)/\partial x_j$, and $\Gamma(\xi)$ is the Gamma function evaluated at $\xi = 1 + \theta(1-\eta)$. For plants from country i, average productivity is:

$$\int_0^\infty x_i^{\theta(1-\eta)} g_i(x_i) dx_i = \frac{\lambda \Gamma(\xi)}{[\sum_k \lambda (t_{ii}/t_{ik})^{\frac{1-\alpha}{\theta}}]^{\theta(1-\eta)}} \tag{49}$$

where $g_i(x_i) = \partial G_i(x_i)/\partial x_i$. Under Assumption 1', $(t_{ii}/t_{ik}) < 1$. Comparing (48) and (49), yields the following inequality: $(\sum_k (t_{ik}/t_{ii})^{\frac{1-\alpha}{\theta}})^{\theta(1-\eta)} < (\sum_k (t_{ik}/t_{ij})^{\frac{1-\alpha}{\theta}})^{\theta(1-\eta)}$. Then, foreign plants from country j are on average more productive than plants from i.■

Proof of Proposition 4. Domestic plants in the open economy have productivity belonging to the set $B_{ii} = \{x \in R_+^n : x_i < (t_{ik}/t_{ii})^{\frac{1-\alpha}{\theta}} x_k \text{ for all } k\}$. Then, the cumulative distribution function for x_i is:

$$G_i^{fdi}(x_i) = 1 - e^{-(\sum_k \lambda_k (t_{ii}/t_{ik})^{\frac{1-\alpha}{\theta}}) x_i} \tag{50}$$

For the closed economy, that distribution is:

$$G_i^c(x_i) = 1 - e^{-\lambda_i x_i} \tag{51}$$

Comparing (50) and (51), it is clear that $G_i^{fdi}(x_i) > G_i^c(x_i)$ for all x_i, i.e., $G_i^c(x_i)$ first order stochastic dominates $G_i^{fdi}(x_i)$.■

Proof of Proposition 5. Summing across j in (26), and dividing by total sales yields the share of foreign plants in the total value of production:

$$\frac{\sum_{j\neq i} X_{ij}}{X_i} = 1 - \frac{\lambda_i t_{ii}^{(1-\alpha)(1-\eta)-1}\Gamma_{ii}}{\sum_j \lambda_j t_{ij}^{(1-\alpha)(1-\eta)-1}\Gamma_{ij}(t_{ij}/t_{ii})} \tag{52}$$

where ς_{ii} is the effective market share of domestic plants in country i, given by (**??**).The share of foreign plants in the total number of plants is given by:

$$\frac{\sum_{j\neq i} m_{ij}}{M_i} = \frac{\sum_{j\neq i} \varsigma_{ij}/t_{ij}}{\sum_j \varsigma_{ij}/t_{ij}} = 1 - \frac{\lambda_i t_{ii}^{(1-\alpha)(1-\eta)-1}\Gamma_{ii}}{\sum_j \lambda_j t_{ij}^{(1-\alpha)(1-\eta)-1}\Gamma_{ij}} \tag{53}$$

Comparing (53) and (52), since $t_{ii} < t_{ij}$, yields the following inequality

$$\frac{1}{\sum_j \lambda_j t_{ij}^{(1-\alpha)(1-\eta)-1}\Gamma_{ij} t_{ij}/t_{ii}} < \frac{1}{\sum_j \lambda_j t_{ij}^{(1-\alpha)(1-\eta)-1}\Gamma_{ij}}$$

Then, it follows that the expression in (**??**) is always higher than the one in (53).■

Proof of Proposition 6. Sales and employment for domestic plants are, respectively:

$$sales_{ij}^d = sales_{ij}^f (\frac{x_j}{x_i})^{\frac{\theta}{1-\alpha}} \tag{54}$$

$$emp_{ij}^d = emp_{ij}^f (\frac{x_j}{x_i})^{\frac{\theta}{1-\alpha}} \tag{55}$$

where $sales_{ij}^f$ and emp_{ij}^f are sales and employment for a foreign plant from country j in country i, given by (45) and (46), respectively. In the set B_{ij}^{fd}, the relationship between productivity draws for countries j and i is $x_j < (t_{ii}/t_{ij})^{\frac{1}{\theta}} x_i$. Since $(t_{ii}/t_{ij})^{\frac{1}{\theta}} < 1$, it follows that $x_j < x_i$. Then, $sales_{ij}^d < sales_{ij}^f$, and $emp_{ij}^d < emp_{ij}^f$.■

