Trade, Multinational Production, and the Gains from Openness

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This paper quantifies the gains from openness arising from trade and multinational production (MP). We present a model that captures key dimensions of the interaction between these two flows: trade and MP are competing ways to serve a foreign market, MP relies on imports of intermediate goods from the home country, and foreign affiliates of multinationals can export part of their output. The calibrated model implies that the gains from trade can be twice as high as the gains calculated in trade-only models, while the gains from MP are slightly lower than the gains computed in MP-only models.

I. Introduction

There is an extensive literature on the gains that countries derive from interacting with each other. The attention has been focused on quantifying the gains from single mechanisms in isolation, especially trade in

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goods (e.g., Eaton and Kortum 2002) and, to a lesser extent, foreign direct investment (FDI), or multinational production (MP) (e.g., Burstein and Monge-Naranjo 2009; McGrattan and Prescott 2009; Ramondo 2012).[1] Much less attention has been given to the quantification of the gains from openness when countries interact through both trade and MP. This is an important omission in light of the strong interactions that exist between trade and MP and given that trade agreements often combine tariff reductions and removal of barriers to MP. In this paper, we construct and calibrate a general equilibrium multicountry model of trade and MP. Because of the rich interactions between these two flows in our model, we find higher gains from trade than in existing trade-only models, while our computed gains from MP are slightly lower than those in models with only MP.

We build on the Ricardian model of international trade developed by Eaton and Kortum (2002). Our main innovation is to incorporate MP into the model by allowing a country's technologies to be used for production abroad. The model has tradable intermediate goods and nontradable consumption goods, as in Alvarez and Lucas (2007). For nontradable goods, serving a foreign market can be done only through MP, but for tradable goods we have to consider the choice between exports and MP.[2] Trade flows are affected by iceberg-type costs that may vary across country pairs. To avoid these costs, or to benefit from lower production costs abroad, firms producing tradable goods may prefer to serve a foreign market through MP rather than through exports. We assume that MP entails some efficiency losses that may vary across country pairs. Further, we allow for the possibility that multinationals' foreign affiliates use imported inputs from their home country; in our empirical approach, we think of this as intrafirm trade.[3] Our setup also allows firms to use a third country as a "bridge," or export platform, to serve a particular market; we refer to this as bridge MP, or simply BMP. For example, a firm from country i producing a tradable good can serve country n by doing MP in country l and shipping it to country n. This entails

[1] Multinational production measures the sales of foreign affiliates of multinational firms. This is arguably at least as important as trade: For example, in 2007, total worldwide MP was almost twice as high as total world exports (UNCTAD 2009).

[2] A significant part of MP flows is in nontradable goods. Around 50 percent of the value of production by US affiliates of foreign multinationals is in sectors other than manufacturing, agriculture, and mining (our own calculations from the Bureau of Economic Analysis [BEA]). Additionally, according to UNCTAD (2009), in 2007, FDI stocks in the service sector represented more than 60 percent of the total stock in developed countries.

[3] The empirical evidence points to significant intrafirm trade flows related to multinational activities (Bernard, Jensen, and Schott 2005; Hanson, Mataloni, and Slaughter 2005; Alfaro and Charlton 2009). According to our own calculations using data from the BEA, intrafirm imports from their headquarters represent more than 7.5 percent of total gross production done by foreign affiliates of American multinationals.

MP costs associated with the pair $\{i, l\}$ as well as trade costs associated with the pair $\{l, n\}$.[4]

Our model captures several dimensions of the complex interaction between trade and MP. First, as in models of "horizontal" FDI (e.g., Horstmann and Markusen 1992; Brainard 1997; Markusen and Venables 2000; Helpman, Melitz, and Yeaple 2004), trade and MP are competing ways to serve a foreign market.[5] This implies that an increase in trade costs generates smaller welfare losses, as MP partially replaces the decline in trade. Second, as in models of "vertical" FDI (e.g., Helpman [1984, 1985] and, more recently, Keller and Yeaple [2010]), the reliance by foreign affiliates on imports of home country inputs implies that MP boosts trade and trade facilitates MP.[6] This complementarity between trade and MP implies that an increase in trade costs leads to larger welfare losses through an indirect negative impact on MP. Finally, complementarity between trade and MP also arises in our model because of the presence of BMP: since BMP flows entail both trade and MP flows, an increase in trade costs decreases MP associated with BMP and generates larger losses.

