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A quantitative approach to multinational production

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ABSTRACT

I examine new data on the number and revenues of foreign affiliates of multinational firms across a large number of country pairs. The data shed light on the behavior of the intensive and extensive margins of multinational production (MP). To capture the patterns observed in the data, I build and calibrate a multi-country general-equilibrium model of MP that combines a Lucas (1978) span-of-control with an Eaton and Kortum (2002) type model, and includes both fixed and variable costs of opening affiliates abroad. I use the calibrated model to calculate the gains that a country would experience from liberalizing access to foreign firms. Those calculations suggest that the welfare losses of closing up to foreign firms would be around 4%, while the gains of liberalizing access to foreign firms would be large, particularly if the variable – rather than the fixed – component of MP costs were lowered.

1. Introduction

One of the most notable features of economic globalization has been the increasing importance of multinational production (MP) around the world.[1] In fact, multinational firms have become one of the most important channels through which countries exchange goods, capital, ideas, and technologies. By 2007, world sales of foreign affiliates of multinational firms were almost twice as high as world exports. Furthermore, over the past two decades, sales of foreign affiliates increased by a factor of seven, while exports increased by a factor of five (United Nations Conference on Trade and Development—UNCTAD).

A natural relevant question is: How large are the gains from hosting foreign firms? Much attention has been devoted to quantifying the gains from trade, but the gains from the activity of multinational firms could be as large, or even larger, given that we observe flows twice as large.

I start by examining new data on the number and revenues of foreign affiliates of multinational firms across a broad set of country pairs. As Eaton et al. (2011) do for French exporters, I document the importance of the extensive versus the intensive margin of multinational activities across countries, and I present evidence on how they react to geographical distance between partners, and to host- and source-country characteristics. While larger markets receive (and send) more and larger foreign affiliates, on average, distant markets receive fewer and smaller foreign affiliates. The extensive margin, however, reacts disproportionately more than the intensive margin to changes in distance and country size.

To capture the patterns observed in the data, I build a multi-country general-equilibrium model of MP that combines a Lucas (1978) span-of-control with an Eaton and Kortum (2002) type model. MP occurs in the model when a technology that originates in a foreign country is used to produce a good in the host country. But using a foreign technology for production entails a cost, one that is a combination of a variable and a fixed component.

The model is novel in that combines a Lucas (1978) span-of-control type model—which features decreasing returns to scale, fixed costs, and perfect competition—with an Eaton and Kortum (2002) type model, from which I borrow the probabilistic representation of technologies. While having firms with a limited span of control allows me to distinguish between the extensive (number of affiliates) and intensive (revenues per affiliate) margins of MP and to generate distinct predictions about them, having a probabilistic representation of technologies allows me to take the model's general equilibrium to the multi-country data. Nevertheless, as a simplification, the modeling strategy eliminates trade altogether: Affiliates use inputs and sell their output exclusively in the host country of production.

I calibrate the model to match the patterns of both revenues and number of affiliates across different country pairs. Including both fixed and variable components of the cost of engaging in multinational activities is crucial to matching the extensive and intensive margins of MP. Moreover, results indicate that the incentives to engage in foreign production vary significantly across countries. In particular, overall, MP costs are lower among rich countries than among poorer countries, which do very little MP. But the value of the fixed cost that foreign affiliates pay in richer countries is higher, as a share of the host country's GDP, than the value they pay in poorer countries. The opposite is true

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[1] I use the term "multinational production", rather than "foreign direct investment" (FDI), as most of the previous literature does, because, here, I refer to the activity of foreign affiliates, such as sales or revenues. FDI is a financial category of the Balance of Payments and, as such, is one possible channel through which affiliates finance their activities abroad.

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for the variable component of MP costs, which is much higher in poorer countries.

Finally, I use the calibrated model to calculate the gains from engaging in multinational activities. My calculations suggest that the gains in real income per capita of moving from autarky to a situation with the observed flows of multinational activity would be around 4%, reaching 5% for richer countries and 3.5% for poorer countries. The gains of liberalizing access to foreign firms would be large for all countries, but larger among the group of poorer countries than among the group of richer countries. Most of these gains come from lowering the variable – rather than the fixed – component of MP costs.

Early work by Markusen (1984) *qualitatively* analyzes the welfare effects of opening up to multinational firms in a model in which knowledge-based, firm-specific assets can be supplied costlessly within the corporation. Only recently have there been attempts to *quantify* the gains from the activity of multinational firms. Efforts in that direction include Burstein and Monge-Naranjo (2009) and McGrattan and Prescott (2009). Both papers extend the neoclassical growth model to allow for foreign production. The main difference from my framework is that theirs are suitable for analyzing the transition dynamics when countries open up to foreign firms. Even though my model is static, by using an Eaton and Kortum (2002) type model, I am able to introduce several sources of heterogeneity and, hence, to calibrate the model to the observed (gravity) pattern of MP across multiple country pairs. Another attempt to quantify the gains from multinational activity, using an Eaton and Kortum (2002) type model, is Garetto (2013). The main difference from my framework is that, while I focus on horizontal MP, she focuses on vertical MP.[2]

More generally, this paper contributes to a recent but growing literature that attempts to quantify the importance of different sources of welfare gains for countries other than trade. Even though trade is only one possible channel through which countries interact, the previous literature has typically equated the gains from trade with the overall gains from openness.[3] An exception is Ramondo and Rodríguez-Clare (2013), which introduces trade and MP into an Eaton and Kortum (2002) framework to quantify the overall gains from openness.[4] Another exception is Irarrazabal et al. (2013), which uses a Melitz-type model to evaluate the joint gains from trade and MP. In comparison with these two papers, my model features foreign firms as the only way of serving a foreign market. The gains calculated from my only-MP model, however, are a valuable benchmark to be compared with calculations coming from trade-only quantitative models.

A final remark regarding this paper's modeling strategy is in order. Most of the literature on multinational firms has introduced this type of firm into an increasing returns to scale and monopolistic competition model, rather than a decreasing returns to scale and perfect competition model, as I do here.[5] These choices, however, do not have any consequence for aggregate MP flows: A model in which firms compete monopolistically and produce under increasing returns to scale would have similar predictions in that regard.[6] A model with a limited span of control, however, seems more realistic for MP since it reflects that managerial know-how, which shapes the firm's productivity, is difficult to reproduce at the affiliate level: A manager with certain abilities can control only a limited amount of inputs to production in a given location.

Table 1
World multinational production and trade.
Source: World Investment Report, UNCTAD (2009).

	1982	1990	2001	2005	2007
World GDP in current U.S. dollars (bn)	11,758	22,610	31,900	40,960	55,114
As % of world GDP:					
World sales of foreign affiliates	24	25	58	51	58
World gross product of foreign affiliates	5	7	11	10	11
World exports	19	19	23	27	31
As % of affiliates' sales:					
world exports of foreign affiliates	26	26	14	18	19

Notes: Exports include goods and non-factor services.

2. Multinational production in the data

Multinational production (MP) – rather than international trade – has become the dominant way through which firms serve foreign consumers. Using data for the period 1982–2007, from the United Nations Conference on Trade and Development (UNCTAD), Table 1 indicates that while world exports went from 19% to 31% of world GDP during this period, total sales of foreign affiliates of multinational firms, as a share of world GDP, increased from 24% in 1982 to 58% in 2007. Gross product of foreign affiliates more than doubled, as a share of world GDP, during the same period. These magnitudes suggest that foreign affiliates of multinational firms are more important than exports as the channel through which firms choose to serve foreign consumers.

Additionally, the fact that, between 1982 and 2007, world exports of affiliates, as a share of world sales of affiliates, decreased from 26 to 19% suggests that the majority of affiliates' output is sold in the host country of production—and, hence, is not exported—and that share increased through time. In other words, "horizontal FDI," which is associated with affiliates that replicate the parents' activities and whose purpose is to serve the host country of production, seems more pervasive than "vertical FDI," which is associated with affiliates that specialize in some slice of the production chain and whose purpose is to export their output to another party within the corporation. The importance of horizontal activities by affiliates of multinational firms is in line with the evidence in Markusen (1995) and, more recently, in Ramondo et al. (2013a).[7]

Next, I explore in more detail the patterns of multinational activity by examining new data on the activities of foreign affiliates of multinational firms, for a sample of 35 countries (of which 18 are richer OECD countries), an average over 1996–2001. The data contain two key variables that allow me to document salient features of the patterns of the extensive and intensive margins of MP across several country pairs: the number and revenues of affiliates of multinational firms. Section 4 describes the data in detail.

Let M_{ni} denote the number of affiliates from i in n, $\bar{x}_{ni}$ revenues per affiliate from i in n, and X_{ni} total revenues of affiliates from i in n. Naturally, total revenue flows can be written as $X_{ni} \equiv \bar{x}_{ni} M_{ni}$, the product of the intensive and extensive margins of MP, respectively. Let X_n denote country n's GDP. Thus, revenue shares, or MP shares, from i in n are defined as $x_{ni} \equiv X_{ni}/X_n$.

[2] Horizontal MP refers to affiliates that replicate the parent's activities, while vertical MP refers to affiliates that specialize in some slice of the production chain.

[3] See, for example, Eaton and Kortum (2002), Anderson and van Wincoop (2004), Waugh (2010), Fieler (2011), and Donaldson (forthcoming), among many others.

[4] Rodríguez-Clare (2007) is another exception. He introduces international trade and international diffusion of ideas into an Eaton and Kortum (2002) model to evaluate the gains arising from both channels.

[5] Exceptions are Burstein and Monge-Naranjo (2009) and McGrattan and Prescott (2009), who, as I do, choose as their modeling strategy decreasing returns to scale-plus-perfect competition at the affiliate level. The first paper introduces managerial know-how, potentially foreign, into a Lucas's (1978) span-of-control setup in which the scarcity of managers creates a constraint that makes replication of technologies across multiple countries impossible. By contrast, McGrattan and Prescott (2009) assume that technology capital is fully replicable in each foreign location, similar to the assumption in my framework and in the early work by Markusen (1984).

[6] This is similar to the results in Arkolakis et al. (2012) about trade-only models.

[7] Using firm-level data for U.S. multinationals, Ramondo et al. (2013a) show that while it is true that intra-firm trade flows are large (particularly North–North flows) as a fraction of total trade, they represent a small fraction of affiliate sales for the median multinational firm, regardless of the destination country or the industry of operation.

Table 2
Multinational production at a glance.

	All	OECD(18)	Non-OECD(18)
Averages			
MP shares by i in n, as share of n' GDP (x_{ni})	0.009	0.019	0.001
Number of affiliates from i in n (M_{ni})	77	191	8
MP per affiliate from i in n ($\bar{x}_{ni}$)	34	60	7.7
Totals			
MP into n, as share of n' GDP ($\sum_{i \neq n} x_{ni}$)	0.30	0.32	0.011
MP from n, as share of n' GDP ($\sum_{i \neq n} X_{in}/X_n$)	0.19	0.24	0.009
Numbers			
Country pairs	1190	306	884
Country pairs with zero MP	93	2	91

Notes: MP shares by i in n are total revenues of affiliates of multinational firms from country i in n, as a share of country n's GDP. MP per affiliate from i in n refers to the ratio of total revenues of affiliates to the number of affiliates from i in n, in millions of current U.S. dollars. Total MP into (from) n refers to total revenues of foreign affiliates into (from) country n, as a share of country n's GDP.

Table 2 shows that among the 35 countries included in the sample, there are 1406 possible bilateral country pairs of which 93% have an MP relationship, with zero MP concentrated in poorer countries. Among the sub-sample of 18 OECD countries, bilateral MP flows, as a share of the host country GDP, are, on average, much higher than among non-OECD countries due to both a larger number of affiliates (i.e., the extensive margin) and higher revenues per affiliate (i.e., the intensive margin).[8] Higher *bilateral* MP shares naturally result in higher *total* shares into and from this subset of countries (0.32 and 0.24, respectively).