Proof of Proposition 7. Comparing individual sales and employment for plants from country i producing $x \in B_{ij}^{fd}$, in the closed and open economy, yields:

$$\frac{sales_{ij}^{fdi}}{sales_{ij}^{c}} = \frac{emp_{ij}^{fdi}}{emp_{ij}^{c}} = (\frac{t_{ij}}{t_{ii}})^{1-\alpha}(\frac{x_j}{x_i})^{\frac{\theta}{1-\alpha}}$$

Under Assumption 1' ($t_{ii} < t_{ij}$), the first term inside the brackets is more than one. By definition of the set B_{ij}^{fd}, it follows that $(x_j/x_i)^{\frac{\theta}{1-\alpha}} > (t_{ij}/t_{ii})$. It follows that

$$(\frac{t_{ij}}{t_{ii}})^{1-\alpha}(\frac{x_j}{x_i})^{\frac{\theta}{1-\alpha}} > (\frac{t_{ii}}{t_{ij}})^{\frac{(2-\alpha)\alpha}{1-\alpha}} > 1.$$

Then, sales and employment are lower for the open than for the closed economy.■

APPENDIX 3. DATA

The procedure to estimate barriers to multinational production requires data from several sources. In particular, I need accurate data on bilateral measures of international production, measures of observable bilateral barriers, and data on GNP of trading partners.

Table A.3.1 summarizes data sources for each variable; table A.3.2 lists the countries in the sample; and tables A.3.3 and A.3.4 present descriptive statistics.

Data on bilateral multinational production.—

Contrary to international trade data, there is no systematic database for bilateral measures of multinational production. I assemble a bilateral data set that includes six different measures of international production and FDI, using as main sources UNCTAD and OECD[27]. These organisms have data on FDI flows and stocks from country j to i as measured in the Balance of Payment of a country, and variables related to the activity of foreign affiliates from country j in i (sales, number of plants, employment, and assets). For the first two variables, there are 109 countries that are information source, for the period 1985-2003. Data related to the activity of foreign affiliates are much more scarce. The sample of countries that are source of information drops to no more than 65, and the number of

[27] As basic data source, I use published and unpublished UNCTAD, and complete with OECD's International Direct Investment, and Globalization databases

years for which data is available also shrinks. I hence restrict the analysis to the period 1990-2002. I end up with a sample of 147 (150) countries observed (at least once) as source (host) countries, for at least one of the measures recorded in the database.

Likewise import and export data, most of the countries record both outward and inward volumes of FDI and multinational production. Thus, I first consider inward magnitudes reported by a given country, and complete missing values with outward magnitudes reported by a partner countries.

Unfortunately, bilateral data on the activity of affiliates of multinational firms are available at the aggregate level, not sector or product level.

The definition of FDI flows and FDI stocks follows the definitions from the IMF Manual of Balance of Payment Statistics. The concept of FDI flows includes capital flows for: (i) acquiring or sell existing firms, (ii) establishing a new firm, (iii) new investments as long as funds come from the parent company or other affiliates, (iv) reinvested earnings, and (v) any debt with the parent company or other affiliates, as long as the foreign resident owns more than 10% of the firm. FDI stocks are the result of accumulating FDI flows. These two variables are comparable across countries[28].

A foreign affiliate is defined as a plant who has more than 10% of its shares owned by a foreigner. For these plants, I record sales, assets, employment and number of affiliates owned by residents from country j in i.

Data on the activity of foreign affiliates are more prone to have some comparability problems. Specifically, while some countries report these variables for affiliates with more than 10% of foreign capital, others do so for only majority-owned affiliates (more than 50% of ownership). Nonetheless, majority-owned affiliates are the largest part of the total number of foreign plants in a host economy.

In terms of sector coverage, data mostly refer to non-financial affiliates in all sectors. However, some countries report data only on foreign affiliates in manufacturing. These countries are marked in red in Table A.3.2.

Data on countries' GDP and GNP are from the World Development Indicators, and

[28] In general, some countries don't include (v) in the definition of FDI flows and stocks.

