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Size, Geography, and Multinational Production*

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Abstract

This paper analyzes the cross-country determinants of multinational production (MP), quantifies its costs, and impact on welfare. Three facts stand out: a small fraction of country-pairs engages in MP with each other; geography is a significant impediment to these activities; and country size matters. I introduce MP in a competitive, multi-country industry model, close to Eaton-Kortum (2002), in which firms can replicate technologies abroad at a cost. The model highlights the role of absolute advantages in determining the cross-country allocation of MP, predicts zero as well as positive MP volumes, and delivers a gravity equation. Using new data on bilateral sales of affiliates, I estimate the cost of MP by matching simulated and actual moments. Estimates suggest that country-pairs twice as distant have 56% higher costs, and there are large unrealized gains of lowering costs of MP.

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1 Introduction

One of the most notable features of economic globalization has been the increasing importance of multinational production (MP) around the world. In fact, international firms have become one of the most important mechanisms through which countries exchange goods, capital, ideas, and technologies.[1] By 2001, total sales of foreign affiliates of multinational firms represented more than 50% 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 MP as a mechanism through which firms serve foreign buyers, and potentially, technologies diffuse across countries, little work has been done that describes, analyzes, and quantifies the cross-country patterns of such flow as well as its impact on welfare. This paper tries to fill that gap by analyzing the determinants of the cross-country allocation and volumes of multinational activities, and quantifying the welfare effects of changing barriers to such activities.

Three new facts stand out from the observed patterns of MP across countries. First, only around 25% of all possible country-pairs engages in multinational activities with each other. Second, distance seems to be important for the location of such activities; remote country-pairs have substantially less, and mostly non-existent, multinational activities with each other. Third, the size of a country also matters in determining both the allocation and volume of MP; in fact, the bulk of multinational activities takes place between

[1]MP involves 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 financial category in the Balance of Payment of a country, and one of the mechanisms, among others, through which multinational firms fund their affiliate plants.

[2]WIR 2006, UNCTAD.

large economies, while the lack of them is mostly observed between small economies.

I introduce MP in a model close to Eaton and Kortum (2002)'s from which I borrow the probabilistic formulation of productivities. I modify their framework in order to incorporate plants' rather than goods' mobility, and to capture the facts above. Firms in an industry decide whether to transfer their home productivity and serve consumers in a foreign country by opening a plant. However, this replication is costly because firms face a fixed cost per new plant that depends on variables specific to the pair of trading countries, such as geographical distance, regulations, and cultural factors, some of which are observable while others are not. A plant's technology is then defined by a productivity parameter and the fixed cost. Moreover, all firms in an industry from the same country of origin have the same technology, and countries are also heterogenous in size. Hence, in this model, the sources of heterogeneity are given at the country and country-pair level, not at the firm or plant level.

Once established in a foreign market, affiliate plants produce using local labor, sell output exclusively in the host market, and eventually, repatriate profits to the home economy.

Similarly to the model in Hopenhayn (1992), the model in this paper is one where industries are competitive, with decreasing returns to scale and a fixed cost at the plant level, but constant returns to scale at the industry level. Consequently, firms from the country with the most efficient technology are the only suppliers in a given foreign industry (i.e. firms with the lowest minimum average cost).

One insight of the model is the role of absolute advantages in determining the allocation of MP across countries. While the allocation of trade in goods between countries is driven by comparative advantages, the allocation of trade in technologies or ideas between countries is driven by absolute advantages. The intuition is as follows: since firms are able to transfer their home technology to their affiliates, and theses affiliates carry production in the foreign market by employing local inputs, as long as input prices are uniform across plants of any origin, input costs do not matter in determining which plants produce in that host market, but only how efficient technologies from different origins are. Hence, the link between wages and technologies, central to comparative advantages, disappears.

The model delivers implications regarding the patterns of MP across countries that, in turn, are used to quantify the model. First, this model is consistent with zero MP flows between some country-pairs as observed in the data. A country j might have inefficient technologies in every single industry and not be able to produce in country i. Second, because of the presence of heterogenous bilateral fixed costs, the model predicts two-way as well as one-way positive MP flows between country-pairs, also observed in the data. Finally, as suggested by the stylized facts, the model generates a gravity equation 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 costs.

I assemble detailed data on the activity of affiliate plants from country j in i to quantify the magnitude of barriers to MP, and calculate welfare gains from eliminating them. The data set I constructed includes variables such as bilateral sales of affiliate plants, as well as other measures of bilateral MP activities and FDI, for OECD and non-OECD countries, from 1990 to 2002.

Regarding the empirical strategy, the presence of bilateral fixed costs and zero volumes does not allow one to apply linear regression methods to consistently estimate the model parameters. Hence I estimate them using an indirect inference procedure that deals with biases typically present in linear estimates of gravity equations.

It turns out that distance is the most important impediment to MP: country-pairs twice as distant face a 56% lower share of sales of affiliates from country j on income of country i. Variables such as bilateral corporate tax rates have a small impact on the bilateral cost of multinational activities. Regarding welfare, estimates suggest that the average real income loss of going to autarky for a country would be of more than 4%, ranging from 2% for the United States, to 10% for Sri Lanka. Conversely, average real income gains of lowering barriers to a uniform level across plants of different origins would be more than 30%. Moreover, if the EU further liberalized MP among its members, it would experience an increase in real income of more than 20%, while further liberalization within NAFTA would increase real income among its members by more than 7%. All these numbers are much higher than the ones calculated for trade flows. [3]

Previous literature has typically examined the determinants of trade volumes across countries using mostly a gravity approach. 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.[4] The relationship between MP volumes and gravity has been less explored. Particularly, Carr, Markusen and Maskus (2001), and Razin, Rubinstein and Sadka (2003) estimate a positive effect of country size and a negative one of distance on bilateral sales of affiliates, and bilateral FDI stocks, respectively.

[3]Eaton and Kortum (2002) calculate that welfare losses of going to trade autarky are 3.5% for OECD countries (0.8% for the United States); the comparable number for MP is 4.4%. Analogously, gains from eliminating barriers to trade are 20%, and 30% for MP, for the same group of countries.

[4]See Harrigan (1996), Hummels (1999), Rose and Van Wincoop (2001), Eaton and Kortum (2002), and Anderson and Van Wincoop (2003).

Regarding welfare and MP, early work by Markusen (1984), and Horstmann and Markusen (1989), qualitatively analyzes the welfare effects of opening up to multinational firms stemming out from a model in which knowledge-based firm-specific assets can be supplied costlessly to additional plants within the corporation.

However, up to my knowledge, no study has quantified the role of gravity on MP flows, and its effects on welfare. This paper does so by introducing bilateral sales of affiliates of multinational firms into a multi-country model, similar to Eaton-Kortum (2002), that delivers gravity, and is used to estimate MP costs, and quantitatively evaluate gains from openness.

This paper contributes to two strands of the international literature: the one related to multinational firms and FDI; and the one related to technology diffusion that is also linked to the industrial organization and growth literature. In fact, MP can be intended as a mechanism through which diffusion of technologies across countries takes place. In particular, diffusion in this paper occurs through immediate but costly replication of technologies. The cost of transmission depends on "gravity" variables such as distance between countries. Estimates of these costs indicate that the incentives to replicate technologies vary significantly across countries, and that geographical distance plays an important role in these decisions. This finding on the importance of geography in location decisions are in line with the finding on the importance of distance for technological spillovers across countries (Keller, 2002), and for the sequential location decision of retail chains such as Wal-Mart (Holmes, 2006).