What is the effect of geography and market size—of both the country hosting and sending affiliates abroad—on the extensive and intensive margins of MP? This evidence will be useful for the calibration results in Section 4. In what follows, variables are in logarithms, so the observations with zero MP are ignored.

The response of the extensive and intensive margins of MP to distance and host- and source-country size can be visualized, respectively, in Figs. 1, 2, and 3. It is clear from these figures that the bilateral number of affiliates is more responsive than the average revenues per affiliate to distance and size. These results are confirmed by the ordinary least squares (OLS) estimates of the following equation:

$$logY_{ni} = a_d logd_{ni} + a_h logX_n + a_s logX_i + u_{ni}, \tag{1}$$

where Y_{ni} denotes M_{ni} and $\bar{x}_{ni}$, alternately, d_{ni} is the geographical distance between i and n, X_n denotes country n's GDP, and u_{ni} denotes all other country-pair specific factors that affect the extensive margin of MP and are orthogonal to the regressors.[9] The expression in Eq. (1) is estimated replacing X_n and X_i, respectively, by host- and source-country fixed effects, as well.[10] Table 3 shows the results.[11]

As the figures suggested, the magnitude of the OLS coefficients confirms that the extensive margin of MP is much more responsive to distance and market size than the intensive margin is. The significant negative effect of geographical distance on both margins of MP survives the inclusion of fixed effects: While a ten-percent increase in distance decreases the number of affiliates from i in n by almost 6.5% (column 1), the average revenues per affiliate from i in n decrease by only 2.5% (column 4). This implies a distance elasticity of 9% for aggregate MP flows (X_{ni}).[12]

An alternative way of presenting the relative importance of the extensive and intensive margins of MP is as Eaton et al. (2011) do for French exporters. MP flows can be written as $X_{ni} \equiv \bar{x}_{ni} M_{ni}$ or, alternately, as $X_{ni} \equiv x_{ni} X_n$, which yields the identity $\bar{x}_{ni} M_{ni} \equiv x_{ni} X_n$. With this identity in mind, the relative importance of the intensive versus the extensive margin of MP can be read from running OLS on

$$logM_{ni} = a_x logx_{ni} + a_X logX_n. \tag{2}$$

Table 4 shows that, when source-country fixed effects are considered, given the size of the destination market, X_n, a higher MP share into destination n, x_{ni}, reflects 49% more affiliates producing there (i.e., the extensive margin) and 51% more revenues per affiliate (i.e., the intensive margin), for the average country in the sample. Similarly, given MP shares into market n, x_{ni}, revenues in a larger market reflect 55% more affiliates and 45% more revenues per affiliate. While the magnitude of the coefficient on market size is similar to the one found by Eaton et al. (2011) for French exporters, the coefficient on MP shares is around half as large as theirs: Conditional on market size, the intensive margin of MP seems to be stronger than the intensive margin of trade.

3. Model

To interpret the relationships found in the data, I introduce multinational production (MP) in a multi-country general-equilibrium model that combines Lucas's (1978) span-of-control model—which entails decreasing returns to scale and fixed costs at the firm level plus perfect competition at the industry level—with the probabilistic representation of technologies from Eaton and Kortum's (2002) model of trade (henceforth, "EK"). The model explains where firms sell, how many firms enter, and how much they sell, in each destination.

In the model, MP by country i in n occurs when a technology from country i is used in country n to produce a good.[13] But using a foreign technology for production entails a cost. This cost of engaging in MP by i in n is a combination of a variable and a fixed component. There is no trade: Affiliates from country i hosted by n produce by using inputs from n and sell exclusively in n.

3.1. A Lucas-Eaton-Kortum model of multinational production

Consider a set of countries indexed by $i \in \{1,\ldots,I\}$. Country i has L_i units of labor. A continuum of goods $u \in [0,1]$ are produced in quantities $q(u)$. They aggregate into a CES composite good Q, given by

$$Q = \left(\int_0^1 q(u)^{\frac{\sigma-1}{\sigma}} du \right)^{\frac{\sigma}{\sigma-1}}, \tag{3}$$

with $\sigma > 1$.

The production function of a firm from i that produces good u in n is

$$q_{ni}(u) = z_{ni}(u) S_{ni}(u)^{\nu}, \tag{4}$$

where $0 < \nu < 1$. This production function exhibits decreasing returns to scale with the span-of-control parameter given by ν. The variable $q_{ni}(u)$ denotes output of an affiliate from i in n, and $S_{ni}(u)$ is the amount of the input bundle required for production by an affiliate from i in n, defined below.

[8] Considering only country pairs with positive MP, the average MP share goes from 0.009 to 0.0095, while the average number of affiliates goes from 77 to 83.

[9] Distance is in thousands of kilometers, from the *Centre d'Etudes Prospectives et Informations Internationales* (CEPII), and GDP is in current U.S. dollars, from the World Development Indicators, an average over 1996–2001.

[10] Regressing the source- and host-country fixed effects on the source- and host-country sizes, respectively, delivers almost identical coefficients for the size variables.

[11] The relation between MP volumes and gravity has been largely explored and documented, among others, by Carr et al. (2001), who uses affiliates' sales, and Razin et al. (2003), and Head and Ries (2008), who uses FDI stocks. None of these papers distinguish between the two margins of MP.

[12] Head and Ries (2008) find that a ten-percent increase in distance decreases bilateral FDI stocks by 12.5%, for a broad set of countries.

[13] The ability of a firm to replicate its technology across locations can be interpreted as the ability to transfer knowledge-based assets within the corporation, as in Markusen's (1984) model of horizontal FDI. See Bloom and Van Reenen (2007) for empirical evidence.

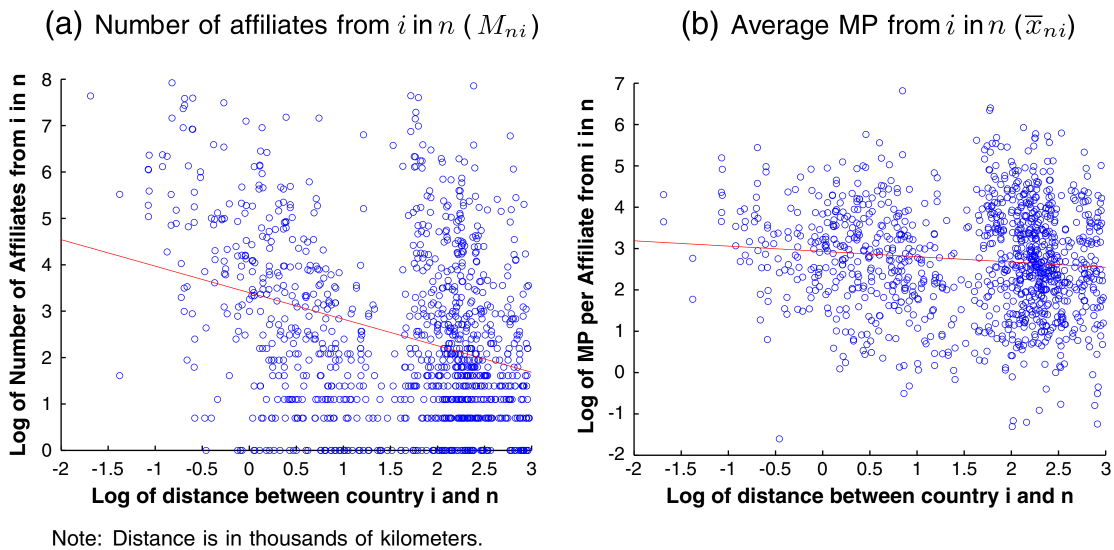

Fig. 1. Multinational production and geography. (a) Number of affiliates from i in n (M_{ni}). (b) Average MP from i in n ($\bar{x}_{ni}$). Note: Distance is in thousands of kilometers.

The variable $z_{ni}(u)$ represents the efficiency level of firms from i in n in the production of good u, and is given by $z_{ni}(u) \equiv z_i(u)\tau_{ni}$. The component $z_i(u)$ is *country- and good-specific* and represents the state of the technology for all firms in i to produce good u. The parameter τ_{ni} is *country-pair specific*, but common across goods, with $\tau_{ii} = 1$. For $n \neq i$, a lower τ_{ni} reflects a lower efficiency level of affiliates from i in n, for all goods. The variable τ_{ni} can be interpreted as a measure of openness between the two MP partner countries. The degree of openness affects the productivity of foreign affiliates from i in n: If $\tau_{ni} = 0$, then country n in completely closed to MP from i; the higher τ_{ni}, the higher the degree of openness of n to affiliates from i.

Additionally, I assume that there is a fixed cost of opening an affiliate in n by a firm from i, denoted by f_{ni}. This fixed cost can be thought as the costs of forming a subsidiary and production networks in the foreign country, as well as an overhead cost of production. Fixed costs are country-pair specific and paid by each affiliate from country i to operate in country n, in units of country n's input bundle. Notice that the model does not distinguish between affiliates and plants; thus, I assume that one affiliate equals one plant. Let c_n denote the unit cost of country n's input bundle (if labor were the only input into production, c_n would be the wage w_n).[14] Then, the value of the fixed cost is $c_n f_{ni}$. Local firms also bear a fixed cost denoted by f_{nn} and normalized to $\widetilde{N}>0$, a constant defined below.[15]

To complete the description of the environment, following EK, I assume that the efficiency parameter $z_i(u)$ is a random variable, independently drawn across goods from a Fréchet distribution with country-specific parameter T_i, and common parameter θ, $F_i(z_i) = exp(-T_i z_i^{-\theta})$, for $z_i > 0$, all i, and $\theta > max(1, \sigma - 1)$. The parameter T_i summarizes the state of technology in country i, while the parameter θ governs the heterogeneity in efficiency across the continuum of goods (i.e., lower θ, more heterogeneity). Draws are also independent across countries, so that $F(z_1, \ldots, z_I) = \prod_{k=1}^{I} F_k(z_k)$. From now on, since goods are identical except for their country-specific efficiency level, I drop the index u and label each good by the vector $\mathbf{z} \equiv [z_1, \ldots, z_I]$.

[14] One can think that labor in the host country constitutes the major part of the input bundle cost c_n, while headquarter services and managerial ability are embedded in the productivity parameter $z_i(u)$. In this sense, some productive resources come from the home country; profits would be the "remuneration" to these factors of production.

[15] Eq. (12) below makes clear that f_{nn} regulates the ratio of domestic to foreign firms into n: The lower f_{nn} is, the higher is the ratio of domestic to foreign firms. The calibration of f_{nn} would, hence, require data on the number of domestic affiliates, which I do not have. This is one of the reasons to normalize f_{nn}. Additionally, f_{nn} is not needed to solve the equilibrium of the model and for the calibration procedure, as explained below in detail.