The existence of these forces of substitutability and complementarity between trade and MP implies that models with only trade and models with only MP may generate inaccurate estimates of the gains from trade and MP.[7] If complementarity forces dominate, for example, the gains from trade calculated in trade-only models will be lower than those in our model, which takes appropriate account of such forces by calculating the gains from trade as the increase in real income as we move from a counterfactual situation with only MP to the equilibrium with both trade and MP. Similarly, the gains from MP calculated in MP-only models may also be incorrect. An important goal in this paper is to gauge the strength of substitutability and complementarity forces and then to explore their effect on the gains from trade and MP.

[4] Foreign subsidiaries of multinationals often sell a sizable part of their output outside of the host country of production. For example, US affiliates in Europe export, on average, 30 percent of their output (Blonigen 2005).

[5] Studies using firm-level data find evidence of such substitutability between trade and MP when considering narrow product lines (see Belderbos and Sleuwaegen 1988; Head and Ries 2001, 2004; Barba Navaretti and Venables 2004). For example, the increased presence of Japanese automakers in the United States accompanied a decline in automobile exports from Japan (Head and Ries 2001).

[6] Several studies find that higher FDI leads to an increase in exports of parts and supplies from the home country to foreign affiliates (see Belderbos and Sleuwaegen 1998; Blonigen 2001; Head and Ries 2001; Barba Navaretti and Venables 2004; Head, Ries, and Spencer 2004).

[7] Gains from trade (MP) are defined as the increase in the real wage from the counterfactual equilibrium when trade (MP) costs are taken to infinity to the benchmark equilibrium. For estimates of gains from trade in trade-only models, see Eaton and Kortum (2002), Alvarez and Lucas (2007), Waugh (2010), and Fieler (2011). For estimates of gains from MP in MP-only models, see Burstein and Monge-Naranjo (2009), McGrattan and Prescott (2009), and Ramondo (2012).

We calibrate the model using data on bilateral trade and MP flows for a set of OECD countries, as well as data on intrafirm trade flows for US multinationals and foreign multinationals operating in the United States. For countries with high inward MP flows, the gains from trade calculated with our model can be much higher than the gains calculated in trade-only models.[8] For example, the gains from trade implied by our model for New Zealand are between 8 and 10 percent, whereas trade-only models imply gains of around 4 percent. The reason is that trade facilitates MP by allowing multinationals' foreign affiliates to import inputs from their home country. Of course, the fact that trade and MP are competing ways to serve foreign markets tends to make the gains from trade in our model lower than in trade-only models, but the large imports of home country inputs by foreign affiliates observed in the data imply that complementarity forces dominate in the model. Since MP entails the sharing of technologies across countries, the result that trade facilitates MP captures the common but largely informal notion that trade enhances international technology diffusion.[9] In contrast to this result for the gains from trade, the gains from MP calculated in our calibrated model are slightly lower than the gains computed in MP-only models. The reason is that in our model, the substitutability forces associated with the fact that trade and MP are competing ways of serving a foreign market dominate the complementarity forces created by BMP.

Our model is, in principle, consistent with the notion that the reallocation of production to foreign countries by US multinationals could depress US wages because outward MP could lead to a decline in US exports, worsening its terms of trade.[10] But there are two countervailing forces: First, outward MP generates a demand for intermediate-good exports from the United States to foreign subsidiaries of US multinationals, and, second, outward MP increases worldwide productivity, and this benefits consumers everywhere and in the United States. Our calibrated model shows that these two positive forces roughly balance the negative terms of trade force for the United States, and, hence, outward MP has basically no net effect on the US real wage.

[8] Our results for trade-only models are derived from our model by driving MP costs to infinity. These results are equivalent to those of Arkolakis, Costinot, and Rodríguez-Clare (2012), who show that for an important class of models, the gains from trade are given by a simple formula combining the share of total expenditures devoted to domestic goods (an inverse measure of trade openness) and the elasticity of trade flows with respect to trade costs.

[9] Yet, our model does not incorporate any causal link whereby trade or MP enhances international knowledge spillovers. The related literature is surveyed in Keller (2004).