The international trade literature has typically equated gains from trade with overall gains from openness. But, trade is only one possible channel through which countries interact, and the gains from openness can be much larger than the gains from trade.

Rodriguez-Clare (2006) shows that once we add diffusion of ideas into an Eaton-Kortum model of trade, the implied gains from trade are low but the overall gains from openness are much larger, suggesting that diffusion of ideas plays a key role in accounting for the gains from openness.[5] One can think of MP as one important mechanism through which diffusion of ideas and technologies between countries takes place. In particular, and in line with Rodriguez-Clare's result, I calculate that gains from lowering costs to MP are large, meaning that gains from diffusion by replication of technologies are also large. In a similar spirit, Burstein and Monge (2005) calculate gains from lowering barriers to multinational activities. However, in their framework, since the scarcity of managers creates a constraint that makes replication of technologies across countries impossible, the gains from diffusion are much lower than the ones found in this paper.

Hence, even though in this paper MP does not have any competing alternative such as trade, it can be seen as a step toward understanding and quantifying the importance of this particular diffusion mechanism and its impediments on the gains from openness. At the same time, it might be a useful and alternative benchmark that complements models with only trade.[6]

Regarding the international empirical literature, studies which incorporate countries that do not trade or do FDI with each other are rare in the international literature, with

[5]He calibrates the model to trade flows and growth rates. He shows that calibrating Eaton-Kortum model to match observed trade flows delivers very low growth rates for OECD countries. Conversely, calibrating the model to match observed growth rates, delivers much higher trade volumes than the ones observed between OECD countries.

[6]The MP benchmark is also useful to evaluate gains from openness for most service sectors where the only way of serving foreign markets is by setting up local operations.

the notable exception of Helpman, Melitz and Rubinstein (2004), Hallak (2005), Silva and Tenreyro (2005), for trade, and Razin, Rubinstein and Sadka (2003), for FDI. Those papers also incorporate zero trade or FDI flows but they deal with the biases present in linear estimates of gravity equations, in a different way from this paper.

The paper is organized as follows. Section 2 presents the stylized facts on MP. 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. 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

	Value at Current Prices (billions of dollars)				Growth (per cent)
	1982	*1990*	*2001*	*2004*	*82-04*
World GDP	11,758	22,610	31,900	40,960	5.6
World sales of foreign affiliates	2,765	5,727	18,517	20,986	9.2
as % of world GDP	24	25	58	51	
World exports*	2,247	4,261	7,430	11,196	7.3
as % of world GDP	19	18	23	27	
World exports of foreign affiliates	730	1,498	2,600	3,733	7.4
as % of sales of affiliates	26	26	14	18	

(*): goods and non-factor services.

Table 1: World International Production and Trade. Source: UNCTAD (WIR, 2006).

multinational firms, and exports, for the period 1982-2001. While world exports have represented between 19% and 27% of world GDP during these period, total sales of foreign affiliates of multinational firms have increased from 24% of world GDP in 1982, to 51% in 2004. Moreover, over the period 1982-2004, while GDP and exports grew at an average annual rate of around 6% and 7%, respectively, sales of foreign affiliates did it at more than 9% per year. Meanwhile, the share of world exports of affiliates in world sales of affiliates, has been decreasing in the last two decades, reaching 18%, in 2004. These magnitudes suggest that not only multinational 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 multinational production (MP). 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. (Data details are in Appendix A).

In what follows, let country-pairs be classify according to their MP 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 relationship with each other. I consider that country j has MP 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 a MP relationship. In particular, 77% of all possible country-pairs do not engage in any MP activity. [7] Table 2 also shows that,

Country-pairs with:	$X_{ij} > 0$ $X_{ji} > 0$	$X_{ij} > 0$ $X_{ji} = 0$	$X_{ij} = 0$ $X_{ji} = 0$
Mean sales of foreign affiliates*	8,015	86	0
Mean bilateral distance (in km)	5,862	7,028	7,504
% of country-pairs with common language	14.3	13.3	14.1
% of country-pairs with common border	8	3	2
% of country-pairs ever in colonial relationship	5	2	1
Mean bilateral corporate tax rate	16.8	26.3	34.1
Mean GNP*	728,764	355,964	82,890
source country j		614,778	
host country i		95,688	
Number of country-pairs	2,404	2,812	17,434
% of country-pairs	**11**	**12**	**77**

(*): millions of current U$. X_{ij}: sales of firms from country j in country i.

Table 2: Bilateral Multinational Production and FDI. Means.

on average, the bulk of MP activities occurs among country-pairs that have positive MP volumes in both direction; sales of foreign affiliates are much smaller for country-pairs with positive volumes in only one direction.

The gravity approach suggests that bilateral volumes of MP are a multiplicative func-

[7] The comparable figure for international trade is around 50% (see Helpman, Melitz and Rubinstein (2004)).

tion of trading partners' sizes, dampened by barriers. One widely used variable for barriers is geography. Table 2 shows that the average distance among the group of country-pairs with no MP 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 MP. Unexpectedly, sharing a language does not seem to be a factor that promotes international production. Finally, average bilateral corporate tax rates are substantially lower among country-pairs with positive flows than among the ones with zero MP activities (16% against 34%).

Lastly, Table 2 suggests that MP mainly takes place among large countries in terms of GNP, and from large to small countries. The lack of this kind of flows is mainly observed among small economies, and from small to large economies. In fact, country-pairs with positive volumes of MP in both directions involve countries with average GNP of almost 729 billions of dollars, almost four times larger than the world average GNP. Among country-pairs with MP 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 MP in both directions are mostly small countries with an average GNP of around 83 billions of dollars, less than half the world average.

Indeed, the evidence in Table 2 suggests that size in terms of income and geography are important factors in explaining the existence, allocation and volumes of MP activities across countries.

3 Model

I introduce the decision to replicate production abroad in a competitive, multi-country model with fixed costs to multinational activities, close to Eaton and Kortum (2002). Firms in a given industry decide whether to open affiliates abroad, and where to locate them. Once established in a host market, affiliate plants carry production using local labor, and sell output exclusively there. Regardless of the country of destination, affiliate plants can replicate the productivity levels of their parent firm. However, to transfer such productivity level, firms face a fixed cost. A plant's technology is then defined by both productivity (which are industry-country specific) and a fixed costs (which are country-pair specific). This technology along with decreasing returns to scale delivers U-shaped average cost curves, that, in a given host industry, differ across plants of different origins. With free-entry, the technology with the lowest minimum average cost is used. Hence, at the industry level, the model displays constant returns to scale with flat supply curves. This turns out to be a standard Marshallian industry model where the supply side determines who serves the market and prices, and the demand side determines the size of the industry. Figure 1 illustrates the basic mechanism of the model for a given industry in a host country i, and three potential source countries k, i (i.e. local suppliers), and j, in which country j that has the best technology ends up supplying country i. This model highlights the role of absolute advantage in determining the allocation of MP across countries. Since technologies are replicable in foreign industries through MP, and production in affiliate plants is done by employing local inputs, only efficiency matters in determining which technology is used, not wages. Finally, the model delivers a structural equation for sales of affiliates from country j in country i that relates volumes to the size