3.2. Equilibrium analysis

There is an unbounded pool of potential entrants into the production of each good $\mathbf{z}$. Given the draw $z_i(\mathbf{z})$, potential entrants decide whether to pay f_{ni} and produce good $\mathbf{z}$ in country n by hiring local inputs. A firm from country i opens an affiliate in country n as long as (net) profits are non-negative,

$$\pi_{ni}(\mathbf{z}) = \max_{S_{ni}(\mathbf{z})} p_{ni}(\mathbf{z})q_{ni}(\mathbf{z}) - c_n S_{ni}(\mathbf{z}) - c_n f_{ni} \geq 0, \tag{5}$$

where $q_{ni}(\mathbf{z})$ is given by Eq. (4). Solving the firm's problem in Eq. (5) yields

$$\pi_{ni}(\mathbf{z}) = m(\tau_{ni} z_i(\mathbf{z}) p_{ni}(\mathbf{z}))^{\frac{1}{1-\nu}} c_n^{\frac{\nu}{\nu-1}} - c_n f_{ni} \geq 0, \tag{6}$$

where $m \equiv (1-\nu)\nu^{\frac{\nu}{1-\nu}} > 0$. In a free-entry equilibrium, (net) profits must be zero, $\pi_{ni}(\mathbf{z}) = 0$. Equivalently, the maximum price for good $\mathbf{z}$ that affiliates from i can charge in n has to be equal to the minimum unit cost of production,

$$p_{ni}(\mathbf{z}) = \frac{c_n h_{ni}}{z_i(\mathbf{z})}, \tag{7}$$

where

$$h_{ni} \equiv N \frac{f_{ni}^{1-\nu}}{\tau_{ni}}, \tag{8}$$

and $N \equiv (1-\nu)^{\nu-1}\nu^{-\nu} > 0$. The unit cost associated with MP from country i in n collapses to $c_n h_{ni}$, where h_{ni} aggregates the effects of the variable and fixed components of doing MP by i in n. With $\tau_{nn} = 1$ and f_{nn} conveniently normalized to $\widetilde{N} = N^{1/(\nu-1)}$, $h_{nn} = 1$. Thus, similar to the setup in Ramondo and Rodríguez-Clare (2013), the parameter h_{ni} can be interpreted as the overall efficiency loss incurred by affiliates of multinational firms from i producing in n.

In a competitive equilibrium, affiliates from the country with the lowest minimum unit cost supply good $\mathbf{z}$ to market n,

$$p_n(\mathbf{z}) = \min_i p_{ni}(\mathbf{z}). \tag{9}$$

Expenditures in country n on good $\mathbf{z}$ produced by affiliates from i in n are given by the expenditure function derived from the CES utility function, $(p_n(\mathbf{z})/P_n)^{1-\sigma}X_n$, where P_n is the price index associated with the

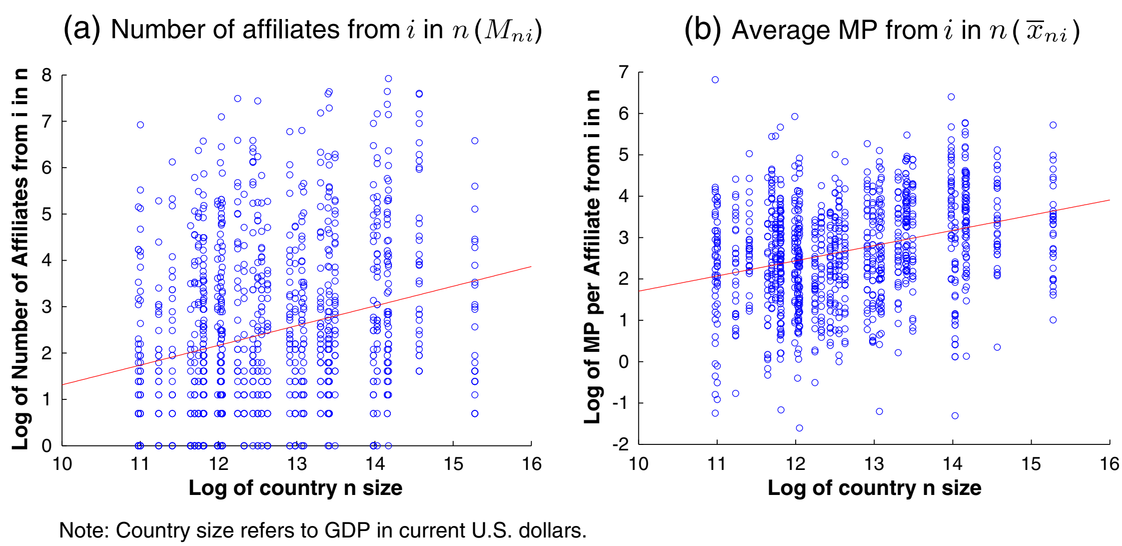

Fig. 2. Multinational production and the size of the destination market. (a) Number of affiliates from i in n (M_{ni}). (b) Average MP from i in n ($\overline{x}_{ni}$). Note: market size refers to GDP in current U.S. dollars.

composite good Q_n, and X_n are total expenditures in country n, $X_n = P_nQ_n$. Substituting $p_n(\mathbf{z})$ in Eq. (9) into the familiar CES formula for the price index P_n and integrating yield

$$P_n = \gamma\left(\sum_{i=1}^{I}(h_{ni}c_n)^{-\theta}T_i\right)^{-1/\theta}, \tag{10}$$

with $\gamma \equiv \Gamma(1 + (1 - \sigma)/\theta)^{1/(1-\sigma)} > 0$ and $\Gamma(.)$ representing the gamma function.

Fig. 4 illustrates the workings of the model's equilibrium. Assume that there are three possible source countries of affiliates that can provide good $\mathbf{z}$ to country n: k, i, and n (i.e., the local producers). Decreasing returns to scale and fixed costs at the affiliate level deliver U-shaped unit cost curves that differ across affiliates of different origins. The minimum unit cost of production for good $\mathbf{z}$ (i.e., for which net profits are zero) is given by $p_{nk}(\mathbf{z})$, $p_{ni}(\mathbf{z})$, and $p_{nn}(\mathbf{z})$, for affiliates from country k, i, and n, respectively. With free entry, the technology with the lowest minimum unit cost is used. In this example, affiliates from country i are the ones with the lowest minimum unit cost and, hence, provide good $\mathbf{z}$ to country n at price $p_{ni}(\mathbf{z})$ (left panel). At the industry level, there are constant returns to scale, as indicated by the flat supply curve (in blue). With decreasing returns at the affiliate level, the size of the market determines not only the total quantity of good $\mathbf{z}$ sold by i in n, but also the number of affiliates from country i producing good $\mathbf{z}$ in country n (right panel).

3.2.1. The extensive and intensive margins of multinational production

Total expenditures in country n devoted to goods produced by affiliates from country i in n aggregate over all goods $\mathbf{z}$ for which country i is the lowest-cost producer,

$$X_{ni} = \frac{h_{ni}^{-\theta}T_i}{\sum_k h_{nk}^{-\theta}T_k}X_n. \tag{11}$$

This is MP done by country i in n or, equivalently, total revenues of affiliates from i in n. This expression is analogous to the one for bilateral trade flows in EK, with the only difference being that the unit cost of country n's input bundle drops from this gravity-like equation since

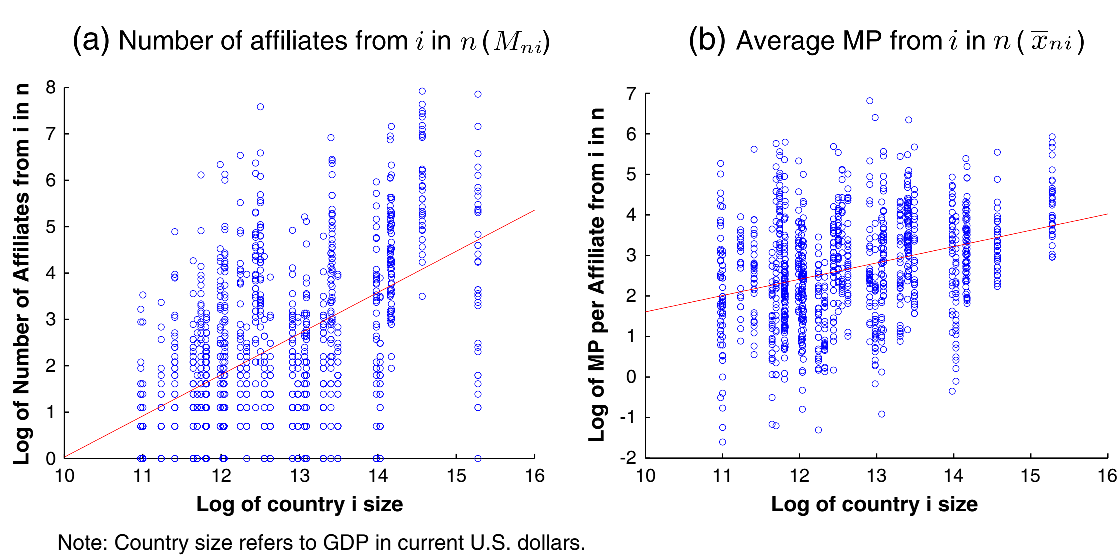

Fig. 3. Multinational production and the size of the source market. (a) Number of affiliates from i in n (M_{ni}). (b) Average MP from i in n ($\overline{x}_{ni}$). Note: market size refers to GDP in current U.S. dollars.

Table 3
Gravity and the margins of multinational production.

Dep. var.	All countries				OECD(18)			
	log M_{ni}		log$\bar{x}_{ni}$		log M_{ni}		log$\bar{x}_{ni}$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log d_{ni}	−0.63***	−0.74***	−0.16***	−0.25***	−0.69***	−0.79***	−0.05	−0.32***
	(0.039)	(0.027)	(0.027)	(0.043)	(0.059)	(0.061)	(0.046)	(0.11)
log X_n	0.49***		0.39***		0.54***		0.37***	
	(0.031)		(0.029)		(0.050)		(0.047)	
log X_i	0.93***		0.43***		0.97***		0.30***	
	(0.029)		(0.025)		(0.049)		(0.041)	
Fixed effects	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1097	1097	1094	1094	304	304	301	301
R-squared	0.55	0.97	0.27	0.93	0.65	0.98	0.27	0.96

Notes: M_{ni} is the number of affiliates from i in n; $\bar{x}_{ni}$ is revenues per affiliate from i in n; d_{ni} is geographical distance between i and n; and X_n (X_i) is GDP in n (i). Fixed effects refer to two sets of destination- and source-country fixed effects. Robust standard errors are in parentheses. Levels of significance are denoted.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

MP by i in n entails hiring in the host country n. Eq. (11) establishes that the larger the destination market (higher X_n), or the more productive the firms from i (higher T_i), the larger MP flows X_{ni}; the higher the MP cost (h_{ni}), the lower MP flows X_{ni}. Additionally, more-productive countries (i.e., higher T_i) should have larger market shares, both abroad and domestically; in other words, they should have higher outward and lower inward MP, as a share of country i's expenditures. Conversely, less-productive countries should have a higher share of production in the hands of foreigners and smaller market shares abroad.

Note that the model with decreasing returns to scale at the firm level and both fixed and variable costs of MP has implications about not only the aggregate MP flows by i in n, but also the number of affiliates and the average MP per affiliate from i in n. These are the novel features of the model with respect to previous work and the ones that allow the model to make direct contact with the facts presented in Section 2.

The number of affiliates from i in n – the extensive margin – is given by

$$M_{ni} = (1-\nu)\frac{X_{ni}}{c_n f_{ni}}. \tag{12}$$

Replacing X_{ni} in Eq. (11) into Eq. (12), after some algebra, yields

$$M_{ni} = \lambda f_{ni}^{-(1-\nu)\theta-1}\tau_{ni}^{\theta}T_i\left(X_n P_n^{\theta}\right), \tag{13}$$

where $\lambda \equiv (1-\nu)(N\gamma)^{-\theta} > 0$. We should expect more affiliates from i in n when the fixed cost is lower (lower f_{ni}), the variable component is higher (higher τ_{ni}), and the host market is larger (higher X_n).

Table 4
The margins of multinational production. Decomposition.