[10] Similar ideas have been presented in relation to the debate about offshoring by rich countries; see Samuelson (2004) and Rodríguez-Clare (2010). See also the empirical work on the effect of outward FDI on employment in the United States by Harrison and McMilan (2011) and in Germany by Becker and Muendler (2010).

The models that come closest to the one we present here are Garetto (forthcoming) and Irarrazabal, Moxnes, and Opromolla (2013). Garetto develops a model in which multinationals from the rich country produce intermediate goods in low-wage locations and then ship those goods back home for final assembly and consumption (there is no BMP). Garetto's model entails an extreme type of complementarity between trade and MP: without trade there would be no MP. Irarrazabal et al. introduce intrafirm trade into Helpman et al.'s (2004) "proximity-concentration trade-off" model of trade and MP to explain the high correlation observed between these two flows across country pairs. The model does not allow for multinationals' foreign affiliates to export their production (there is no BMP). Consistent with our results, Irarrazabal et al. find gains from MP that are smaller than the gains that would be computed in models with only MP, again, because of the substitutability forces between trade and MP. But the absence of BMP implies that the gains from MP computed by Irarrazabal et al. are significantly lower than the ones we calculate using our model.

We acknowledge that countries could be gaining from openness in ways other than through trade and MP. In particular, technologies originated in one country may be used in other countries in ways that are not recorded as MP. This happens, for example, if US technologies are used for production in Canada by Canadian firms. This way of sharing technologies is partly captured as royalties and license fees from unaffiliated foreign sources, but, for the most part, this leaves no clear paper trail.[11] Klenow and Rodríguez-Clare (2005), Rodríguez-Clare (2007), and Ramondo and Rodríguez-Clare (2010) all follow indirect model-based approaches to compute gains from openness that, in principle, include all ways through which countries share technologies. In contrast, the approach in this paper is to restrict our attention to the gains from openness that take place through trade and MP, which have clear counterparts in the data.

II. The Model

We extend Eaton and Kortum's (2002) model of trade to incorporate MP. Our model is Ricardian with a continuum of tradable intermediate goods and nontradable final goods, produced under constant returns to scale. We adopt the probabilistic representation of technologies as first introduced by Eaton and Kortum, but we enrich it to incorporate MP.

[11] According to the BEA, total income earned by US multinationals from their foreign affiliates amounted to $325 billion in 2009, whereas in that same year, US income via royalties and license fees from unaffiliated foreign sources amounted to a comparatively low $31 billion.

We embed the model into a general equilibrium framework similar to the one in Alvarez and Lucas (2007).

A. *The Closed Economy*

To introduce the notation and main features of our model, consider, first, a closed economy with L units of labor. A representative agent consumes a continuum of final goods indexed by $u \in [0, 1]$ in quantities $q^f(u)$. Preferences over final goods are constant elasticity of substitution (CES) with elasticity $\sigma^f > 0$. Final goods are produced with labor and a continuum of intermediate goods indexed by $v \in [0, 1]$. Formally, intermediate goods in quantities $q^g(v)$ are aggregated into a *composite intermediate good* via a CES production function with elasticity $\sigma^g > 0$. (Note that we use superscripts f and g to denote variables pertaining to final and intermediate goods, respectively.) For simplicity, we henceforth assume that $\sigma^g = \sigma^f = \sigma$. Denoting as Q the total quantity of the composite intermediate good produced, we have

$$Q = \left[\int_0^1 q^g(v)^{(\sigma-1)/\sigma} dv\right]^{\sigma/(\sigma-1)}.$$

The composite intermediate good and labor are used to produce final goods via Cobb-Douglas technologies:

$$q^f(u) = z^f(u) L^f(u)^{\alpha} Q^f(u)^{1-\alpha}. \tag{1}$$

The variables $L^f(u)$ and $Q^f(u)$ denote the quantity of labor and the composite intermediate good used in the production of final good u, respectively, and $z^f(u)$ is a productivity parameter for good u. Similarly, intermediate goods are produced according to

$$q^g(v) = z^g(v) L^g(v)^{\beta} Q^g(v)^{1-\beta}. \tag{2}$$

Resource constraints are

$$\int_0^1 L^f(u) du + \int_0^1 L^g(v) dv = L,$$
$$\int_0^1 Q^f(u) du + \int_0^1 Q^g(v) dv = Q.$$

To complete the description of the environment in the closed economy, the productivity parameters $z^f(u)$ and $z^g(v)$ are drawn independently from a Fréchet distribution with parameters T and $\theta > \max\{1, \sigma - 1\}$, namely, $F(z) = \exp(-Tz^{-\theta})$ for $z > 0$.