International Financial Indicators (IMF). These are nominal values, converted to US dollars, and they are not on purchasing power parity basis.

Data on bilateral barriers.—

As observable measures for bilateral barriers to multinational production, I include the following variables: bilateral distance between trading partners, common border, common language, and common colonial past (ever in a colonial relationship). I also include a dummy variable for country-pairs that have signed a double taxation treaty by virtue of which affiliates of multinational firms have their tax rate in the host country reduced. Variables related to geography, language, and colonial ties, are compiled by the *"Centre d'etudes prospectives et informations internationales (CEPII)"*[29]. Bilateral distance is the distance in kilometers between the largest cities of the two countries. Common language is a dummy equal to one if both countries have the same official language or more than 20% of the population share the same language even if it is not the official one. Common border is equal to one if two countries share a border. Colonial ties is equal to one if the two countries had ever been in a colonial relationship. The list of countries that signed a bilateral double taxation treaty is compiled by UNCTAD. This variables is equal to one if the countries have signed a bilateral treaty, and zero otherwise.

Bilateral corporate tax rates are computed from tax rates applied to foreign corporations in country i, corrected by the preferential rate stipulated in the bilateral double taxation treaty, if there were one. A country j that has signed a double taxation treaty with country i, but no data is available on bilateral tax rates, is assigned the average bilateral tax rate in country i. Country pairs without a treaty and missing values for bilateral tax rates are assumed to be subject to the corporate tax rate in the host country.

[29] See the following link for documentation: www.cepii.fr/anglaisgraph/bdd/distance.htm

Table A.3.1
Data Sources

Variables:	Sources:
Bilateral measures for international production and FDI:	
Stocks and Flows	*FDI database for individual countries (UNCTAD), unpuplished data* *International Direct Investment Database (OECD)*
Sales, number, employment and assets of affiliates	*FDI database for individual countries (UNCTAD), unpublished data* *Globalisation Database (OECD)*
Gross National Product (in current U$)	*World Development Indicators, WB* *International Financial Statistics, IMF*
Population	*World Development Indicators, WB*
Bilateral Barriers:	
Distance **Common Language** **Common Border** **Colonial Ties***	*Centre d'etudes prospectives et informations internationales (CEPII)* *(www.cepii.fr/anglaisgraph/bdd/distance.htm)*
Bilateral Double Taxation Treaties	*UNCTAD*
Bilateral Corporate Tax Rates	*World Tax Database from U. of Michigan and www.taxanalysts.com*

Table A.3.2
List of countries, by observed source/host status, and data availability

Country	Observed as:		Data source for:				
	source	host	flows/stocks of FDI	sales	assets	employment	number of plants
Afghanistan	X	X					
Albania	X	X					
Algeria	X	X	X	X	X	X	X
Angola	X	X	X	X	X	X	X
Argentina	X	X	X	X	X	X	X
Armenia	X	X	X	X		X	X
Australia	X	X	X			X	
Austria	X	X	X				X
Azerbaijan	X	X	X				
Bangladesh	X	X	X				
Belarus	X	X					
Belgium	X	X	X				
Belgium/Luxembourg	X	X	X				
Benin	X	X	X				
Bolivia	X	X	X	X	X	X	X
Bostwana	X		X	X	X	X	X
Bosnia and Herzegovina	X	X					
Brazil	X	X	X	X	X	X	X
Bulgaria	X	X	X				
Burkina Faso	X	X	X	X	X		X
Burundi	X	X	X				
Cambodia	X	X	X				X
Cameroon	X	X	X	X	X	X	X
Canada	X	X	X	X	X	X	
Central African Republic	X	X	X	X	X		
Chad	X	X	X				
Chile	X	X	X	X	X	X	X
China	X	X	X				
Colombia	X	X	X	X	X	X	X
Congo, Republic of	X	X					
Costa Rica	X	X	X	X	X	X	X
Cote d'Ivoire	X	X					
Croatia	X	X	X				
Cuba	X	X	X		X	X	X
Czech Republic	X	X	X	X		X	
Dem. People's Rep. of Korea	X	X					
Denmark	X	X	X	X		X	X
Dominican Republic	X	X	X	X	X	X	X
Ecuador	X	X	X	X	X	X	X
Egypt	X	X					
El Salvador	X	X	X	X	X	X	X
Estonia	X	X	X				
Ethiopia	X	X	X				
Finland	X	X	X	X	X	X	X
France	X	X	X	X		X	
Gabon	X	X					
Gambia	X	X	X				
Georgia	X	X	X				
Germany	X	X	X	X	X	X	X
Ghana	X	X					
Greece	X	X	X				
Guatemala	X	X	X	X	X	X	X
Guinea	X	X					