Dep. var.	log M_{ni}			
	All		OECD(18)	
log x_{ni}	0.62***	0.49***	0.71***	0.59***
	(0.011)	(0.022)	(0.019)	(0.036)
log X_n	0.55***	0.55***	0.59***	0.59***
	(0.019)	(0.017)	(0.033)	(0.030)
Constant	0.13		0.082	
	(0.26)		(0.466)	
Source country fixed effect	No	Yes	No	Yes
Observations	1094	1094	301	301
R-squared	0.78	0.96	0.84	0.97

Notes: M_{ni} is the number of affiliates from i in n; x_{ni} is revenues of affiliates from i in n, as a share of country n's GDP, X_n. Robust standard errors are in parentheses. Levels of significance are denoted.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

Conversely, revenues per affiliate from i in n – the intensive margin – increases only with the value of the fixed cost,

$$\bar{x}_{ni} \equiv \frac{X_{ni}}{M_{ni}} = \frac{c_n f_{ni}}{1-\nu}. \tag{14}$$

The empirical regularities documented in Section 2 establish that both the number of affiliates and revenues per affiliate from i in n decrease with distance, and change with characteristics of the countries hosting and sending affiliates abroad — in particular, with their size. From Eqs. (13) and (14), it is clear that, for the model to match the MP facts, it has to be that the fixed cost, f_{ni}, decreases with distance and also changes with characteristics of host and source markets — among then, country size; at the same time, the variable component τ_{ni} has to decrease with distance (i.e., firms from i going to a more-distant market n have higher efficiency losses) and vary with host- and source-market characteristics. To calibrate the model, rather than imposing these relationships, I will use Eqs. (13) and (14), as well as the data on M_{ni} and $\bar{x}_{ni}$, to calculate directly the matrices of MP parameters, f_{ni} and τ_{ni}. Section 4 explains the procedure in detail.

3.2.2. Closing the model

I assume that there is an intermediate and final goods sector, denoted by the superscripts "g" and "f," respectively. The CES aggregate good Q is used for the production of each intermediate good $\mathbf{z}$ and for final consumption. Following EK and Alvarez and Lucas (2007), the production function for each intermediate good $\mathbf{z}$ is Cobb–Douglas, with parameter $\beta < 1$, and combines the CES aggregate good with labor, so that the input bundle is given by $S^g(\mathbf{z}) = l^g(\mathbf{z})^{\beta}Q^g(\mathbf{z})^{1-\beta}$.[16] The unit cost of the input bundle for intermediate goods in country n is then given by

$$c_n^g = Bw_n^{\beta}\left(P_n^g\right)^{1-\beta}, \tag{15}$$

where $B \equiv \beta^{-\beta}(1-\beta)^{\beta-1} > 0$. The unit cost of production for the final good in country n is given simply by the price index associated with the composite intermediate good, P_n^g, in Eq. (10). In a competitive equilibrium, the price of the final good is equal to its unit cost of production,

$$P_n^f = P_n^g. \tag{16}$$

Replacing c_n^g in Eq. (15) into Eq. (10) and solving for P_n^g yields

$$P_n^g = \tilde{\gamma}\left(\sum_{i=1}^{I} h_{ni}^{-\theta}T_i\right)^{-1/(\beta\theta)} w_n, \tag{17}$$

where $\tilde{\gamma} = (\gamma B)^{-1/\beta} > 0$ and h_{ni} is defined in Eq. (8).

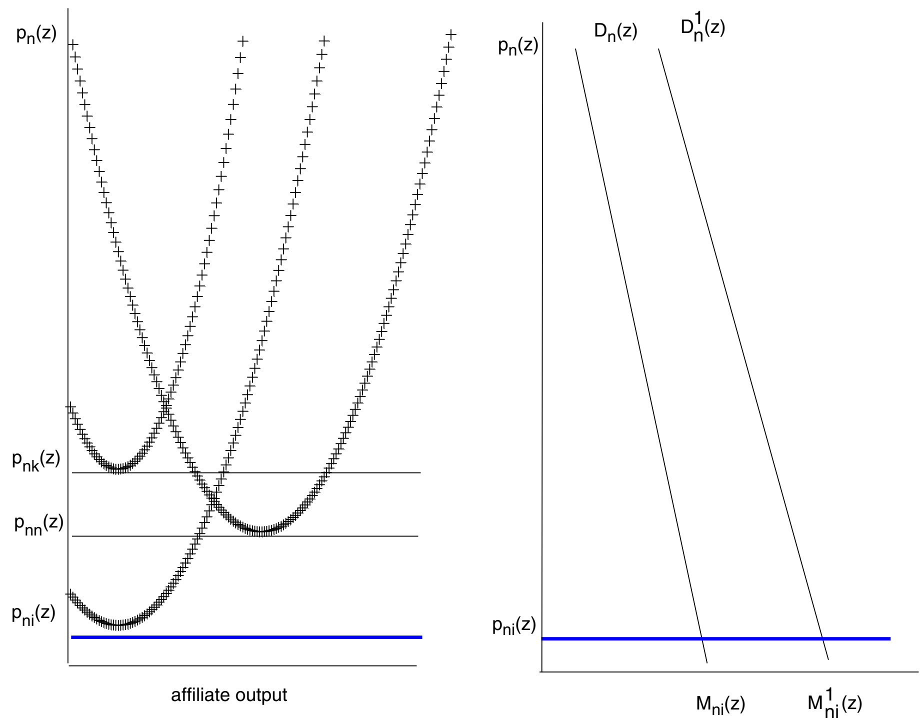

Fig. 4. Equilibrium with multinational production.

Total expenditures in country n on the final good are equal to total income in country n, $X_n^f = w_n L_n$, while total expenditures on the intermediate-goods sector are $X_n^g = X_n^f/\beta$.[17] In this economy, X_n^f is gross domestic product (GDP) and X_n^g is gross output.

Finally, since countries interact only through MP, not trade, the equilibrium for each country can be solved separately and the wages normalized in each economy. I set $w_n = 1$, for all n.

3.3. The gains from multinational production

The gains to country n from opening up to multinational firms are computed as the change in the real wage of moving from autarky ($h_{ni} \to \infty$, for all $i \neq n$) to a situation with multinational firms ($h_{ni} < \infty$, for $i \neq n$). The real wage for country n in an equilibrium with MP is given by

$$\frac{w_n}{P_n^f} = (\tilde{\gamma})^{-1}\left(\sum_{i=1}^{I} h_{ni}^{-\theta} T_i\right)^{1/(\beta\theta)}, \tag{18}$$

while for $h_{ni} \to \infty$, for all $i \neq n$, Eq. (18) collapses to the real wage under autarky,

$$\frac{w_n}{P_n^f} = (\tilde{\gamma})^{-1}(T_n)^{1/(\beta\theta)}. \tag{19}$$

Dividing Eq. (18) by Eq. (19), the gains from MP for country n are obtained:

$$GMP_n = \left(\sum_{i=1}^{I} h_{ni}^{-\theta}\frac{T_i}{T_n}\right)^{1/(\beta\theta)}. \tag{20}$$

Opening up to foreign firms gives country n access to better production technologies from the rest of the world, "discounted" by the cost h_{ni}. The lower the cost of hosting foreign affiliates, the higher the gains for the host country.

Analogous to the results for the gains from trade in Arkolakis et al. (2012), the gains from MP for country n can be written as a function of MP shares. For $i = n$, the expression in Eq. (11) collapses to

$$\frac{X_{nn}}{X_n^g} = \left[\sum_{i=1}^{I} h_{ni}^{-\theta}\frac{T_i}{T_n}\right]^{-1}. \tag{21}$$

Replacing Eq. (21) into Eq. (20) yields

$$GMP_n = \left(\frac{X_{nn}}{X_n^g}\right)^{-1/(\beta\theta)}. \tag{22}$$

If MP flows were normalized by X_n^f, the counterpart of GDP in the data, replacing $X_n^g = X_n^f/\beta$ in Eq. (22), would deliver

$$GMP_n = \left(1 - \beta\sum_{i\neq n} x_{ni}\right)^{-1/(\beta\theta)}, \tag{23}$$

where $x_{ni} \equiv X_{ni}/X_n^f$. The expression in Eq. (23) is very convenient since the gains of moving from autarky to a situation with the observed MP flows can be calculated using the data on revenues of affiliates from i in n, as a share of country n's GDP, as well as some calibrated values for β and θ. Moreover, the gains of moving from the current situation observed in the data to any counterfactual situation (e.g., lower MP costs) can be written as $GMP_n' = ((1 - \beta\sum_{i\neq n} x_{ni}')/(1 - \beta\sum_{i\neq n} x_{ni}))^{-1/(\beta\theta)}$, where x_{ni}' indicates the share of MP done by firms from i in n in the counterfactual equilibrium. Of course, calculating each x_{ni}' entails calibrating the model parameters and solving for the model's equilibrium.

[17] Total expenditures in the composite intermediate good are $X_n^g = P_n^g Q_n = P_n^g(Q_n^f + Q_n^g) = X_n^f + (1-\beta)X_n^g$, where $(1-\beta)$ is the expenditure share on the input Q from the intermediate-goods sector. Thus, $X_n^g = (1/\beta)X_n^f$.

Table 5
Data and model variables.

Country Name	Country Code	MP shares Outward	MP shares Inward	No. of affiliates Outward	No. of affiliates Inward	*GDP*	R&D	*RGDPL* Data	*RGDPL* $\theta = 8.2$	*RGDPL* $\theta = 4.2$
Argentina	ARG	0.05	0.17	221	1227	0.03	0.19	0.24	0.29	0.09
Australia[a]	AUS	0.15	0.37	603	2474	0.04	0.79	0.88	0.45	0.21
Austria[a]	AUT	0.09	0.39	1766	4038	0.02	0.57	0.86	0.36	0.13
Benelux[a]	BNX	1.05	0.62	8465	5198	0.07	0.69	0.87	0.52	0.28
Brazil	BRA	0.02	0.21	260	2466	0.08	0.09	0.18	0.30	0.10
Canada[a]	CAN	0.31	0.51	1766	3440	0.07	0.74	0.84	0.52	0.27
Switzerland	CHE	1.08	0.49	5637	3066	0.03	0.70	0.92	0.41	0.17
Chile	CHL	0.03	0.21	108	495	0.01	0.12	0.24	0.19	0.04
China	CHN	0.00	0.07	250	3781	0.14	0.10	0.07	0.34	0.12
Czech Republic	CZE	0.01	0.71	96	1850	0.01	0.31	0.43	0.24	0.06
Denmark[a]	DNK	0.26	0.19	2017	999	0.02	0.75	0.84	0.35	0.13
Spain[a]	ESP	0.05	0.28	486	3394	0.07	0.43	0.65	0.42	0.19
Finland[a]	FIN	0.59	0.31	1126	1674	0.01	1.48	0.72	0.39	0.16
France[a]	FRA	0.18	0.22	4921	6514	0.16	0.73	0.76	0.59	0.36
Great Britain[a]	GBR	0.29	0.48	5823	5254	0.16	0.63	0.76	0.59	0.36
Germany[a]	GER	0.46	0.33	21,553	12,724	0.23	0.72	0.80	0.66	0.45
Greece[a]	GRC	0.01	0.11	116	472	0.01	0.33	0.53	0.27	0.08
Indonesia	IDN	0.01	0.19	102	1059	0.02	0.05	0.08	0.18	0.04
India	IND	0.01	0.05	145	525	0.05	0.04	0.05	0.21	0.05
Ireland	IRL	0.26	0.55	499	1159	0.01	0.55	0.80	0.30	0.09
Israel	ISR	0.04	0.10	280	225	0.01	0.59	0.59	0.30	0.10
Italy[a]	ITA	0.10	0.18	2204	2798	0.13	0.34	0.74	0.47	0.23
Japan[a]	JPN	0.20	0.07	8196	1667	0.48	1.12	0.79	0.85	0.72
Korea	KOR	0.11	0.11	709	933	0.05	0.56	0.47	0.42	0.18
Mexico	MEX	0.04	0.32	357	2062	0.05	0.06	0.28	0.25	0.07
Norway[a]	NOR	0.25	0.11	1286	673	0.02	0.92	1.17	0.36	0.14
New Zealand[a]	NZL	0.15	0.69	122	470	0.01	0.61	0.62	0.28	0.08
Poland	POL	0.01	0.33	139	3402	0.02	0.37	0.28	0.30	0.10
Portugal[a]	PRT	0.05	0.58	100	972	0.01	0.35	0.50	0.29	0.09
Russia	RUS	0.04	0.04	197	600	0.03	0.84	0.21	0.41	0.18
Sweden[a]	SWE	0.44	0.43	2953	4355	0.03	1.06	0.75	0.44	0.20
Thailand	THA	0.01	0.49	89	1585	0.01	0.03	0.15	0.16	0.03
Turkey	TUR	0.01	0.10	219	622	0.03	0.10	0.21	0.23	0.06
United States[a]	USA	0.22	0.19	18,572	8558	1.00	1.00	1.00	1.00	1.00
South Africa	ZAF	0.09	0.20	229	881	0.02	0.08	0.15	0.20	0.04
Average All		0.19	0.30	2206	2490	0.06	0.51	0.55	0.37	0.17
Average OECD(18)		0.27	0.34	4560	3649	0.14	0.74	0.78	0.49	0.28
Average non-OECD(18)		0.11	0.25	561	1526	0.04	0.28	0.32	0.28	0.09

Notes: Inward MP shares: Total revenues of foreign affiliates in n, as a share of n's GDP. Outward MP shares: Total revenues of affiliates from n abroad, as a share of n's GDP. Inward number of affiliates: total number of foreign affiliates in n. Outward number of affiliates: total number of affiliates abroad from n. R&D refers to employment in the R&D sector, as a share of total employment. Gross domestic product in current U.S. dollars (*GDP*), R&D, and real GDP per capita (*RGDPL*) are relative to the U.S.