To describe the competitive equilibrium for this economy, it is convenient to introduce the notions of an *input bundle for the production of final goods* and an *input bundle for the production of intermediate goods*, both of which are produced via Cobb-Douglas production functions with labor and the composite intermediate good and used to produce final and intermediate goods, as specified in (1) and (2), respectively. The unit cost of the input bundle for final goods is $c^f = Aw^{\alpha}(P^g)^{1-\alpha}$, and the unit cost of the input bundle for intermediate goods is $c^g = Bw^{\beta}(P^g)^{1-\beta}$, where w and P^g are the wage and the price of the composite intermediate good, respectively, and A and B are constants that depend on α and β, respectively. In a competitive equilibrium, prices of final goods are given by $p^f(u) = c^f/z^f(u)$, and prices of intermediate goods are given by $p^g(v) = c^g/z^g(v)$. In turn, the aggregate price for intermediates is $P^g = [\int_0^1 p^g(v)^{1-\sigma}dv]^{1/(1-\sigma)}$. Figure 1 illustrates the cost structure in the closed economy.

The characterization of the equilibrium closely follows the analysis in Eaton and Kortum (2002) and Alvarez and Lucas (2007), so we omit the details. Suffice it to say here that the equilibrium real wage is given by

$$\frac{w}{P^f} = \tilde{\gamma} \cdot T^{(1+\eta)/\theta}, \tag{3}$$

where $P^f = [\int_0^1 p^f(u)^{1-\sigma}du]^{1/(1-\sigma)}$ is the price index for final goods, $\eta \equiv (1-\alpha)/\beta$, and $\tilde{\gamma}$ is a positive constant.

B. *The World Economy*

Now consider a set of countries indexed by $i \in \{1, \dots, I\}$ with preferences and technologies as described above. Country i has L_i units of labor.

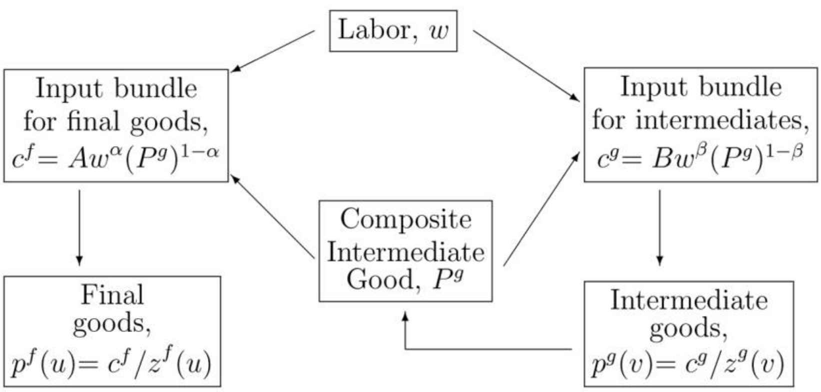

FIG. 1.—Cost structure in the closed economy

Multinational production.—Each country i has a technology to produce each final good and each intermediate good, at home or abroad. These technologies are described by the vectors $\mathbf{z}_i^f(u) \equiv \{z_{1i}^f(u), \ldots, z_{Ii}^f(u)\}$ and $\mathbf{z}_i^g(v) \equiv \{z_{1i}^g(v), \ldots, z_{Ii}^g(v)\}$. When a country i produces in another country $l \neq i$, we say that there is multinational production or MP by country i in country l. Sometimes, we also say that MP in country l is carried out by country i's "multinationals." The corresponding productivity parameter in this case is $z_{li}^f(u)$ or $z_{li}^g(v)$. We adopt the convention that the subscript n denotes the destination country, subscript l denotes the country of production, and subscript i denotes the country in which the technology originates. Note that if $z_{li}^f(u) = z_{li}^g(v) = 0$ whenever $l \neq i$, for all $u, v \in [0, 1]$, our model becomes virtually identical to Alvarez and Lucas's (2007) version of Eaton and Kortum's (2002) model of trade with no MP.[12]