Country	Observed as:		Data source for:				
	source	host	flows/stocks of FDI	sales	assets	employment	number of plants
Guinea-Bissau	X						
Haiti	X	X	X	X	X	X	X
Honduras	X	X	X	X	X	X	X
Hong Kong (China)	X	X	X				X
Hungary	X	X	X				
India	X	X	X	X			X
Indonesia	X	X	X				
Iran	X	X					
Iraq	X	X					
Ireland	X	X	X	X		X	X
Israel	X	X					
Italy	X	X	X	X		X	X
Jamaica	X	X	X	X	X	X	X
Japan	X	X	X	X	X	X	X
Jordan	X	X					
Kazakhstan	X	X	X				
Kenya	X	X					
Korea	X	X	X				
Kuwait	X	X					
Kyrgyzstan	X	X	X				
Laos	X	X					
Latvia	X	X	X				
Lebanon	X	X					
Lesotho	X	X					
Liberia	X	X					
Libya	X	X					
Lithuania	X	X	X				
Madagascar	X	X					
Malawi	X	X	X	X	X	X	X
Malaysia	X	X	X				
Mali	X	X	X	X	X	X	X
Mauritania	X	X					
Mauritius	X	X	X				
Mexico	X	X	X	X	X	X	X
Moldova	X	X	X				
Mongolia		X	X				
Morocco	X	X	X	X	X	X	X
Mozambique	X	X					
Myanmar		X	X				X
Namibia	X	X					
Nepal	X	X					
Netherlands	X	X	X	X	X	X	X
New Zealand	X	X	X				
Nicaragua	X	X	X	X	X		X
Niger		X					
Nigeria	X	X					
Norway	X	X	X	X		X	X
Oman	X	X					
Pakistan	X	X	X				
Panama	X	X	X	X	X	X	X
Papua New Guinea	X	X	X				
Paraguay	X	X	X	X	X	X	X
Peru	X	X	X	X	X	X	X
Philippines	X	X	X				
Poland	X	X	X	X	X	X	X

Country	Observed as:		Data source for:				
	source	host	flows/stocks of FDI	sales	assets	employment	number of plants
Portugal	X	X	X	X		X	X
Puerto Rico	X	X					
Romania	X	X					
Russia	X	X	X				
Rwanda	X	X	X		X		
Saudi Arabia	X	X					
Senegal	X	X					
Serbia and Montenegro	X	X					
Sierra Leone	X	X	X				
Singapore	X	X	X				
Slovak Republic	X	X	X				
Slovenia	X	X	X				X
Somalia	X	X	X		X	X	
South Africa	X	X	X				
Spain	X	X	X	X		X	
Sri Lanka	X	X	X				
Sudan	X	X					
Suriname	X	X	X	X	X	X	X
Sweden	X	X	X	X	X	X	X
Switzerland	X	X	X			X	
Syria	X	X					
TFYR Macedonia	X	X	X				
Taiwan	X	X	X				
Tajikistan	X	X					
Tanzania		X	X				X
Thailand	X	X	X				
Togo		X					
Trinidad and Tobago	X	X	X	X	X	X	X
Tunisia	X	X	X				
Turkey	X	X	X	X		X	
Turkmenistan	X	X					
Uganda	X	X	X	X	X	X	X
Ukraine	X	X					
United Arab Emirates	X	X					
United Kingdom	X	X	X	X		X	X
United States	X	X	X	X	X	X	X
Uruguay	X	X		X	X	X	X
Uzbekistan	X	X	X	X		X	X
Venezuela	X	X	X	X	X	X	X
Vietnam	X	X	X				
Yemen	X	X					
Zambia	X	X	X	X	X	X	X
Zimbabwe	X	X	X	X	X	X	X
Zaire	X	X					

(X) : Source OECD, Globalisation data set. Includes only manufacturing sector

Table A.3.3
Descriptive statistics for bilateral measures of international production and FDI