[a] Countries in the OECD(18).

4. Quantitative analysis

4.1. Data

In contrast with the bilateral trade data, there is no systematic data set on the *bilateral* activity of foreign affiliates of multinational firms. I assemble a data set that includes total revenues of affiliates from country i in n and the number of affiliates of firms from country i producing in n. A foreign affiliate is defined as a firm that has more than 10% of its shares owned by a foreigner. The data include both OECD and non-OECD countries from which I consider a sample of 35 countries with real GDP per capita of more than 2000 dollars (PPP-adjusted), and, in general, better-quality data on multinational firms. Countries are listed in column 1 of Table 5.

The main information sources are both published and unpublished data from the FDI country profiles found in the FDI statistics recorded by the Investment and Enterprise Program at UNCTAD.[18] Additionally, missing values for both bilateral revenues and number of affiliates are imputed following the procedure in Ramondo et al. (2013b), which complements the UNCTAD data with data on cross-border Mergers and Acquisition from Thomson and Reuters. Each observation is at the country-pair level, an average over 1996–2001. The data refer to non-financial affiliates in all sectors; no data are available by sector.

The empirical counterpart for MP by i in n in the model, X_{ni}, is total revenues of affiliates of multinational firms from country i in n, while the empirical counterpart for M_{ni} is the total number of affiliates (not plants) of firms from i in n. I normalize total revenues of affiliates from country i in n by GDP in country n, in current U.S. dollars, from the World Development Indicators, an average over 1996–2001.[19] Revenues per affiliate from i in n are calculated by dividing total revenues by the number of affiliates from i in n.

In the calibration, I again use data from the World Development Indicators on research and development (R&D) employment, as a share of total employment, by country, an average over 1996–2001. Data on real GDP per capita, PPP-adjusted, are from the Penn World Tables (7.1), an average over 1996–2001. Table 5 presents total revenues of foreign affiliates from and into country n, as a share of country n's GDP, total number of affiliates from and to country n, GDP, R&D employment shares, and real GDP per capita, by country.

[18] Unpublished data are available upon request at fdistat@unctad.org.

[19] Taking averages smoothes out year-to-year fluctuations and trade imbalances about which the theory is silent.

Table 6
Calibrated costs of multinational production.

Calibration with	F_n^{inward}	$F_n^{outward}$	$\theta = 8.2$		$\theta = 4.2$	
			τ_n^{inward}	$\tau_n^{outward}$	τ_n^{inward}	$\tau_n^{outward}$
Argentina	5.16	1.43	0.47	0.60	0.16	0.26
Australia[a]	10.98	4.47	0.80	0.70	0.37	0.29
Austria[a]	11.70	2.74	0.51	0.47	0.19	0.19
Benelux[a]	18.55	31.49	1.05	1.12	0.51	0.60
Brazil	6.42	0.49	0.64	0.58	0.22	0.25
Canada[a]	15.43	9.29	0.95	0.88	0.46	0.37
Switzerland	14.59	32.47	0.59	1.04	0.24	0.56
Chile	6.19	0.85	0.33	0.36	0.08	0.17
China	2.00	0.10	0.42	0.41	0.13	0.15
Czech Republic	21.38	0.48	0.46	0.44	0.15	0.15
Denmark[a]	5.61	7.87	0.58	0.71	0.20	0.32
Spain[a]	8.30	1.39	0.74	0.64	0.31	0.24
Finland[a]	9.27	17.56	0.68	1.07	0.29	0.49
France[a]	6.63	5.33	1.02	0.81	0.52	0.35
Great Britain[a]	14.29	8.73	1.39	0.87	0.75	0.40
Germany[a]	10.03	13.91	1.14	0.97	0.69	0.47
Greece[a]	3.22	0.36	0.41	0.43	0.12	0.16
Indonesia	5.63	0.17	0.29	0.30	0.07	0.17
India	1.38	0.18	0.08	0.00	0.07	0.09
Ireland	16.49	7.75	0.51	0.70	0.18	0.33
Israel	2.97	1.16	0.28	0.36	0.07	0.14
Italy[a]	5.49	3.02	1.09	0.84	0.52	0.36
Japan[a]	2.08	5.95	0.89	0.96	0.47	0.37
Korea	3.23	3.20	0.51	0.79	0.19	0.33
Mexico	9.67	1.12	0.52	0.50	0.16	0.23
Norway[a]	3.16	7.49	0.52	0.74	0.18	0.32
New Zealand[a]	20.73	4.47	0.52	0.54	0.19	0.27
Poland	10.02	0.23	0.51	0.40	0.19	0.13
Portugal[a]	17.46	1.61	0.73	0.63	0.27	0.24
Russia	1.23	1.07	0.44	0.54	0.16	0.20
Sweden[a]	12.76	13.28	0.65	0.78	0.29	0.38
Thailand	14.77	0.19	0.37	0.40	0.09	0.21
Turkey	2.88	0.21	0.31	0.34	0.08	0.13
United States[a]	5.69	6.62	1.97	1.09	1.54	0.45
South Africa	5.99	2.78	0.26	0.61	0.06	0.40
Average All	8.90	5.70	0.65	0.65	0.29	0.29
Average OECD(18)	10.08	8.09	0.87	0.79	0.44	0.35
Average non-OECD(18)	7.52	3.30	0.40	0.49	0.13	0.23

Notes: F_n^{inward} indicates the total value of the fixed costs for foreign affiliates *into* country n, as percentage of country n's GDP, $100 \times \sum_{k \neq n} c_n f_{nk} M_{nk}/(w_n L_n)$. $F_n^{outward}$ indicates the total value of the fixed costs for affiliates *from* country n abroad, as percentage of country n's GDP, $100 \times \sum_{k \neq n} c_k f_{kn} M_{kn}/(w_n L_n)$. τ_n^{inward} is the average country-pair specific productivity for foreign affiliates *into* country n, $\sum_{i \neq n} \tau_{ni}/(I-1)$. $\tau_n^{outward}$ is the average country-pair specific productivity for foreign affiliates *from* country n, $\sum_{i \neq n} \tau_{in}/(I-1)$.
[a] Countries in the OECD(18).

4.2. Calibration procedure

The parameters to calibrate in the model are: β, ν, θ, the vectors $\mathbf{L} = \{L_1,\ldots,L_I\}$ and $\mathbf{T} = \{T_1,\ldots,T_I\}$, and the matrices $\mathbf{t} = \{\tau_{ni}\}_{i \neq n}$, and $\mathbf{f} = \{f_{ni}\}_{i \neq n}$.

4.2.1. The parameter β

The labor share β is calibrated to match the ratio of GDP to gross output in the large sample of countries. My own calculations for the United States, using the Annual Industry Accounts from the Bureau of Economic Analysis (BEA), for the period 1996–2001 and non-financial sectors only, suggest that this ratio is around half.[20] Jones (2011), using the OECD input–output database, calculates for a sample of 35 OECD countries and 9 non-OECD countries, typically for the year 2000, a share of intermediate goods in production that ranges from around 0.4 for Greece to 0.68 for China, with 0.47 for the United States; the average is 0.53. According to Alvarez and Lucas (2007), the share of intermediate goods in the tradable-goods sector is 0.5.[21] Hence, I choose $\beta = 0.5$.

4.2.2. The parameter ν

I set the span of control parameter ν to 0.7, as estimated by Cooper and Haltinwanger (2006) using a model with capital adjustment costs, plant-level data, and an indirect inference approach.

4.2.3. The parameter θ

It is well-known from quantitative trade models that the parameter θ cannot be separately identified from the cost parameters. I set this parameter to 8.2 and 4.2, alternately. These two values encompass the estimates in Eaton and Kortum (2002), Bernard et al. (2003), Alvarez and Lucas (2007), Simonovska and Waugh (2014), Donaldson (forthcoming), and Ramondo and Rodríguez-Clare (2013).

4.2.4. The vector $\mathbf{L}$

Similar to the approach in Alvarez and Lucas (2007), I set the vector $\mathbf{L}$ to match the observed GDP data, in current U.S. dollars, in each country n. In the model, GDP is given by $w_n L_n$. Since wages are normalized to one, it is straightforward to set L_n equal to GDP as observed in the data. Since the model abstracts from physical and human capital, the reason to choose GDP as the empirical counterpart of $w_n L_n$ is to interpret L_n as efficiency-equipped units of labor in country n, that are different from the number of people, or workers, in country n.

4.2.5. The vector $\mathbf{T}$

Finally, as in Ramondo and Rodríguez-Clare (2013), I assume that T_n/L_n varies directly with the share of R&D employment observed in the data. For example, the share of R&D employment for Ireland is 0.54 the one in the United States, indicating that in Ireland, T_{IRL}/L_{IRL} is half as high as the one in the United States. This assumption reflects the common idea from semi-endogenous growth models that the stock of ideas in a country is proportional to its size, L_n, and that countries have different productivity in the research sector. Additionally, calibrating T's in this way avoids the appearance that small rich countries, such as Denmark, have systematically high T's (see Ramondo et al., 2012). I set $T_{USA} = 1$.

4.2.6. MP parameters

To calibrate the matrices $\mathbf{f}$ and $\mathbf{t}$, it is convenient to use Eq. (8) and calibrate first the matrix $\mathbf{h} = \{h_{ni}\}_{i \neq n}$.

1. Given the set $\Delta = \{\beta, \nu, \theta, \mathbf{L}, \mathbf{T}\}$, I pick the matrix $\mathbf{h}$ (with $h_{nn} = 1$), to match exactly the matrix of bilateral revenues of affiliates observed in the data. To do so, I solve the $I \times (I-1)$ system of equations,

$$X_{ni}^{data} - X_{ni}^{model}(\mathbf{h}; \Delta) = 0,$$

where $X_{ni}^{model}(\mathbf{h};\Delta)$ is given by Eq. (11).
2. The matrix $\mathbf{f}$ is computed directly from the data on the bilateral revenues per affiliate, using Eq. (14),

$$f_{ni} = (1-\nu)\frac{\overline{x}_{ni}^{data}}{c_n(\mathbf{h}; \Delta)}. \tag{24}$$

The equilibrium variable c_n is calculated using Eq. (15), which, in turn, uses the expression for the equilibrium price index in Eq. (17), which requires the matrix $\mathbf{h}$, calculated in step 1.

[20] Ratios are very similar whether the Government sector is included or not.

[21] They match the share of value added in gross output using input–output data from the BEA (1996–1999), and UNIDO Industrial Statistics database (1998). They include as tradable sectors mining, agriculture, manufacturing, and tradable services. Moreover, labor is interpreted, as I do here, as labor-plus-capital, or value-added, not just compensation of employees. These are the reasons why their share is higher than the 0.21 calculated by EK.