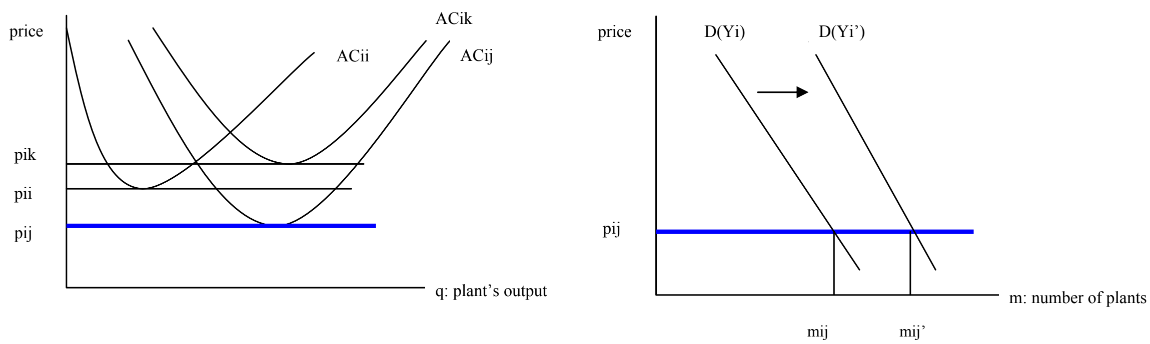

Figure 1: A: Industry supply with MP. B: Industry equilibrium with MP. i : host, j : source

of country i, technology of of country j, and the cost of access the host market, and allows for zero volumes between some country-pairs.

I present the basic set up, and the equilibrium where MP is allowed.

3.1 Set up

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. MP 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 home company, carry production hiring local labor, sell output exclusively in the host market, and eventually repatriate profits (in units of the homogenous good).

Technology. There is a continuum of plants in the production of each good ω that behaves competitively. Each plant operates under a decreasing returns to scale production function of the form:

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

where $\alpha < 1$, $q_{ij}(\omega)$ is output produced and $s_{ij}(\omega)$ labor required by a plant from country j in country i. The parameter $z_j(\omega)$ is stochastic, specific to plants from country j that produce good ω. In each country i, the productivity parameter $z_i(\omega)$ is randomly drawn across symmetric goods from a density function $\phi_i(z_i)$ with *bounded* support, $[\underline{z}, \bar{z}]$. In particular, define $z_i \equiv x_i^{-\theta}$ where x_i is distributed exponential:[8]

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

and $x_i \in [\underline{x}, \bar{x}]$. Since productivity is independently distributed across countries, the density function for the vector $z(\omega) = [z_1(\omega), z_2(\omega), ..., z_n(\omega)]$ is:

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

where $z \in \mathbf{Z} = [\underline{z}, \bar{z}]^n$. This stochastic representation of productivity is similar to Eaton-Kortum (2002) and Alvarez and Lucas (2006).

[8]The parameter $\theta > 0$ is necessary for the existence of the integral when $x \in [0, \infty]$.

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:

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

where $\eta > 1$ is elasticity of substitution. The parameter μ is the 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 Q_i:

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

The aggregate demand for Q_i is given by the expenditure condition $L_i P_i Q_i = \mu Y_i$, where Y_i is income in country i.

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 z. From now on, I refer to "good z" instead of "good ω", where z is the vector of productivity draws across countries $(z_1, z_2, ..., z_n)$. The aggregate good in equation (4) and the price index in (6) is rewritten as:

$$
\begin{aligned}
Q_i &= [\int_{\mathbf{Z}} q_i(z)^{\frac{\eta-1}{\eta}} \phi(z) dz]^{\frac{\eta}{\eta-1}}, \qquad (7)\\
P_i &= [\int_{\mathbf{Z}} p_i(z)^{1-\eta} \phi(z) dz]^{\frac{1}{1-\eta}} \qquad (8)
\end{aligned}
$$

and the production function in equation (1) as:

$$q_{ij}(z) = z_j s_{ij}(z)^{\alpha}. \qquad (9)$$

Bilateral fixed cost. There is an unbounded pool of potential entrants into the production of good z. An affiliate plant from country j producing good z in country i has to pay a fixed cost, t_{ij} (in units of the homogenous consumption good). This cost is country-pair specific and can be thought as the costs of forming the subsidiary, and adapting the foreign technology to the local environment. Local plants also bear a fixed cost, denoted by t_{ii}, that can be thought as an overhead cost of production.

Given the vector $z = [z_1, z_2, ..., z_n]$, potential entrants decide whether to enter the production of good z, 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 z, is denoted by $m_{ij}(z)$.

3.2 Equilibrium with Multinational Production

Each country i has the structure described above, with preferences and technology parameters, ρ, η, μ, θ, and α, common across countries. Given $z = [z_1, z_2, ..., z_n]$, a producer from country j opens a plant in country i as long as profits are at least as high as the fixed cost:

$$\pi_{ij}(z) \geq t_{ij} \tag{10}$$

where $pi_{ij}(z)$ is the profit function. [9] Since there is an unbounded pool of potential entrants and free entry, in equilibrium, (10) holds with equality. The price for good z at which new plants from country j break even in country i is:

$$p_{ij}(z) = \gamma_0 \cdot w_i^{\alpha} \cdot t_{ij}^{1-\alpha} \cdot \frac{1}{z_j} \tag{11}$$

for all i, j, where γ_0 is a constant.[10] There are n source countries of potential suppliers of good z, but consumers buy from the cheapest one. Hence, the price for good z in country i is the minimum price among all potential sources that satisfies (11):

$$p_i(z) = \gamma_0 \cdot w_i^{\alpha} \cdot \min_j \{t_{ij}^{1-\alpha} \cdot z_j\}. \tag{12}$$

From (12), it is clear that prices are fully determined by the supply side of the economy: productivity z, costs t, and wages w (see Figure 1).

Under which conditions the model generates zero MP? Let B_{ij} be the set of goods z produced in country i by affiliate plants of firms from country j, defined by:

$$B_{ij} = \{z \in \mathbf{Z} : p_{ij}(z) < p_{ik}(z) \text{ for all } k \neq j\}, \tag{13}$$

[9] $\pi_{ij}(z) = \max_{s_{ij}(z)} p_i(z) z_j s_{ij}(z)^{\alpha} - w_i s_{ij}(z)$, for all i, j, where z_j is the productivity draw for good z specific to firms from country j, and $p_i(z)$ is the price for good z in country i.

[10] $\gamma_0 \equiv (\frac{\alpha}{1-\alpha})^{1-\alpha} \frac{1}{\alpha}$.

or equivalently:

$$B_{ij} = \{z \in \mathbf{Z} : \frac{z_j}{t_{ij}^{1-\alpha}} > \frac{z_k}{t_{ik}^{1-\alpha}} \text{ for all } k \neq j\}. \tag{14}$$

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

$$\frac{\overline{z}}{t_{ij}^{1-\alpha}} > \frac{\underline{z}}{t_{ik}^{1-\alpha}} \tag{15}$$

for *all* $k \neq j$. When this condition is not satisfied, no firm from country j produces in i.