Trade and MP costs.—Intermediate goods are tradable, but final goods are not. Trade is subject to iceberg-type costs: $d_{nl} \geq 1$ units of any good must be shipped from country l for one unit to arrive in country n. We assume that $d_{nn} = 1$ for all n and that the triangle inequality holds: $d_{nl} \leq d_{nj} d_{jl}$ for all n, l, j. Similarly, MP is subject to costs that we model as iceberg-type efficiency losses. Letting c_{li}^f and c_{li}^g denote the unit costs of the input bundle for final and intermediate goods in country l for firms from country i, respectively, MP costs imply that c_{li}^s may be different from $c_l^s \equiv c_{ll}^s$ for $l \neq i$ and $s = f, g$. When trade and MP costs are taken into account, the unit cost of a final good u in country n produced with a technology from country i is $c_{ni}^f / z_{ni}^f(u)$, while the unit cost of an intermediate good v in country n produced in country l with a technology from country i is $c_{li}^g d_{nl} / z_{li}^g(v)$.

We now provide additional detail about our assumptions regarding MP costs. For final goods, we simply assume that there is an iceberg cost $h_{li}^f \geq 1$ associated with using a technology from i to produce in l, with $h_{ii}^f = 1$ for all i. This implies that $c_{li}^f = c_l^f h_{li}^f$ while $c_l^f = A w_l^{\alpha} (P_l^g)^{1-\alpha}$. For intermediate goods, we assume that MP requires the use of what we call a *multinational input bundle for the production of intermediate goods.* In particular, we assume that the multinational input bundle combines the national input bundle from the home country (i.e., the country where the technology originates) and the host country (i.e., the country where production takes place). The home country's national input bundle must be shipped to the host country, and this implies paying the corre-

[12] We say "virtually identical" rather than "identical" because our model exhibits varying productivity levels across a continuum of final goods, whereas in Alvarez and Lucas's (2007) model there is a single final good. In our model, T also affects the productivity of final goods. Hence, while in Alvarez and Lucas's model the real wage is proportional to $T^{\eta/\theta}$, in our setup, the real wage is proportional to $T^{(1+\eta)/\theta}$ (in Eaton and Kortum [2002], the real wage is proportional to $T^{1/\beta\theta}$ since they do not have nontradable goods).

sponding transportation cost. The unit cost of the home country's national input bundle used in MP by country i in country l is then $c_i^g d_{li}$. The host country's national input bundle has unit cost c_l^g, but MP in intermediates incurs an efficiency loss of $h_{li}^g \geq 1$, so the unit cost of the host country's national input used in MP by i in l is $c_l^g h_{li}^g$. When the costs of the home and host countries' national input bundles are combined into a CES aggregator, the unit cost of the multinational input bundle for intermediates produced by i in l is

$$c_{li}^g = [(1-a)(c_l^g h_{li}^g)^{1-\xi} + a(c_i^g d_{li})^{1-\xi}]^{1/(1-\xi)}, \quad (4)$$

where $a \in [0, 1]$ and $\xi > 1$. Note that $c_{ii}^g = c_i^g = Bw_i^\beta (P_i^g)^{1-\beta}$. Moreover, if $a = 0$, then $c_{li}^g = c_l^g h_{li}^g$. The parameter ξ indicates the degree of substitutability between the national input bundles from the home and host countries.

Productivity distributions.—We assume that the productivity vectors $\mathbf{z}_i^f(u)$ and $\mathbf{z}_i^g(v)$ for each good are random variables that are drawn independently across goods and countries from a multivariate Fréchet distribution with parameters T_i, $\theta > \max\{1, \sigma - 1\}$, and $\rho \in [0, 1)$, namely,

$$F(\mathbf{z}_i^s; T_i) = \exp\left\{-T_i \left[\sum_l (z_{li}^s)^{-\theta/(1-\rho)}\right]^{1-\rho}\right\} \quad (5)$$

for $s = f, g$.[13] Note that

$$\lim_{x\to\infty} F(x, x, \ldots, z_{li}^s, \ldots, x; T_i) = \exp[-T_i (z_{li}^s)^{-\theta}],$$

so that the marginal distributions are Fréchet. The parameter ρ determines the degree of correlation among the elements of $\mathbf{z}_i^s$: if $\rho = 0$, productivity levels are uncorrelated across production locations, while in the limit as $\rho \to 1$ they are perfectly correlated, so that productivity is independent of the location of production (i.e., $z_{ii}^s = z_{li}^s$, for all l).