Table 7
Gravity and the costs of multinational production.

Dep. var.	All countries				OECD(18)			
	$\log f_{ni}$		$\log \tau_{ni}$		$\log f_{ni}$		$\log \tau_{ni}$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\log d_{ni}$	-0.31^{***}	-0.25^{***}	-0.24^{***}	-0.18^{***}	-0.09^{*}	-0.32^{**}	-0.12^{***}	-0.24^{***}
	(0.039)	(0.049)	(0.021)	(0.024)	(0.049)	(0.13)	(0.021)	(0.054)
$\log X_n$	0.49^{***}		0.26^{***}		0.50^{***}		0.27^{***}	
	(0.048)		(0.024)		(0.049)		(0.022)	
$\log X_i$	0.45^{***}		0.16^{***}		0.34^{***}		0.13^{***}	
	(0.032)		(0.019)		(0.044)		(0.019)	
Fixed effects	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1076	1076	1097	1097	304	304	304	304
R-squared	0.15	0.78	0.13	0.86	0.37	0.81	0.46	0.73

Notes: Calibration with $\theta = 8.2$. d_{ni} is geographical distance between i and n; and X_n (X_i) is GDP in n (i). Fixed effects refer to two sets of destination- and source-country fixed effects. Robust standard errors are in parentheses. Levels of significance are denoted.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

3. The matrix $\mathbf{t}$ is calculated as a residual using Eq. (8),

$$\tau_{ni} = N \frac{f_{ni}^{\nu-1}}{h_{ni}}, \tag{25}$$

with h_{ni} and f_{ni} coming from steps 1 and 2, respectively.

Some remarks about the calibration procedure are in order. First, the data include both positive and zero observations on the bilateral revenues of affiliates. The model does not generate exact zeros in step 1, but it generates extremely small MP flows by simply picking a very high h_{ni} for those observations with $X_{ni}^{data} = 0$.[22] In step 2, observations with zero MP cannot be included because $\bar{x}_{ni} \equiv X_{ni}/M_{ni}$ is undetermined for $X_{ni}^{data} = M_{ni}^{data} = 0$. Consequently, these observations also are not included in step 3 to calculate τ_{ni}. These indeterminacies, however, are innocuous since the only variable that matters for computing the equilibrium is the price index in Eq. (17), which requires only the matrix $\mathbf{h}$ from step 1. The statistics presented in the next subsection do not include calibrated values corresponding to observations with zero MP in the data.

Second, the calibration procedure cannot assign a value to f_{nn} in step 2 since data on the number of domestic affiliates and, consequently, data on revenues per domestic affiliate are not available. As explained in Section 3, f_{nn} is normalized to a positive constant. This normalization is innocuous since it does not affect the equilibrium variables of the model (i.e., P_n and c_n), which can be calculated immediately after step 1.

Third, even though the calibrated model exactly matches GDP in current U.S. dollars, in each country, it is not designed to match real GDP per capita, whose model counterpart is w_n/P_n^f. The last two columns of Table 5 present the implications of the model regarding this variable, for the calibrations with $\theta = 8.2$ and 4.2, respectively. The average country in the data is richer than in the calibrated model (0.55 versus 0.39 for the calibration with $\theta = 8.2$), while the correlation between this variable in the data and in the model is around 0.6. The data also present more variation than the calibrated model (s.d. of 0.31 versus 0.18), with a minimum of 0.05 (India) and a maximum of 1.17 (Norway); the model with $\theta = 8.2$ achieves a minimum of 0.16 (Thailand) and a maximum of 1 (the United States).

Finally, from steps 1 and 2 in the calibration procedure, it is clear that the calibrated model matches the extensive and intensive margins of MP exactly as observed in the data. The question is how the two components of the MP cost, f_{ni} and τ_{ni}, do that job; I turn to that question next.

[22] Since zero observations represent only seven percent of the observations, including or ignoring them in the procedure delivers undistinguishable results.

4.3. Results

Table 6 reports summary statistics for the matrix of calibrated fixed costs $\mathbf{f}$ and of country-pair specific productivity $\mathbf{t}$, by country. The last three rows present averages. Results in columns 1 and 2 do not depend on the value of the parameter θ and represent the value of the fixed cost paid by all foreign affiliates in country n, and by all affiliates from country n abroad, respectively, as a share of country n's GDP:

$$F_n^{\text{inward}} = 100 \times \sum_{i \neq n} \frac{M_{ni} c_n f_{ni}}{w_n L_n}; \; F_n^{\text{outward}} = 100 \times \sum_{i \neq} \frac{M_{in} c_i f_{in}}{w_n L_n}.$$

In the calibrated model, these two variables are pinned down directly by the data on inward and outward MP shares (columns 1 and 2 in Table 5) and $\nu = 0.7$: Using Eq. (14) and $x_{ni} \equiv X_{ni}/(w_n L_n)$ implies that $M_{ni} c_n f_{ni}/(w_n L_n) = (1 - \nu) x_{ni}$. For the average country in the sample, the total value of the fixed cost that foreign multinational firms paid for opening affiliates in country n (F_n^{inward}) represents 8.9% of the host country's GDP, while aggregating the value of the fixed cost that multinational firms paid for their affiliates abroad (F_n^{outward}) represents less than 6% of the home country's GDP. Among the subset of OECD countries, both the average inward and outward values of the fixed costs are much higher than for the non-OECD countries. The reason is simple: F_n^{inward} and F_n^{outward} are pinned down directly by the data on the share of revenues of foreign affiliates (in terms of the host country's GDP) and of affiliates abroad (in terms of the home country's GDP), respectively, which are much higher for the former group of countries than for the latter group (see Table 5). Additionally, there is great heterogeneity across countries in the fixed cost of engaging in MP activities that purely reflects the heterogeneity in MP flows, from $F_n^{\text{inward}} = 1.23$ percent for Russia, the country with the lowest inward MP shares, and $F_n^{\text{outward}} = 0.10$ percent for China, the country with the lowest level of firm internationalization, to $F_n^{\text{inward}} = 21$ percent for Czech Republic, a small and very open country, and $F_n^{\text{outward}} = 32$ percent for Switzerland, with outward MP flows that represent more than 100% of its GDP. For the United States, the largest source of multinational firms, the total value of the fixed cost faced by U.S. affiliates abroad represents almost 7% of U.S. GDP, while for affiliates of foreign multinationals in the United States, these costs represent almost 6% of U.S. GDP.[23]

[23] To calculate the value of the fixed cost paid by affiliates from a given source country i into a host country n, as a share of country n's GDP, the data in Table 2 suffice: With $M_{ni} c_n f_{ni}/(w_n L_n) = (1 - \nu) x_{ni}$ and $\nu = 0.7$, the value of the fixed cost for foreign affiliates from i in n represents 0.26% of the host country's GDP (i.e., 0.3×0.0087), for the average country pair, 0.56% (i.e., 0.3×0.0187) for the average country pair belonging to OECD(18), and 0.021% (i.e., 0.3×0.0007) for the average country pair not belonging to OECD(18).

Table 8
The role of the fixed and variable costs of multinational production.

	Model with MP costs		
	Fixed and variable	Only variable	Only fixed
Average			
Number of affiliates from i in n	83	5287	1358
Revenues per affiliate from i in n	34	1.5	374
Median			
Number of affiliates from i in n	9	89	42
Revenues per affiliate from i in n	15	1.5	3
Coefficient of variation (s.d. to mean)			
Number of affiliates from i in n	105	182	257
Revenues per affiliate from i in n	57	7	184

Notes: The magnitudes for the calibrated model with both variable and fixed costs of MP correspond to the magnitudes observed in the data (considering only observations with non-zero MP flows). Revenues per affiliate are in millions of current U.S. dollars.

Turning to the variable component of MP costs – the country-pair specific productivity parameter τ_{ni} – its average is 0.65 for the calibration with $\theta = 8.2$, meaning that a foreign affiliate of a multinational firm experiences, on average, an efficiency loss of 35% (i.e., 0.35 = 1–0.65) when moving production abroad, with respect to producing in it in home market. Losses are very different depending on the type of country: Among richer countries, the loss is much lower than among poorer non-OECD countries — around 10–20% versus 50–60%, both for foreign affiliates entering those countries $(1-\tau_n^{\text{inward}})$ and affiliates from those countries going abroad $(1-\tau_n^{\text{outward}})$. In particular, U.S. affiliates abroad are, on average, 24% more productive than firms at home when going to a rich country in the OECD, but 10% less productive when they are hosted by a poorer country. Conversely, the United States receives much more productive affiliates of foreign firms than any other country. This outcome is driven by the fact that revenues per affiliate and the number of affiliates in the United States are, on average, \$133 million and 245, respectively, much higher than the averages recorded in Table 2.

The values for τ_{ni} from the calibration with $\theta = 4.2$ are much lower. A lower θ means more disperse productivity draws within a country across goods. That translates into MP shares being less elastic to changes in MP costs—see Eq. (11). Hence, matching the observed shares requires higher MP costs h_{ni} in step 1 of the calibration procedure, which, in turn, translate into lower τ's in step 3.

4.3.1. The role of the fixed and variable costs of multinational production

How do the calibrated MP costs reconcile the model with the facts in Section 2 that relate the intensive and extensive margins of multinational activities with characteristics of the host and the source countries and geographical distance between partners? The elasticities of the variable and fixed MP costs with respect to distance and the characteristics of the origin and destination markets are intimately related to the way the model links the bilateral number of affiliates and revenues per affiliate, respectively, to the MP costs and characteristics of the partner countries.

Regarding revenues per affiliate, taking logs in Eq. (14) yields

$$log\bar{x}_{ni} \equiv -log(1-\nu) + logf_{ni} + logc_n. \tag{26}$$

This expression, together with the estimates in columns 3 and 4 of Table 2, makes clear that, for the model to capture the data, f_{ni} has to vary negatively with distance between the country of origin and the destination of affiliates. Additionally, this cost has to vary with characteristics of the source and destination countries of affiliates. Assume that the fixed cost of opening affiliates of firms from country i in n behaves according to the following log-linear equation:

$$logf_{ni} = im_n^f + ex_i^f + \delta^f logd_{ni} + \varepsilon_{ni}^f, \tag{27}$$

where im^f and ex^f denote, respectively, destination- and source-country fixed effects, d_{ni} denotes geographical distance between i and n, and ε_{ni}^f captures all other idiosyncratic country-pair specific component that are orthogonal to the regressors. Replacing Eq. (27) in Eq. (26) yields

$$log\bar{x}_{ni} \equiv -log(1-\nu) + \delta^f logd_{ni} + S_i^x + D_n^x + \varepsilon_{ni}^f, \tag{28}$$

where the variables S_i^x and D_n^x collect all the terms specific to the source and destination countries of foreign affiliates, respectively, that affect the intensive margin of MP.[24] Estimates in column 4 of Table 3 indicate that $\delta^f = -0.25$: MP partners that are twice as far away have 25% lower fixed costs. This result is confirmed when I estimate Eq. (27) by OLS (column 2 of Table 7), reconciling the model with the fact that revenues per affiliate decrease with distance in the data.