Hence, in each country i, goods are supplied by either foreign or local plants, but not both, and all goods are produced (i.e. $\cup_j B_{ij} = \mathbf{Z}$). However, due to country-pair specific costs, goods are not necessarily produced by plants from the country with the best productivity draw z; plants from different countries might produce the same good in different parts of the world. Moreover, some countries might not produce any good in some countries, generating zero MP.

Note that the comparison in (14) does not involve source country wage w_j, as standard trade models do. Since country-specific technologies are replicable in foreign countries through MP, and production in affiliates is done by employing local labor, only efficiency matters in determining which technology is used in country i, not wages. In this sense, while the allocation of trade in goods is driven by comparative advantage, the allocation of trade in technologies, or ideas, is driven by absolute advantage.

Bilateral sales of affiliate plants. The total value of sales of affiliates from country j

in country i, is given, in equilibrium, by[11]:

$$X_{ij} = \begin{cases} \mu \cdot \int_{B_{ij}} (\frac{p_i(z)}{P_i})^{1-\eta} \cdot Y_i \cdot \phi(z) \cdot dz \text{ if } B_{ij} \neq \varnothing \\ \\ 0 \text{ if } B_{ij} = \varnothing \end{cases} \tag{16}$$

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

$$P_i^{1-\eta} = (\gamma_0 w_i^{\alpha})^{1-\eta} \sum_j \int_{B_{ij}} t_{ij}^{(1-\alpha)(1-\eta)} \cdot z_j^{\eta-1} \cdot \phi(z) \cdot dz \tag{17}$$

Plugging $p_i(z)$ from (12) and P_i from (17) in (16), yields:

$$X_{ij} = \mu \cdot \frac{t_{ij}^{(1-\alpha)(1-\eta)} \lambda_j \Gamma_{ij}}{\sum_k t_{ik}^{(1-\alpha)(1-\eta)} \lambda_k \Gamma_{ik}} \cdot Y_i, \tag{18}$$

and $X_{ij} = 0$ for $B_{ij} = \varnothing$. The expression $\lambda_j \Gamma_{ij}$ is defined by:

$$\lambda_j \Gamma_{ij} \equiv \int_{B_{ij}} z_j^{\eta-1} \phi(z) dz.$$

The variable Γ_{ij} mirrors the one in Helpman, Melitz and Rubinstein (2004). Here Γ_{ij} depends on *all* (relative) fixed costs in country i, $\{t_{ij}/t_{ik}\}_{k \neq j}$, as well as mean productivities, $(\lambda_1, ..., \lambda_n)$, and the support bounds, $\underline{z}$ and $\bar{z}$. 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

[11]Besides sales, employment, assets, and the number of affiliate plants of firms from country j in i, could be considered as measures of MP. Bilateral employment from country j in i is $S_{ij} = (\alpha/w_i)X_{ij}$; the bilateral number of affiliate plants is $m_{ij} = ((1-\alpha)/t_{ij})X_{ij}$; and the bilateral value of assets is given by the value of installed plants from country j in i, $a_{ij} = t_{ij} m_{ij} = (1-\alpha)X_{ij}$. The assumption on decreasing returns to scale is the one giving additional implications regarding these extra variables

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 might 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 MP 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, equation (18) relates the bilateral sales of from country j in i to the "importer" size, Y_i, "exporter" technology, λ_j, and costs to access the importer's market, t_{ij}. The higher Y_i or λ_j, the larger X_{ij}; the higher t_{ij}, the lower X_{ij}.

In the next section, costs t_{ij} will be related to geography and other (observable and unobservable) bilateral variables. Hence, equation 18 *qualitatively* captures the observed cross-country patterns of MP presented in Section 2.

4 Empirical framework

Equation (18) relates bilateral sales of foreign affiliates to characteristics of the source country, host country, and costs of MP; zero sales are also possible between some country-pairs.

Define $T_{ij} \equiv t_{ij}^{(1-\alpha)(\eta-1)}$. Rearranging terms and taking logs, equation (18) becomes:

$$\ln \frac{X_{ij}}{Y_i} = \ln \mu + \ln \lambda_j - \ln[\sum_k \lambda_k \Gamma_{ik}/T_{ik}] - \ln T_{ij} + \ln \Gamma_{ij} \tag{19}$$

for $\Gamma_{ij} > 0$. The cost parameter T_{ij} has observable and unobservable components. Following the gravity trade literature, I relate it to observable variables such as geography, language, colonial past, and corporate taxation, as well as to unobservable frictions that are country-pair specific, and denoted by ϵ_{ij}. I assume the following functional form:

$$\ln T_{ij} = \delta_d \ln d_{ij} - \epsilon_{ij} \tag{20}$$

for $i \neq j$, where d_{ij} is an observable variable, easily extended to be a vector, and ϵ_{ij} is unobservable, i.i.d. across country-pairs, and normally distributed with mean zero and variance σ^2. Notice that T_{ii} cannot be approximated by the observable variables used for T_{ij}. Hence, I set T_{ii} to be a fraction τ of the minimum cost faced by foreign firms in country i:

$$T_{ii} = \tau \cdot \min_{j \neq i} \{T_{ij}\}. \tag{21}$$

. Replacing (20) in (19), for $j \neq i$, yields:

$$\ln \frac{X_{ij}}{Y_i} = \ln \mu + S_j - H_i - \delta_d \ln d_{ij} + \ln \Gamma_{ij} - \epsilon_{ij} \tag{22}$$

for $\Gamma_{ij} > 0$, where $S_j \equiv \ln \lambda_j$, and $H_i \equiv \ln[\sum_k \lambda_k T_{ik}^{-1} \Gamma_{ik}]$. Equation (22) looks much as a gravity equation traditionally estimated through OLS using only positive flows, and two sets of country fixed effects. The first difference that equation (22) 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 (relative) costs of MP in country i, $\{T_{ij}/T_{ik}\}_{k \neq j}$, transforming equation (22) in a non-linear function of the coefficient δ_d, and error terms ϵ_{ij}. When $\ln \Gamma_{ij}$ is not included as a regressor, an omitted variable bias is generated; the OLS estimate of the coefficient on d_{ij}, can no longer be interpreted as an estimate of δ_d. The second difference is that, considering positive flows only, the error term in 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 MP are likely to have low unobservable barriers (high ϵ_{ij}), inducing a downward bias in the OLS coefficient on d_{ij}. The OLS bias is evaluated below.

4.1 Estimation procedure

The goal is to quantify the model to calculate welfare gains of changing the costs of MP. As shown in the previous subsection, when information on zero volumes is disregarded, and there are bilateral costs of MP 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 a simulation-based indirect inference procedure to estimate the parameters of the model. The indirect inference estimator is the one that minimizes the distance between a vector of moments computed from the actual and simulated data. 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:[12]

$$\Delta^* = \arg\min_{\Delta} \, [\rho_d - \frac{1}{H}\sum_{h=1}^{H}\rho_s^h(\Delta)]'\hat{\Omega}[\rho_d - \frac{1}{H}\sum_{h=1}^{H}\rho_s^h(\Delta)] \tag{23}$$

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 matrix $\hat{\Omega}$ is the optimal weighting matrix.