	All possible country pairs *	Country-pairs with $X^j_i > 0$ and $X^i_j > 0$
FDI stocks	**146**	**1079**
	[2513]	[6761]
	21784	2946
FDI flows	**22**	**158**
	[359]	[951]
	21886	3048
Sales of affiliates	**289**	**6718**
	[5736]	[26896]
	19684	846
Assets of affiliates	**369**	**15577**
	[10296]	[65181]
	19295	457
Number of affiliates	**4.4**	**86**
	[60]	[254]
	19847	1009

* For country-pairs with zero bilateral FDI, missing values are replaced by zeros
Standard errors in brackets
Xij = multinational activities of affiliates from country j to country i

Table A.3.4
Descriptive statistics for observable barriers'

	Mean	Std. Dev.	Min	Max
Bilateral distance (km)	7270	4204	10	19951
% of country-pairs with common language	0.140	0.347	0	1
% of country-pairs with common border	0.024	0.154	0	1
% of country-pairs with a double taxation treaties	0.136	0.342	0	1
% of country-pairs ever in a colonial relationship	0.013	0.114	0	1
Bilateral corporate tax rates	31.3	12.12	0.5	57.3
number of observations	22650			

All possible country pairs

Table A.3.5

Traditional gravity and bilateral FDI stocks. OLS.

Dependent variable: stocks from country j in i (in log, as % of country i' s GNP)	Country-pairs with positive FDI			All possible country-pairs [1,2]		
	I	**II**	**III**	**IV**	**V**	**VI**
log of bilateral distance	**-1.185**	**-1.152**	**-1.173**	**-1.397**	**-1.057**	**-1.17**
(thousands of km)	[0.050]**	[0.050]**	[0.050]**	[0.037]**	[0.036]**	[0.036]**
1 for pairs with common official language or	**0.879**	**0.59**	**0.622**	**0.088**	**-0.015**	**-0.002**
>20% pop. same language	[0.133]**	[0.135]**	[0.136]**	[0.072]	[0.069]	[0.070]
1 for pairs with a common border	**0.724**	**0.595**	**0.604**	**0.932**	**1.016**	**1.045**
	[0.159]**	[0.158]**	[0.159]**	[0.152]**	[0.145]**	[0.148]**
1 for pairs ever in colonial relationship		**1.269**	**1.213**		**-0.062**	**0.018**
		[0.188]**	[0.188]**		[0.193]	[0.197]
1 for pairs with double taxation treaty		**0.67**			**3.727**	
		[0.095]**			[0.075]**	
bilateral corporate taxes			**-0.022**			**-0.096**
			[0.004]**			[0.002]**
Observations	**2992**	**2894**	**2894**	**21732**	**21732**	**21732**
R-squared	**0.74**	**0.75**	**0.75**	**0.49**	**0.55**	**0.52**

Notes:
Standard errors in brackets
* significant at 5%; ** significant at 1%
All specifications with constant, and source and host country fixed effects
Observations with dependent variables < 1.5
Countries with popupation over one million
(1): FDI=0 if all measures of FDI are zero or missing values
(2): for country-pairs with no FDI, stocks are replaced by one dollar

Table A.3.6

Traditional gravity and bilateral number of affiliate plants. OLS.

Dependent variable: number of affiliate plants from country j in i (in log, as % of country i' s GNP)	Country-pairs with positive FDI			All possible country-pairs [1,2]		
	I	II	III	IV	V	VI
log of bilateral distance	**-0.937**	**-0.905**	**-0.905**	**-0.676**	**-0.549**	**-0.585**
(thousands of km)	[0.058]**	[0.058]**	[0.057]**	[0.024]**	[0.024]**	[0.024]**
1 for pairs with common official language or	**0.417**	**0.39**	**0.388**	**-0.132**	**-0.17**	**-0.165**
>20% pop. same language	[0.148]**	[0.148]**	[0.148]**	[0.045]**	[0.044]**	[0.045]**
1 for pairs with a common border	**0.556**	**0.511**	**0.523**	**0.445**	**0.501**	**0.513**
	[0.176]**	[0.177]**	[0.176]**	[0.105]**	[0.102]**	[0.103]**
1 for pairs ever in colonial relationship		**0.679**	**0.674**		**-0.235**	**-0.129**
		[0.192]**	[0.191]**		[0.140]	[0.141]
1 for pairs with double taxation treaty		**0.365**			**1.829**	
		[0.115]**			[0.054]**	
bilateral corporate taxes			**-0.016**			**-0.045**
			[0.004]**			[0.002]**
Observations	**1009**	**1009**	**1009**	**19847**	**19847**	**19847**
R-squared	**0.89**	**0.89**	**0.89**	**0.64**	**0.66**	**0.65**