Applying a similar reasoning for the bilateral number of affiliates in Eq. (13) yields

$$logM_{ni} = log\lambda - [(1-\nu)\theta + 1]logf_{ni} + \theta log\tau_{ni} + logT_i + logX_n + \theta logP_n, \tag{29}$$

where $(1-\nu)\theta + 1 > 0$. Given the OLS estimates in columns 1 and 2 of Table 3, this expression implies that τ_{ni} has to depend negatively on geographical distance: The farther away the origin is from the host country of affiliates, the greater the loss in country-pair specific productivity experienced by foreign firms (i.e., lower τ_{ni}). Assume that the variable cost of opening affiliates of firms from country i in n behaves according to the following log-linear equation:

$$log\tau_{ni} = im_n^\tau + ex_i^\tau + \delta^\tau logd_{ni} + \varepsilon_{ni}^\tau, \tag{30}$$

where im^τ and ex^τ denote, respectively, destination- and source-country fixed effects, and ε_{ni}^τ is an idiosyncratic country-pair specific component that is orthogonal to the regressors. Replacing Eq. (30) in Eq. (29) yields

$$logM_{ni} = log\lambda + \left[\theta\delta^\tau - \delta^f - (1-\nu)\theta\delta^f\right]logd_{ni} + S_i^M + D_n^M + \varepsilon_{ni}, \tag{31}$$

where the variables S_i^M and D_n^M collect all the terms specific to the source and destination countries of foreign affiliates, respectively, that affect the extensive margin of MP, while ε_{ni} collects the error terms in Eqs. (27) and (30).[25] Clearly, with $\theta = 8.2$, $\nu = 0.7$, and $\delta^f = -0.25$, the OLS estimate in column 2 of Table 3 implies that $\delta\tau = -0.18$: Affiliates originating in countries twice as far from the host country experience 18% higher losses in their country-pair specific productivity. Column 4 in Table 7, again, confirms the result by estimating Eq. (30) by OLS.

Further, columns 1 and 3 of Table 7, similarly to columns 1 and 3 of Table 3, explore the relation between the variable and fixed cost of MP with host- and source-country size, for the sample both OECD and non-OECD countries.[26] While both components of the costs of doing MP increase less than proportionally with the size of the origin and the destination countries of affiliates, fixed costs are more responsive: For instance, a host country that is 10% larger has fixed costs almost 5% larger, while it attracts foreign affiliates that experience, on average, 2.5% lower efficiency losses.

As a final exercise, I assess the importance of including in the model both fixed and variable costs of engaging in multinational activities in

24 $S_i^x \equiv logex_i^f$ and $D_n^x \equiv logc_n + logim_n^f$.

25 $S_i^M \equiv logT_i + [(1-\nu)\theta + 1]ex_i^f + \theta ex_i^\tau$, and $D_n^M \equiv logX_n + \theta logP_n + [(1-\nu)\theta + 1]im_n^f + \theta im_n^\tau$.

26 Regressing the host- and source country fixed effects on host- and source-country GDP, respectively, delivers virtually the same coefficients.

Table 9
The gains from liberalizing multinational production.

Calibration with:	Gains from MP-autarky		Gains from MP liberalization		L_n
	$\theta = 8.2$	$\theta = 4.2$	$\theta = 8.2$	$\theta = 8.2$	
	(1)	(2)	(3)	(4)	(5)
Argentina	1.022	1.044	2.21	1.08	0.03
Australia[a]	1.051	1.101	2.56	1.16	0.04
Austria[a]	1.054	1.109	2.26	1.17	0.02
Benelux[a]	1.094	1.193	2.28	1.24	0.07
Brazil	1.028	1.055	2.33	1.10	0.08
Canada[a]	1.075	1.152	2.26	1.21	0.07
Switzerland	1.070	1.142	2.64	1.20	0.03
Chile	1.027	1.053	2.31	1.10	0.01
China	1.008	1.016	1.79	1.03	0.14
Czech Republic	1.113	1.234	3.03	1.26	0.01
Denmark[a]	1.024	1.048	2.23	1.09	0.02
Spain[a]	1.037	1.074	2.27	1.13	0.07
Finland[a]	1.042	1.083	2.17	1.14	0.01
France[a]	1.029	1.057	1.91	1.10	0.16
Great Britain[a]	1.069	1.138	2.02	1.19	0.16
Germany[a]	1.046	1.091	1.82	1.14	0.23
Greece[a]	1.014	1.027	1.99	1.05	0.01
Indonesia	1.024	1.048	2.26	1.09	0.02
India	1.004	1.011	1.60	1.02	0.05
Ireland	1.081	1.165	2.92	1.22	0.01
Israel	1.012	1.025	1.95	1.05	0.01
Italy[a]	1.023	1.047	2.13	1.09	0.13
Japan[a]	1.009	1.017	1.37	1.04	0.48
Korea	1.014	1.027	1.99	1.05	0.05
Mexico	1.044	1.087	2.57	1.14	0.05
Norway[a]	1.013	1.026	1.87	1.05	0.02
New Zealand[a]	1.109	1.224	2.64	1.26	0.01
Poland	1.046	1.091	2.49	1.15	0.02
Portugal[a]	1.087	1.178	2.87	1.23	0.01
Russia	1.005	1.010	1.61	1.02	0.03
Sweden[a]	1.060	1.121	2.30	1.18	0.03
Thailand	1.07	1.144	2.85	1.20	0.01
Turkey	1.01	1.024	1.94	1.05	0.03
United States[a]	1.02	1.049	1.20	1.08	1.00
South Africa	1.03	1.051	2.30	1.09	0.02
Average All	1.042	1.085	2.20	1.13	0.09
Average OECD(18)	1.048	1.096	2.12	1.14	0.14
Average non-OECD(18)	1.035	1.071	2.26	1.11	0.04

Notes: Columns 1 and 2: changes in the real wage from autarky (i.e., $h_{ni} \to \infty$ for $i \neq n$) to the calibrated equilibrium. Column 3: changes in the real wage from the calibrated equilibrium to an equilibrium with 50% higher τ_{ni}, for all $i \neq n$. Column 4: changes in the real wage from the calibrated equilibrium to an equilibrium with 50% lower f_{ni}, for all $i \neq n$.
[a] Countries in the OECD(18).

order to capture the patterns of the extensive and intensive margins of MP observed in the data. To do so, I first assume that $f_{ni} = \widetilde{N}$, for all n, i, and recalibrate the matrix of country-specific productivity **t** to match exactly the total revenues of affiliates from i in n. Alternately, I assume that $\tau_{ni} = 1$, for all n, i, and recalibrate the matrix of fixed costs **f** to match exactly the total revenues of affiliates from i in n. What are the implications for revenues per affiliate and the number of affiliates from i in n in the two cases? Table 8 shows the results for the calibrated model with $\theta = 8.2$.[27]

A model with only variable costs of engaging in multinational activities would overstate the extensive margin of MP: There would be, on average, too many very small affiliates. Moreover, as indicated by the coefficients of variation, the heterogeneity across country pairs in MP flows would come from the extensive margin exclusively since affiliates from different source countries operating in the same host country would have the same average size (i.e., the same amount of revenues per affiliate).[28] The distribution of the extensive margin across country-pairs would be extremely skewed, much more than in the data, as suggested by the differences between the mean and the median.

Conversely, a model with only fixed costs of engaging in multinational activities would generate very large affiliates and, on average, much more of them than observed in the data. Additionally, as hinted by the coefficient of variation, the heterogeneity across country pairs for both margins of MP would be too high, and the distributions too skewed (medians are extremely low in comparison to the means).

In conclusion, to capture both the extensive and intensive margins of MP observed in the data, both fixed and variable components for MP costs are necessary. Not only the average magnitudes of the two margins, but also their distribution across country pairs, would be off.

5. The gains from multinational production

I use the calibrated model to evaluate the gains from engaging in multinational activities, both from autarky and to a situation in which the activity of multinational firms is liberalized. These gains are measured as the change in the real wage in country n, w_n/P^f_n, of going from the calibrated to the counterfactual equilibrium.

As shown in Eq. (23), the gains from MP-autarky can be written as a function of the share of foreign affiliates' revenues in the GDP of the host country. Using the revenue shares observed in the data, which the calibrated model matches exactly, $\beta = 0.5$, and $\theta = 8.2$ and 4.2, alternately, columns 1and 2 in Table 9 present the implied gains of moving from MP-autarky to an equilibrium with the observed MP flows, for each country in the sample.

[27] Results for $\theta = 4.2$ yield a very similar pattern (not shown).
[28] From Eq. (14), with $f_{ni} = \widetilde{N}$, $\bar{x}_{ni} = \widetilde{N}c_n/(1-\nu)$.

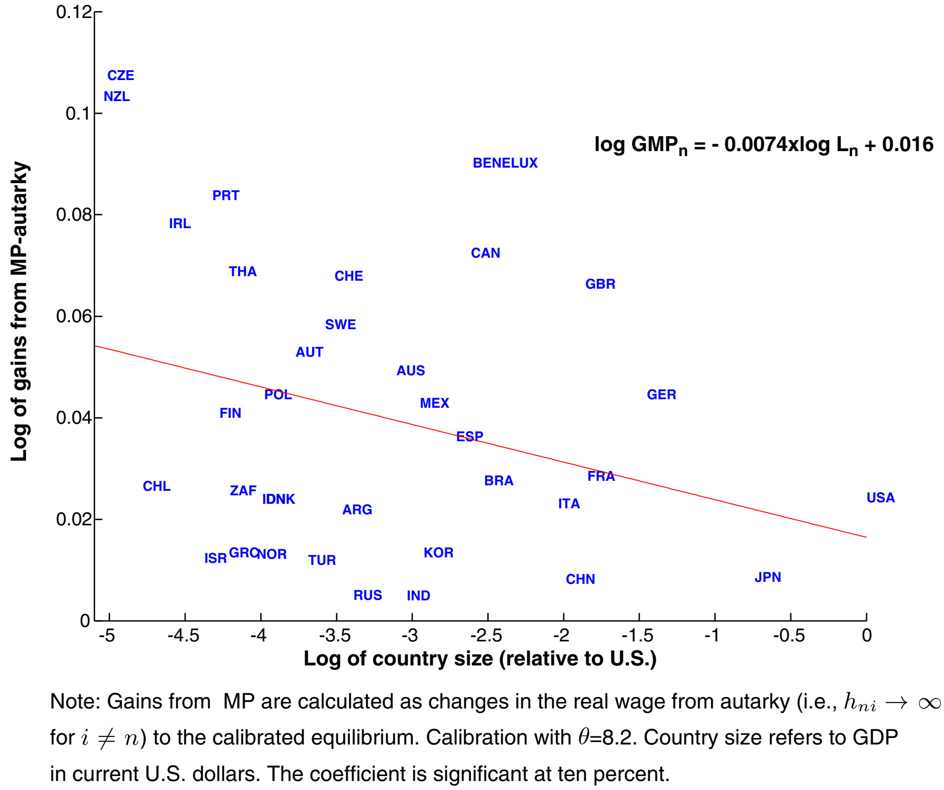

Fig. 5. Country size and the gains from MP-autarky. Note: Gains from MP are calculated as changes in the real wage from autarky (i.e., $h_{ni} \to \infty$ for $i \neq n$) to the calibrated equilibrium. Calibration with $\theta = 8.2$. Country size refers to GDP in current U.S. dollars. The coefficient is significant at 10%.

The gains from MP-autarky range from 0.4% (India) to 11% (Czech Republic). Among the richer OECD countries, the gains are larger than the gains for the remaining countries in the sample, indicating that the latter group is closer to MP-autarky than the former group. The United States has gains from MP-autarky of 2.4%, much higher than the gains from trade-autarky of 0.8% calculated by EK. This is simply because MP flows into the United States are higher than U.S. import flows. These calculations suggest that the activity of multinational firms is an important channel for the gains from openness. As expected, for $\theta = 4.2$, the calculated gains are larger.

To complement the results in Table 9 and give a better idea of the distribution of gains across countries, Fig. 5 shows the gains from MP-autarky as a function of country size (L_n). The relationship between the gains from MP-autarky and country size is negative: A regression line with robust standard errors and a constant delivers an elasticity of -0.0074 (s.e. 0.0039). Smaller countries are further away from autarky than larger countries, but the effect is not very big: Doubling size decreases the gains from MP-autarky by less than 1%. Calculations in Waugh (2010) and Fieler (2011) show that small (and rich) countries have the largest gains from trade-autarky. Even though the correlation between country size and the gains from MP-autarky is not very strong, the results in Fig. 5 suggest that openness to trade and openness to MP are correlated.