In particular, I choose the vector Δ to be a subset of the parameters of the model:

$$\Delta = [\delta_d, \sigma^2, \tau, \underline{z}, \kappa]$$

where δ_d is the coefficient of the observable component of costs in equation (20); σ^2 is the variance of ϵ_{ij} in equation (22); τ is defined by equation (21); and $\underline{z}$ is the lower bound of the productivity support. The vector of technology parameters across countries $(\lambda_1, ..., \lambda_n)$ is not observable. I calibrate it to countries' TFP's, relative to the United States. [13] The parameter κ is a scale parameter:

$$\lambda_i = \kappa \frac{TFP_i}{TFP_{us}}$$

Besides dimensionality problems in the numerical computations, I choose these parameters to be in Δ because they are the ones that govern the magnitude of MP costs, as well as the allocation and volume of MP across countries in the model.

[12] The indirect inference estimator Δ^* is consistent under the assumptions in Gourieroux, Monfort and Renault (1993). The minimized value of (23) is distributed $\chi^2(p-q)$.

[13] I am very grateful to Torsten Persson that provided me with these data.

I set the remaining model parameters at the values summarized in Table 3.[14] The parameter μ is the expenditure share in the aggregate good. Since I calibrate it to the observed average sales of foreign affiliates (as share of host country's GNP), for selected developed economies, it can be thought as a lower bound.[15] The moments to match

Parameter	Value	Definition	Source
η	3.1	elasticity of substitution	Broda-Weinstein
μ*	0.5	$U = c^{1-\mu} Q^{\mu}$	UNCTAD
θ	4	$z \equiv x^{-\theta}$	Eaton-Kortum
$\overline{z}$	1.778	upper bound of productivity support	normalization
Y_i	GNP_i	GNP for country i	WDI
H	1	number of simulations	

(*): average sales of foreign affiliates in a host economy, as share of GDP: United States, Ireland,Czech Rep., Finland, Germany, Hungary, Sweden, Netherlands, Poland, Slovenia, Canada.

Table 3: Calibrated parameters of the model.

are chosen to properly capture the empirical patterns of the allocation and volume of MP across countries. I first divide the sample of country-pairs in three groups: pairs with $X_{ij} > 0$ and $X_{ji} > 0$; pairs with $X_{ij} = 0$ and $X_{ji} > 0$; and pairs with $X_{ij} = 0$ and $X_{ji} = 0$. The vector of moments contains the following statistics for each group of country-pairs: fraction of country-pairs in each group; mean values of observable cost components; mean

[14] Notice that the parameter α, i.e. the degree of returns to scale, is not identified using sales data only; data on bilateral number of plants, employment, or assets are needed.

[15] The parameter μ could be estimated assuming that it is host-country specific rather than common across countries. In particular, it could be a function of observable (and unobservable) variables, such as governance and human capital levels in the host country. This is also the way of incorporating host-country fixed effects into the estimation.

bilateral sales of foreign affiliates; mean GNP and mean TFP, for each group of country-pairs, and for source and host countries in the group of country-pairs with one-way MP. Additionally, I include the OLS coefficients of the following "gravity" equation:

$$\ln \frac{X_{ij}}{Y_i} = a + a_d \ln d_{ij} + \tilde{H}_i + \tilde{S}_j + e_{ij}, \tag{24}$$

for $X_{ij} > 0$, where $\tilde{H}_i$ and $\tilde{S}_j$ are host and source country fixed effects, respectively, and the error term e_{ij} has variance σ_e^2.

To compute the moments, I use data on bilateral sales of affiliates (actual and simulated) and observable measures of cost components for each country-pair in the sample, as well as data on GNP and TFP measures for each country in the sample.[16]

The indirect inference method focuses on some moments of the data, rather than the whole joint distribution. In particular, I focus on the moments highlighted by the stylized facts in Section 2, that are informative about the parameters of the model. An alternative to indirect inference is a maximum likelihood procedure that requires one to write down the likelihood function from the set of conditional probabilities that the model dictates. Alternatively, a two-step procedure that corrects for the selection of country-pairs into MP partners could be derived, similarly to the procedure derived for trade flows in Helpman, Melitz, and Rubinstein.[17] However, a two-step procedure would recover the parameters of the "gravity" equation, δ_d, but not the other parameters of the model necessary to perform welfare analysis; that is why the structural approach is needed.

[16]Table 13 in the Appendix summarizes the moments calculated from the actual and simulated data at the optimal model parameters' value.

[17]The complex structure of the variable Γ_{ij}, a multivariate truncated distribution that depends on the entire vector of bilateral barriers in country i, makes both maximum likelihood and two-step methods hard to apply.

5 Estimates

The following variables are used as the observable components of the cost of MP T_{ij}: bilateral distance d_{ij}, common border δ^c_{ij}, common language δ^l_{ij}, colonial ties δ^{col}_{ij}, and corporate tax rates applied to firms from country j in i, τ_{ij}. [18] Equation (20) ends up being:

$$\ln T_{ij} = \delta_d \ln d_{ij} - \delta_\tau \ln(1-\tau_{ij}) - \sum_{s=c,l,\text{col}} \delta^s_{ij} \ln b_s - \epsilon_{ij}.$$

where $\delta^{'}_{ij}$s are dummy variables. Table 4 shows estimates of the model parameters, by

Parameters	Estimates				Variable
	All countries		OECD countries		
	IIE	OLS	IIE	OLS	
δ_d	0.56**	1.13**	0.61	0.84**	bilateral distance
$\ln b_c$	0.16	-0.1	0.21	0.62*	common border
$\ln b_l$	0.18	0.48*	0.26	0.25	common language
$\ln b_{col}$	0.56	0.84**	0.13	0.47	common colonial ties
δ_t	0.02	-0.1	0.02	-1.12	1- bilateral corporate tax rate
σ^2_ε	0.26		0.21		standard error of ε_{ij}
τ	0.59*		0.20		barriers for domestic plants
κ	0.024*		0.02		scale parameter
$\underline{z}$	0.60*		0.42*		productivity support lower bound

** significant at 10%; * significant at 1%.

Table 4: Parameters' Estimates.

indirect inference and OLS. [19] Results for the 151 countries in the sample, and only OECD

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

[19]See Table 12 in the Appendix for OLS estimates of gravity equations for MP. In particular, coefficients in columns (I) and (III) of table 12 are the ones included among the moments to match.

countries are shown. According to these estimates, bilateral distance is the most important component of the costs of MP: country-pairs twice as distant have a 56% higher cost of MP, T_{ij}, equivalent to a tax rate of 66%. Sharing a border or a language decreases the bilateral cost by 16% and 18%, respectively, while sharing a colonial past does it by 56%; tax equivalents are 17%, 20%, and 75%, respectively. Bilateral corporate tax rates have a small effect on costs: doubling them increases the fixed cost by 0.8%. Regarding the remaining estimates of the model's parameters, results in Table 4 suggest that domestic plants face a fixed cost T_{ii} that are almost two third of the cost faced by the most favored foreign plants, i.e., $\tau = 0.59$ in equation (21)).

Which are the differences between the indirect inference and OLS estimates of costs to MP? Among the 151 countries in the sample, there are 22,801 possible pairs; only 3,810 of these pairs have non-zero MP relationships, suggesting that, potentially, biases in OLS results can be severe.[20] Conversely, for OECD countries, the presence of zero MP is very small. Using OLS, doubling distance between country-pairs increases the fixed cost by 115%, while sharing a language decreases it by 48%, and sharing colonial past by 83%. The comparison with the indirect inference estimator suggests that OLS estimates are upward biased, similarly to the findings for bilateral trade flows in Helpman, Melitz, and Rubinstein (2004); the omitted variable bias seems then to dominate. Moreover, for the sample of OECD countries where there is no zero MP, the OLS estimate is systematically larger. How well does the model fit the data? Table 5 shows some correlation coefficients between actual and simulated data. The correlation between simulated and actual data on bilateral sales of affiliates from country j in i is 0.21, while the one for *total* sales of foreign

[20]A country j has no MP relationships with country i, for the period 1990-2002, if *all the six measures* of MP and FDI recorded in the data base are missing values or zeros.