Notes:

Standard errors in brackets

* significant at 5%; ** significant at 1%

All specifications with constant, and source and host country fixed effects

Observations with dependent variables < 1.5

Countries with popupation over one million

(1): FDI=0 if all measures of FDI are zero or missing values

(2): for country-pairs with no FDI, number of plants is replaced by 0.001

Table A.3.7
Auxiliary parameters

Parameters	All Countries		OECD countries		Definition
	ρ_d	$\rho_s(\Delta^*)$	ρ_d	$\rho_s(\Delta^*)$	
a_d	-0.011	-0.003	-0.008	-0.0035	OLS coefficient on bilateral distance
a_c	-0.0007	0.001	0.0060	0.0008	OLS coefficient on common border
a_l	0.0049	0.001	0.0026	0.0012	OLS coefficient on common language
a_{col}	0.009	0.002	0.0041	0.0013	OLS coefficient on common colonial past
a_{dtt}	0.001	0.000	-0.0080	-0.0001	OLS coefficient on bilateral double taxation treaty
σ_e	0.18	0.025	0.1858	0.0317	Standard error of error term, in OLS regression
f_0	0.11	0.09	0.91	0.45	fraction of country-pairs with Xji>0 and Xij>0
f_2	0.77	0.67	0.01	0.11	fraction of country-pairs with Xji=0 and Xij=0
d_0	0.81	0.291	0.96	0.35	mean distance, country-pairs with Xji>0 and Xij>0
c_0	3.36	9.061	1.06	2.15	fraction of country-pairs with Xji>0 and Xij>0 sharing a border
l_0	1.02	2.606	1.03	1.11	fraction of country-pairs with Xji>0 and Xij>0 sharing a language
col_0	3.64	4.069	1.10	1.33	fraction of country-pairs with Xji>0 and Xij>0 sharing past colonial ties
dtt_0	4.88	2.135	0.98	1.03	fraction of country-pairs with Xji>0 and Xij>0 with a double taxation treaty
Y_0	3.94	0.839	1.06	0.62	mean value of GNP, country-pairs with Xji>0 and Xij>0
X_0	27.74	6.840	1.13	1.40	mean value of sales of affiliates, country pairs with Xji>0 and Xij>0
d_2	1.03	1.167	1.87	1.60	mean distance, country-pairs with Xji=0 and Xij=0
c_2	0.63	0.011	0.00	0.00	fraction of country-pairs with Xji=0 and Xij=0 sharing a border
l_2	1.00	0.532	0.00	0.51	fraction of country-pairs with Xji=0 and Xij=0 sharing a language
col_2	0.48	0.315	0.00	0.00	fraction of country-pairs with Xji=0 and Xij=0 sharing past colonial ties
dtt_2	0.30	0.723	2.51	0.96	fraction of country-pairs with Xji=0 and Xij=0 with a double taxation treaty
Y_2	0.45	1.050	0.17	2.47	mean value of GNP, country-pairs with Xji=0 and Xij=0
d_1	0.97	0.815	1.36	1.52	mean distance, country-pairs with Xji>0 and Xij=0
c_1	1.23	0.564	0.41	0.07	fraction of country-pairs with Xji>0 and Xij=0 sharing a border
l_1	0.95	1.665	0.70	1.01	fraction of country-pairs with Xji>0 and Xij=0 sharing a language
col_1	1.82	1.693	0.00	0.91	fraction of country-pairs with Xji>0 and Xij=0 sharing past colonial ties
dtt_1	1.98	1.322	1.09	0.97	fraction of country-pairs with Xji>0 and Xij=0 with a double taxation treaty
Y_1	1.92	0.923	0.35	1.02	mean value of GNP, country-pairs with Xji>0 and Xij=0
X_1	0.05	1.472	0.03	0.84	mean value of sales of affiliates, country pairs with Xji>0 and Xij=0
Y_1^s	3.32	0.783	0.43	0.94	mean value of GNP for country i (source), country-pairs with Xji>0 and Xij=0
Y_1^h	0.52	1.064	0.27	1.10	mean value of GNP for country j (host), country-pairs with Xji>0 and Xij=0