The liberalization exercises presented next are meant to illustrate the workings of the model; they are not meant to be policy experiments. Columns 3 and 4 in Table 9 present the gains, in terms of the real wage, of moving from the calibrated equilibrium to an equilibrium with 50% higher τ's and 50% lower f's for all country pairs, alternately. The largest gains are obtained when country-pair specific productivity is raised by 50% for foreign firms. In this case, the gains for the average country reach 120%, with a lower value among OECD countries and a higher one among the non-OECD countries. When fixed costs are reduced by 50%, the gains are much lower, around 13%, with the average OECD(18) country gaining more than the average non-OECD(18) country. For example, China would experience increases in the real wage of almost 80% if country-pair specific productivities were 50% higher than the ones in the equilibrium with the observed levels of MP. The same country would experience gains of only 3% if the fixed cost of opening foreign firms were reduced by 50%. Nevertheless, these three-percent gains would be sustained by revenues of foreign firms in China of more than 30% (as a share of China's GDP), much higher than the FDI shares observed in 2010 for this country.[29]

Not surprisingly, small countries gain more from liberalizing access to foreign firms than large countries do, but less so in the case of lowering the fixed cost: An OLS regression (with robust standard errors and a constant) delivers an elasticity of gains from lowering the variable MP cost of -0.11 (s.e. 0.023) with respect to country size, while the gains from lowering the fixed MP cost delivers an elasticity of -0.014 (s.e. 0.008).

Interestingly, the response of the extensive and intensive margins of MP is different for the two liberalization exercises. When the variable component of MP costs is liberalized, the average number of affiliates of firms from country i in n goes up from 83 to 480, while the average revenue per affiliate increases from \$34 to \$46 millions of current U.S. dollars, across country pairs, implying average bilateral MP flows of 6% of the host country's GDP (versus 0.95% in the baseline). When the fixed cost of MP is cut in half, the average number of affiliates, across country pairs, goes up to 291, while the average revenues per affiliate of firms from i in n goes down to \$31 millions of current U.S. dollars. The two margins combine into MP shares of 2.8%, on average, almost three times higher as the share observed in the data.

[29] FDI shares refer to FDI stocks into China, as a share of China's GDP, rather than to revenues of foreign affiliates in China (not available yet).

5.1. Comparison with the literature

How do the gains from opening up to multinational firms calculated here compare with other calculations in the literature? The closest calculations are the ones in Ramondo and Rodríguez-Clare (2013). In a model that features both trade and MP, the gains from MP are defined as the change in real wages from a counterfactual equilibrium with trade but no MP to an equilibrium with both international flows. The calculations in that paper suggest that the average gains from MP-autarky for an OECD country are around 10%. For $\theta = 4.2$ (which encompasses Ramondo and Rodríguez-Clare's (2013) estimates of θ), the model I present here delivers gains from MP-autarky of almost 10% for the same set of OECD countries. This is not, however, very surprising: Both models match MP shares as observed in the data — the key variable for calculating the gains of moving from autarky to an equilibrium with the observed MP flows.

Calibrating an only-MP model using aggregate FDI stocks into a country, Burstein and Monge-Naranjo (2009) calculate that removing taxes on foreign firms would increase a developing country's welfare by 5%, on average. The gains from lowering the costs of engaging in multinational activities would be much higher according to my calculations, especially if the variable component of MP costs were lowered. These differences might suggest that corporate tax rates applied to foreign firms represent a small part of total MP costs.[30] Finally, Garetto's (2013) calibration suggests that the losses from closing up to vertical MP would be very small for the United States – around 0.7% of consumption per capita – while the gains from liberalizing this type of MP could be around 7%. For the United States, using my calibrated model, I find that the losses from closing up to horizontal MP would be much higher – around 2% – while the gains from liberalizing horizontal MP would be of about the same magnitude as Garetto's (2013) – 8% – if the fixed cost of MP were cut in half, but almost three times higher – 20% – if the variable component of MP costs were reduced by half.

How do the gains from MP compare with the gains from trade? EK calculate a loss of moving to trade-autarky of 3.5% for an average OECD country (using $\theta = 8.3$); the analogous number for MP is almost 5%, as shown in Table 9. Since the MP flows observed in the data are larger than the trade flows, it is not surprising that the gains from autarky to the observed equilibrium are higher for MP than for trade. Using a large sample of countries, both Waugh (2010) and Fieler (2011) find that OECD countries are relatively closer to frictionless trade than non-OECD countries are, and that they are further away from autarky; their result is similar to the one I find for MP. The magnitude of the gains from MP liberalization, however, suggests that there are much larger gains to be realized from liberalizing access to foreign firms than from further liberalizing trade, a result similar to that in McGrattan and Prescott (2009).

6. Conclusions

This paper quantifies the gains that a country experiences from opening up to multinational firms. I start by examining new data on the revenues and the number of foreign affiliates of multinational firms across a large number of country pairs. As Eaton et al. (2011) do for French exporters, I document the importance of the extensive versus the intensive margin of multinational activities across countries, and I present evidence on how they react to geographical distance between partners, and to host- and source-country characteristics. While larger markets receive (and send) more and larger foreign affiliates, on average, distant markets receive fewer and smaller foreign affiliates. The extensive margin, however, reacts disproportionately more than the intensive margin to changes in distance and country size.

To capture the patterns observed in the data, I build a quantitative multi-country general equilibrium model that captures the cross-country patterns of the activity of multinational firms observed in the data. Multinational production (MP) in the model occurs when a technology that originates in a foreign country is used to produce a good in the host country. But using a foreign technology for production entails a cost that is a combination of a variable and a fixed component. The model combines Lucas's (1978) span-of-control model – which entails decreasing returns to scale and fixed costs at the firm level plus perfect competition at the industry level – with the probabilistic representation of technologies from Eaton and Kortum's (2002) model of trade. While having firms with a limited span of control allows me to distinguish between the extensive and intensive margins of multinational activities, having a probabilistic representation of technologies allows me to take the model to the multi-country data. Nevertheless, as a simplification, the modeling strategy eliminates trade altogether: Affiliates use inputs and sell their output exclusively in the host country of production.

I calibrate the model to match the patterns of both revenues and number of affiliates across different country pairs. Including both fixed and variable components of the cost of engaging in multinational activities is crucial to matching the extensive and intensive margins of MP. Results indicate that the incentives to engage in foreign production vary significantly across countries. In particular, overall, MP costs are lower among rich countries than among poorer countries, which do very little MP. But the value of the fixed cost that foreign affiliates pay in richer countries is higher, as a share of the host country's GDP, than the value they pay in poorer countries. The opposite is true for the variable component of MP costs, which is much higher in poorer countries.

I use the calibrated model to calculate the gains that a country experiences from opening up to foreign firms. My calculations suggest that the gains in real income per capita of moving from autarky to a situation with the observed MP activity would be around 4%; the gains of liberalizing access to foreign firms would be large, coming mainly from lowering the variable – rather than the fixed – component of the MP cost. Indeed, an important topic left for future research is to understand better the nature of the restrictions on foreign firms.

This paper contributes to a recent, but growing literature that attempts to quantify the gains from liberalizing international flows other than trade in goods. The focus here is on the activity of multinational firms as one key channel through which countries interact. Even though the analysis is restricted to multinational firms as the only way of serving a foreign market, the calculated gains from the activity of these firms are a benchmark to be compared with calculations coming from trade-only quantitative models.

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References

Alvarez, Fernando, Lucas, Robert E., 2007. General equilibrium analysis of the Eaton–Kortum model of international trade. J. Monet. Econ. 54 (6).
Anderson, James, van Wincoop, Eric, 2004. Trade costs. J. Econ. Lit. 42, 691–751.

[30] According to my calculations, the correlation between bilateral corporate tax rates applied to foreign firms and bilateral revenues of foreign affiliates, as a share of the host country's GDP, is very low in the cross section.

Arkolakis, Costas, Costinot, Arnaud, Rodríguez-Clare, Andres, 2012. New theories, same old gains? Am. Econ. Rev. 102 (1), 94–130.
Bernard, Andrew, Eaton, Jonathan, Jensen, J. Bradford, Kortum, Samuel, 2003. Plants and productivity in international trade. Am. Econ. Rev. 93 (4), 1268–1290.
Bloom, Nicholas, Van Reenen, John, 2007. Measuring and explaining management practices across firms and countries. Q. J. Econ. 122 (4), 1351–1408.
Burstein, Ariel, Monge-Naranjo, Alex, 2009. Foreign know-how, firm control, and the income of developing countries. Q. J. Econ. 124 (1), 149–195.
Carr, David, Markusen, James, Maskus, Keith, 2001. Estimating the knowledge-capital model of the multinational enterprise. Am. Econ. Rev. 91, 693–708.
Cooper, Russell, Haltinwanger, J., 2006. On the nature of capital adjustment costs. Rev. Econ. Stud. 73, 611–633.
Donaldson, David, 2014. Railroads of the Raj: estimating the economic impact of transportation infrastructure. Am. Econ. Rev. (forthcoming).
Eaton, Jonathan, Kortum, Samuel, 2002. Technology, geography and trade. Econometrica 70 (5), 1741–1779.
Eaton, Jonathan, Kortum, Samuel, Kramarz, Francis, 2011. An anatomy of international trade: evidence from French firms. Econometrica 79 (5), 1453–1498.
Fieler, Ana Cecilia, 2011. Non-homotheticity and bilateral trade: evidence and a quantitative explanation. Econometrica 79 (4), 1069–1101.
Garetto, Stefania, 2013. Input sourcing and multinational production. Am. Econ. J. Macroecon. 5 (2), 118–151.
Head, Keith, Ries, John, 2008. FDI as an outcome of the market for corporate control: theory and evidence. J. Int. Econ. 74 (1), 2–20.
Irarrazabal, Alfonso, Moxnes, Andreas, Opromolla, Luca D., 2013. The margins of multinational production and the role of intra-firm trade. J. Polit. Econ. 121 (1), 74–126.
Jones, Charles I., 2011. Intermediate goods and weak links in the theory of economic development. Am. Econ. J. Macroecon. 3 (2), 1–28.
Lucas, Robert, 1978. On the size distribution of business firms. Bell J. Econ. 9 (2), 508–523.
Markusen, James, 1984. Multinationals, multi-plant economies, and the gains from trade. J. Int. Econ. 16, 205–226.
Markusen, James, 1995. The boundaries of multinational enterprises and the theory of international trade. J. Econ. Perspect. 9 (2), 169–189.
McGrattan, Ellen, Prescott, E., 2009. Openness, technology capital, and development. J. Econ. Theory 144 (6), 2454–2476.
Ramondo, Natalia, Rodríguez-Clare, Andrés, 2013. Trade, multinational production, and the gains from openness. J. Polit. Econ. 121 (2), 273–322.
Ramondo, Natalia, Rodríguez-Clare, Andrés, Saborío-Rodríguez, Milagro, 2012. Scale effects and productivity across countries: does country size matter? NBER Working Paper No. 18532.
Ramondo, Natalia, Veronica Rappoport, Kim J. Ruhl, 2013. "Horizontal versus Vertical Foreign Direct Investment: Evidence from U.S. Multinationals". Mimeo.
Ramondo, Natalia, Rodríguez-Clare, Andrés, Tintelnot, Felix, 2013b. Multinational Production Data Set.
Razin, Assaf, Rubinstein, Yona, Sadka, Efraim, 2003. Which countries export FDI, and how much? NBER Working Paper No. 10145.
Rodríguez-Clare, Andrés, 2007. "Trade, Diffusion, and the Gains from Openness". Unpublished.
Simonovska, Ina, Waugh, Michael, 2014. The elasticity of trade: estimates and evidence. J. Int. Econ. 92 (1), 34–50.
UNCTAD, 2009. The World Investment Report.
Waugh, Michael, 2010. International trade and income differences. Am. Econ. Rev. 100 (5), 2093–2124.