	All countries	OECD countries
Correlation actual and simulated data:		
bilateral sales of affiliates:	0.21	0.19
total sales of foreign affiliates *in* country i:	0.80	0.10
total sales of affiliates *from* country i abroad:	0.16	0.05

Table 5: Goodness of fit: model and data.

affiliates *into* country i is 0.81. The model does not perform that well on the outward side: correlation between simulated and actual data for *total* sales of affiliates abroad *from* country i is 0.16. [21] In fact, Table 6 shows sales of foreign affiliates for selected economies, model and data: while for individual countries simulated inward flows match fairly well the data, outward flows are systematically underestimated, particularly, for the United States. More generally, even though the model captures fairly well the fraction of country-pairs with zero and positive MP, the mean values of the observable components of costs, and the mean value of bilateral sales of affiliates, it fails to pick features related to size.[22]

Table 6 also shows, for the world average and some selected countries, estimates of costs of MP. The average cost of MP as percentage of host country's GNP is 0.45%, ranging from 0.28% for Australia to 9.2% for Zaire. On average, foreign plants face 16 times higher costs than domestic plants, ranging from 7 times for Australia to 78 times for Zaire!

[21] These two correlation are illustrated in Figure 2 and 3 in the Appendix.

[22] Table 13 in the Appendix shows the moments calculated with the actual and simulated data for estimates in Table 4.

	Fixed Costs[a]		Sales of foreign affiliates (*in billions of US$*)			
	% of host	ratio foreign	Model		Data	
	country's GNP[b]	to domestic[c]	inward	outward	inward	outward
World	10	17	35.9	35.9	40.47	54.8
United States	5.6	16	988.2	59.34	1,526	1,519
Japan	10.4	9.8	987.5	10.3	245.6	671.1
Germany	7	27	331.9	90.71	676.9	694.9
Australia	13	7	104.7	4.09	103.6	34.9
Brazil	16	6	194.7	2.28	107.9	5.26
Congo	4	112	0.17	2.19	0.69	n/a

$\left({}^{a}\right)$: $t_{ij} \equiv T_{ij}^{\frac{1}{(1-\alpha)(\eta-1)}}$ where $\alpha = 0.55$. $\left({}^{b}\right)$: $\sum_{j \neq i} t_{ij} m_{ij}/Y_i$. $\left({}^{c}\right)$: $\overline{t_{ij}}/t_{ii}$.

Table 6: Cost of MP, and MP volumes, world average and selected economies.

5.1 Welfare gains of Multinational Production (MP)

The estimation above provides parameters' values to quantify the model, and pursue welfare analysis. Welfare in country i is measured by real income Y_i/P_i^{μ}.[23] Since total labor supply L_i and wages w_i are fixed in country i, total income Y_i, in terms of the numeraire good, is also fixed. Therefore, changes in welfare are only due to changes in the price index P_i, given by (17):

$$\ln \frac{W_i'}{W_i} = -\mu \ln \frac{P_i'}{P_i} \tag{25}$$

where P_i' denotes the counterfactual value.

Proposition 1. *For each country i, the price index under MP, P_i^{MP}, is lower than (or*

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

equal to) the price index under autarky, P_i^{AUT}.

Proof.[24] Let P_i^{MP} be given by (17), and rewritten as:

$$(P_i^{MP})^{1-\eta} = (\gamma_0 w_i^{\alpha})^{1-\eta} \int_{\mathbf{Z}} [\min_j \{t_{ij}^{1-\alpha} \cdot \frac{1}{z_j}]^{1-\eta} \phi(z) dz \tag{26}$$

Let P_i^{AUT} be:

$$(P_i^{AUT})^{1-\eta} = (\gamma_0 w_i^{\alpha})^{1-\eta} t_{ii}^{(1-\alpha)(1-\eta)} \int_{\mathbf{Z}} z_j^{\eta-1} \phi(z) dz,$$

and rewritten as:

$$(P_i^{AUT})^{1-\eta} = (\gamma_0 w_i^{\alpha})^{1-\eta} \int_{\mathbf{Z}} [t_{ii}^{1-\alpha} \cdot \frac{1}{z}]^{1-\eta} \phi(z) dz \tag{27}$$

It follows that $t_{ii}^{1-\alpha} \cdot \frac{1}{z_i} \geq \min t_{ij}^{1-\alpha} \cdot \frac{1}{z_j}$. Comparing (26) and (27), $P_i^{MP} \leq P_i^{AUT}$.■

Table 7 presents welfare exercises. I consider the effects of: (i) moving to autarky ($t_{ij} \to \infty, i \neq j$); (ii) reducing costs of MP to a common level across foreign and domestic plants ($t_{ij} = t_{ii}$, for all $j \neq i$),in each country simultaneously ("zero-gravity"); (iii) moving only the United States to autarky; (iv) reducing costs of MP within NAFTA, for members only; and (v) reducing costs of MP within the EU, for members only. Using estimates in Table 4, for all countries, the average real income would decrease by more than 4% if each of the 151 countries in the sample moved to autarky from the baseline case. Going to a "zero-gravity" world would increase world average real income by 31%; unrealized gains of removing bilateral costs of MP seem quite large. These two estimates are higher than the ones calculated by Eaton and Kortum (2002), for OECD countries, in a model with only trade, and they seem consistent with the finding in Rodriguez-Clare (2006) that the gains from diffusion of ideas are more important in accounting for the overall gains from

[24] I owe this proof to Constantino Hevia.

	% change (average)		
	welfare	sales of affiliates	
		(inward)	(outward)
Effects of moving from baseline to:			
autarky	-4.13		
"zero-gravity"	31	89	168
United States in autarky	-0.03	-0.5	-8.8
"zero-gravity" among NAFTA members	0.15	1.7	-1.8
"zero-gravity" among EU members	3.1	12.6	-4.7

baseline: estimates from Table 4; autarky: $t_{ij} \to \infty, i \neq j$; "zero-gravity": $t_{ij} = t_{ii}$, for all $j \neq i$.

Table 7: Welfare gains of changing costs of MP, average.

openness than trade. [25] Welfare would decrease by 0.3% if the United States moved to autarky. The average effect on world welfare of lowering costs of MP within NAFTA for members only is also small, 0.15%. Conversely, the effect of lowering costs of MP within the EU for members only increases average real income in the world by 3.2%. Table 8 shows welfare gains for the United States, Mexico Canada, and the European Union (25), for the same experiments as in Table 7. Real income losses of moving to autarky would be larger for the EU, while gains of removing bilateral costs of MP world-wide ("zero-gravity") would be more than 30% for each of the countries shown. The effect on neighbors' countries if United States moved to autarky is larger for Canada than Mexico.