Table A.3.8

Auxiliary parameters

Parameters	*All Countries*		*OECD countries*		*Definition*
	ρ_d	$\rho_s (\Delta^*)$	ρ_d	$\rho_s (\Delta^*)$	
a_d	-0.01144	-0.0039	-0.0084	-0.0043	*OLS coefficient on bilateral distance*
a_c	-0.0009	0.0010	0.0062	0.0005	*OLS coefficient on common border*
a_l	0.0049	0.0010	0.0025	0.0015	*OLS coefficient on common language*
a_{col}	0.00848	0.0028	0.0047	0.0021	*OLS coefficient on common colonial past*
a_t	0.00001	-0.0001	0.0001	-0.0001	*OLS coefficient on bilateral corporate tax rate*
σ_e	0.18	0.02	0.19	0.023	*Standard error of error term, in OLS regression*
f_0	0.11	0.08	0.91	0.4312	*fraction of country-pairs with Xji>0 and Xij>0*
f_2	0.77	0.78	0.01	0.1349	*fraction of country-pairs with Xji=0 and Xij=0*
d_0	0.81	0.24	0.96	0.336	*mean distance, country-pairs with Xji>0 and Xij>0*
c_0	3.36	10.99	1.06	2.244	*fraction of country-pairs with Xji>0 and Xij>0 sharing a border*
l_0	1.02	2.93	1.03	1.224	*fraction of country-pairs with Xji>0 and Xij>0 sharing a language*
col_0	3.64	5.04	1.10	1.546	*fraction of country-pairs with Xji>0 and Xij>0 sharing past colonial ties*
t_0	0.54	0.83	0.98	0.858	*mean corporate tax rate, country-pairs with Xji>0 and Xij>0*
Y_0	3.94	0.81	1.06	0.685	*mean value of GNP, country-pairs with Xji>0 and Xij>0*
X_0	27.74	10.42	1.13	1.552	*mean value of sales of affiliates, country pairs with Xji>0 and Xij>0*
d_2	1.03	1.16	1.87	1.762	*mean distance, country-pairs with Xji=0 and Xij=0*
c_2	0.63	0.051	0.00	0.000	*fraction of country-pairs with Xji=0 and Xij=0 sharing a border*
l_2	1.00	0.65	0.00	0.206	*fraction of country-pairs with Xji=0 and Xij=0 sharing a language*
col_2	0.48	0.29	0.00	0.000	*fraction of country-pairs with Xji=0 and Xij=0 sharing past colonial ties*
t_2	1.09	1.04	2.51	1.425	*mean corporate tax rate, country-pairs with Xji=0 and Xij=0*
Y_2	0.45	1.06	0.17	2.233	*mean value of GNP, country-pairs with Xji=0 and Xij=0*
d_1	0.97	0.54	1.36	1.423	*mean distance, country-pairs with Xji>0 and Xij=0*
c_1	1.23	0.94	0.41	0.074	*fraction of country-pairs with Xji>0 and Xij=0 sharing a border*
l_1	0.95	1.91	0.70	1.024	*fraction of country-pairs with Xji>0 and Xij=0 sharing a language*
col_1	1.82	2.72	0.00	0.768	*fraction of country-pairs with Xji>0 and Xij=0 sharing past colonial ties*
t_1	0.84	0.87	1.09	1.010	*mean corporate tax rate, country-pairs with Xji>0 and Xij=0*
Y_1	1.92	0.79	0.35	0.930	*mean value of GNP, country-pairs with Xji>0 and Xij=0*
X_1	0.05	1.52	0.03	0.763	*mean value of sales of affiliates, country pairs with Xji>0 and Xij=0*
Y_1^s	3.32	0.98	0.43	0.854	*mean value of GNP for country i (source), country-pairs with Xji>0 and Xij=0*
Y_1^h	0.52	0.60	0.27	1.006	*mean value of GNP for country j (host), country-pairs with Xji>0 and Xij=0*