[25] While Eaton and Kortum (2002) calculate a loss of moving to trade autarky of -3.5% for OECD countries, I estimate a loss of -4.4% for the same set of countries, if they closed to MP. Analogously, they calculate a gain of 19.9% if OECD countries remove trade costs ("zero-gravity "), while I find a much higher gain, 30.4%, if they do so for MP. Burstein and Monge (2005), using their model of rivalrous MP, calculate a welfare gain of globally moving from autarky to "zero-gravity" that ranges from 7.8% in a model with exogenous occupational choice, to 15.1% in a model with endogenous occupational choice (see Table 5 in their paper).

	United States	Mexico	Canada	EU
	(% change in real income)			
Effects of moving from baseline to:				
autarky	-2.1	-2.8	-2.3	-4.1
"zero-gravity"	33	32	33	31
United States in autarky	-2.1	-0.01	-1.7	0.0
"zero-gravity" among NAFTA members	7.3	7.7	7.4	0.0
"zero-gravity" among EU members	0.0	0.0	0.0	21.5

baseline: estimates from Table 4; autarky: $t_{ij} \to \infty, i \neq j$; "zero-gravity": $t_{ij} = t_{ii}$, for all $j \neq i$.

Table 8: Welfare gains of changing costs of MP, selected economies.

Further liberalizing NAFTA ("zero-gravity" among NAFTA members) would be beneficial for all three members, with real income gains above 7%. There are large unrealized gains of further liberalizing MP within the EU for members only: real income would increase by almost 22%!

6 Conclusions

This paper analyzes the determinants of the cross-country allocation and volume of multinational production (MP), quantifies the size of its costs, and the impact on welfare. For that purpose, I introduce MP in a competitive, multi-country model with fixed costs, close to Eaton-Kortum's (2002). 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. Similarly to international trade theories, gravity governs positive volumes of multinational activities, modified to deliver zero bilateral flows. However, differently to model of trade in goods, this model highlights the role of absolute advantages in determining the cross-country allocation of multinational activities; while trade in goods is driven by comparative advantages, trade in technologies or ideas is driven by absolute advantages. The intuition is the following: even the best country in the world might not export all goods everywhere because higher wages deter this possibility; however, the link between wages and technology is broken for MP flows because firms can replicate their technology in the host country, and operate it there using local labor.

Using new data on the activities of foreign affiliates at the country-pair level, I quantify the costs of MP, and evaluate welfare gains from opening to MP. I specifically concentrate on bilateral sales of affiliates, but the availability of several bilateral measures of MP activities allows me to accurately construct the sample of country-pairs with no MP relationships. I use a simulation-based procedure to estimate the model, including information on both country-pairs with zero as well as positive bilateral multinational activities.

It turns out that geographical distance between country-pairs is the most important impediment to MP: country-pairs twice as distant face a 56% higher cost than otherwise.

Welfare gains of lowering the cost to MP are large: more than 30% increase in real income for the average country. Moreover, if the EU further liberalized multinational activities among its members, it would experience an increase in real income of 22%. Conversely, welfare losses of moving to autarky are more than 4% of average real income. These numbers are higher than the ones calculated by Eaton and Kortum (2002) for trade in goods, and are consistent with the finding in Rodriguez-Clare (2006) that the gains from diffusion of ideas are much more important in accounting for overall gains from openness than trade. Certainly, MP can be thought as one important mechanism through which technologies and ideas diffuse across countries.

The importance of distance for the location of MP might be indicating a complex relationship between trade and MP flows. Theories where trade and MP are substitutes would predict that more MP should be observed for countries further away. However, both trade and MP decrease with distance, pointing out to a complementary between these two flows, at least for some country-pairs. [26] Indeed, a theory in which trade and MP interact, not only as substitutes, is the next step to pursue. This paper contributes to that line of research by presenting a tractable framework to analyze and quantify the determinants and impediments of international production across countries. It is a new and insightful benchmark that complements trade models to evaluate gains from openness.

[26] Helpman, Melitz and Yeaple (2004) as well as Brainard (1997) find that the *ratio* of exports to sales of affiliates decreases with distance, meaning that exports decrease more than MP. See also Markusen and Venables (1998).

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A Data

The procedure to estimate the model requires data on bilateral measures of MP, measures of the observable components of bilateral costs, and data on GNP. Table 9 summarizes data sources for each variable; Table 10 presents descriptive statistics; and Table 11 lists the countries in the sample. Contrary to international trade data, there is no systematic database for **bilateral** measures of MP. I assemble a data set that includes six different measures of bilateral MP and FDI, using as main sources UNCTAD and OECD.[27] I record data on FDI flows and stocks from country j to i as measured in the Balance of Payment of a country, and data on four 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. For data on the activity of foreign affiliates, the sample of countries that are source of information drops to no more than 65, and the number of years for which data is available also shrinks. I restrict the analysis to an average of available years from the period 1990-2002. I end up with a sample of 147 (150) countries observed as source (host) countries, for at least one of the measures recorded in the database. Most of the countries record both outward and inward FDI and MP. Thus, I first consider inward magnitudes reported by a given country, and complete with outward magnitudes reported by a partner

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

countries. 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 stocks follows the definitions from the IMF Manual of Balance of Payment Statistics. These two variables are comparable across countries. 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. 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. [28] As the observable components of MP costs, I include: bilateral distance, common border, common language, and common colonial past (ever in a colonial relationship), and bilateral corporate tax rates for foreign firms. 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. Corporate tax rates are computed from tax rates applied to foreign corporations from country j in 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 tax rates for foreign firms, is assigned the average tax rate in country i for foreign plants with preferential treatment. Country-pairs without a treaty and missing values for bilateral tax rates are assumed to be subject to the same corporate tax rate as domestic plants.

Data on countries' GNP are nominal values, converted to US current dollars, not on purchasing power parity basis.

[28] These countries are highlighted in Table A.2.

Variables	**Sources**
Sales, employment, assets, number of affiliates, FDI Stocks, and FDI Flows	*FDI database for individual countries, UNCTAD (published and unpublished data)* *International Direct Investment Database, OECD*
Gross National Product (current dollars)	*WDI, World Bank; IFS, IMF*
TFP (current dollars)	*Torsten Persson's data set*
Distance; Common Language; Common Border; Colonial Ties	*Centre d'etudes prospectives et informations internationales (CEPII) (www.cepii.fr/anglaisgraph/bdd/distance.htm)*
Bilateral Corporate Tax Rates	*World Tax Database from U. of Michigan (www.taxanalysts.com)*

Table 9: Data Sources.

	Mean	Std. Dev.	Obs.
Bilateral distance (km)	7,270	4,204	22,650
% of country-pairs with common language	14	0.35	22,650
% of country-pairs with common border	2.4	0.15	22,650
% of country-pairs with colonial ties	1.3	0.11	22,650
Bilateral corporate tax rates	31	12	22,650
Sales of affiliates: all possible country-pairs	289	5,736	19,684
Sales of affiliates: country-pairs with $X_{ij} > 0$	6,718	26,896	846
GNP (millions of current dollars)	185,494	767,575	22,650
TFP (current dollars)	4,417	2,449	22,650

Table 10: Summary Statistics.

Country	source	host	Data source for:				
			FDI	sales	assets	employ.	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	

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

Table 11: List of countries, by observed source/host status, and data availability.

Country	source	host	Data source for:				
			FDI	sales	assets	employ.	plants
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					
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				

Table 11 continued

Country	source	host	Data source for:				
			FDI	sales	assets	employ.	plants
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
Portugal	X	X	X	X		**X**	**X**
Puerto Rico	X	X					
Romania	X	X					

Table 11 continued

Country	source	host	Data source for:				
			FDI	sales	assets	employ.	plants
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
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					
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					

Table 11 continued

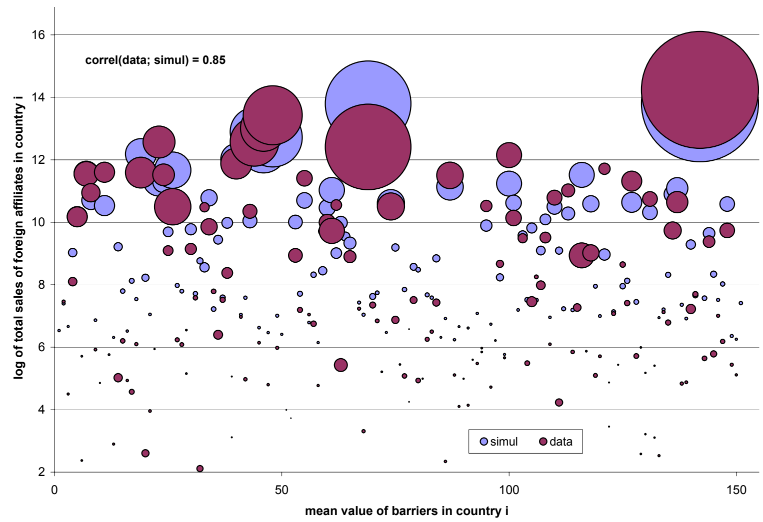

Figure 2: Sales of foreign affiliates and estimated fixed costs, by host country: actual and simulated data (size of bubble is proportional to host country's GNP)

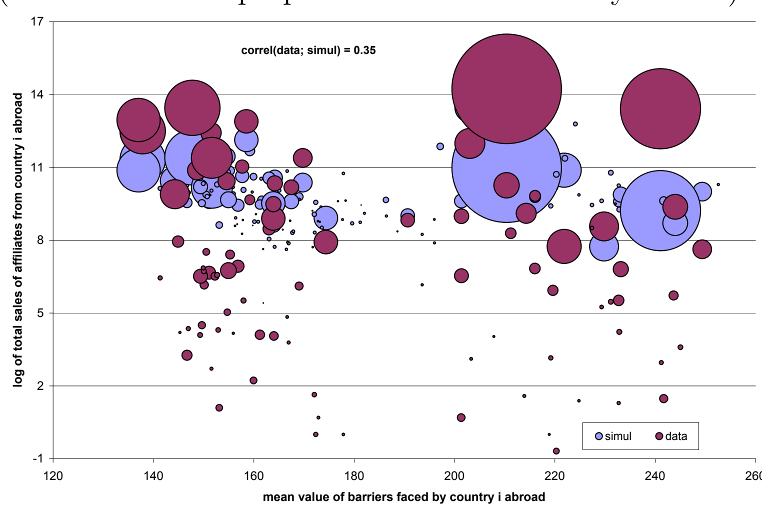

Figure 3: Sales of affiliates abroad and estimated fixed costs: actual and simulated data (size of bubble is proportional to source country's GNP)

Dependent Variable:	Bilateral sales of affiliates			
	All countries		OECD countries	
	I	*II*	*III*	*IV*
log of bilateral distance	-1.13	-1.15	-0.85	-0.84
	[0.09]**	[0.11]***	[0.13]**	[0.13]**
1 for pairs with common official language	0.48	0.49		0.25
or > 20% pop. same language	[0.22]*	[0.24]**		[0.27]
1 for pairs ever in colonial relationship	0.83	0.85		0.47
	[0.28]**	[0.27]***		[0.31]
1 for pairs with a common border		-0.1	0.81	0.62
		[0.34]	[0.26]**	[0.27]*
log of (1- bilateral corporate tax rates)		-0.10		-1.12
		[0.53]		[0.79]
Observations	846	846	396	396
R-squared	0.86	0.86	0.82	0.82

Standard errors in brackets. * significant at 5%; ** significant at 1%. All specifications with constant, source, and host country fixed effects. Dependent variable is sales of affiliates from country j in i, in logs, as share of country i's GNP. Country-pairs with $X_{ij} > 0$

Table 12: Traditional Gravity for MP. All and OECD countries. OLS.

Parameters	All Countries		OECD countries		Definition
	ρ_d	$\rho_s(\Delta^*)$	ρ_d	$\rho_s(\Delta^*)$	
a_d	-1.13**	-2.00**	-0.85**	-1.52	OLS bilateral distance
a_c	-	-	0.81**	0.98	OLS common border
a_l	0.48*	0.58**	-	-	OLS common language
a_{col}	0.83**	1.87**	-	-	OLS common colonial past
σ_e^2	1.32	1.19	1.24	1.44	Variance of OLS error term
d_0	5,862	2,805	5,232	1,734	mean distance
c_0	0.08	0.14	0.09	0.24	common border
l_0	0.14	0.33	0.10	0.13	common language
col_0	0.05	0.05	0.04	0.07	common colonial past
t_0	17	29	12	12	mean corporate tax
Y_0	728,764	151,583	866,878	526,540	mean GNP
TFP_0	6,339	4,362	7,237	7,395	mean TFP
X_0	8,015	1,302	12,757	2,145	mean sales of affiliates
d_2	7,505	9,045	10,190	9,525	mean distance
c_2	0.02	0.00	0.00	-	common border
l_2	0.14	0.06	0.00	-	common language
col_2	0.01	0.001	0.00	-	common colonial past
t_2	34	32	32	13	mean corporate tax
Y_2	82,576	198,727	142,143	1,251,295	mean GNP
TFP_2	4,039	4,399	5,882	7,186	mean TFP
d_1	7,027	6,620	7,402	5,677	mean distance
c_1	0.03	0.01	0.03	0.02	common border
l_1	0.13	0.17	0.07	0.07	common language
col_1	0.02	0.01	0.00	-	common colonial past
t_1	26	31	14	13	mean corporate tax
Y_1	355,964	179,878	284,711	762,039	mean GNP
TFP_1	5,117	4,474	6,923	7,073	mean TFP
Y_1^h	95,558	228,591	216,355	763,464	mean GNP, country i (host)
Y_1^s	615,050	131,165	353,067	760,615	mean GNP, country j (source)
TFP_1^h	3,997	1,302	6,312	2,145	mean TFP, country i (host)
TFP_1^s	6,237	127	7,533	579	mean TFP, country j (source)
X_1	86	127	308	579	mean sales of affiliates
f_2	0.77	0.52	0.01	0.26	% of country-pairs
f_0	0.11	0.16	0.91	0.31	% of country-pairs
X_{ij}	308	247	11,635	915	mean sales of affiliates, all country pairs

Z_0: country-pairs with $X_{ji} > 0$ and $X_{ij} > 0$; Z_1: country-pairs with $X_{ji} > 0$ and $X_{ij} = 0$; Z_2: country-pairs with $X_{ji} = 0$ and $X_{ij} = 0$. ** significant at 1%; * significant at 5%.

Table 13: Moments: simulations ($\rho_s(\Delta^*)$) and data (ρ_d). All and OECD countries.