C. Equilibrium Analysis

In a competitive equilibrium, the price of final good u in country n is simply the minimum unit cost at which this good can be obtained, $p_n^f(u) = \min_i c_{ni}^f / z_{ni}^f(u)$. Similarly, the price of intermediate good v in country n is $p_n^g(v) = \min_{i,l} c_{li}^g d_{nl} / z_{li}^g(v)$. Note that if $l = i$, then the intermediate good is exported from i to n, while if $i \neq l = n$, there is MP from i to n. Finally, if $i \neq l$ and $l \neq n$, then country i uses country l as an export platform to serve country n. We say that, in this case, there is bridge MP, or simply BMP, by country i in country l.

[13] This distribution is discussed in Eaton and Kortum (2002, n. 14).

Recall that in Eaton and Kortum (2002), the allocation of expenditures across exporters is elegantly characterized by simple formulas of the technology parameters, unit costs, and trade costs. Thanks to the assumption that technologies are distributed according to the multivariate Fréchet distribution, this property extends in a natural way in our model to the allocation of expenditures across technology sources and production locations (see App. A). For final (nontradable) goods, the result is quite simple: The share of expenditures by country n on final goods produced in country n with country i technologies is

$$\pi^f_{ni} = \frac{T_i(c^f_{ni})^{-\theta}}{\sum_j T_j(c^f_{nj})^{-\theta}}. \quad (6)$$

For intermediate (tradable) goods, we need to take into account all the different ways in which they can be made available to a particular country. As shown in Appendix A, the share of expenditures by country n on intermediate goods produced in country l with country i technologies is

$$\pi^g_{nli} = \frac{T_i(\tilde{c}^g_{ni})^{-\theta}}{\sum_j T_j(\tilde{c}^g_{nj})^{-\theta}} \frac{(c^g_{li} d_{nl})^{-\theta/(1-\rho)}}{\sum_k (c^g_{ki} d_{nk})^{-\theta/(1-\rho)}}, \quad (7)$$

where $\tilde{c}^g_{ni} \equiv [\sum_k (c^g_{ki} d_{nk})^{-\theta/(1-\rho)}]^{-(1-\rho)/\theta}$.[14] This expression has a natural interpretation: The first term on the right-hand side is the share of expenditures that country n allocates to intermediate goods produced with country i's technologies (independently of the location where they are produced), while the second term on the right-hand side is the share of these goods that are produced in country l. The price index for final ($s = f$) and intermediate ($s = g$) goods is given by

$$P^s_n = \gamma \left[\sum_i T_i(\tilde{c}^s_{ni})^{-\theta} \right]^{-1/\theta}, \quad (8)$$

where $\tilde{c}^f_{ni} = c^f_{ni}$ and γ is a positive constant.[15]

We next use the previous results to characterize trade and MP flows and present the trade balance conditions.[16]

Country n's total expenditures on final goods are equal to the country's total income, $w_n L_n$, while its total expenditures on intermediate

[14] Note that when $d_{nl} \to \infty$ for $n \neq l$, $\tilde{c}^g_{ni} = c^g_{ni}$ and $\pi^g_{nni} = T_i(c^g_{ni})^{-\theta}/\sum_j T_j(c^g_{nj})^{-\theta}$, just as in the case of final goods.

[15] The constant $\gamma \equiv \Gamma(1 + (1 - \sigma)/\theta)^{1/(1-\sigma)}$, where $\Gamma(\cdot)$ is the gamma function.

[16] The trade balance conditions are the appropriate equilibrium conditions given that MP entails no profits under perfect competition.

goods are proportional to the country's total income: $P_n^g Q_n = \eta w_n L_n$ for all n (see App. A). The value of MP in final goods by i in n is then

$$Y_{ni}^f = \pi_{ni}^f w_n L_n, \tag{9}$$

while the value of MP in intermediates by country i in country l to serve country n is $\pi_{nli}^g \eta w_n L_n$. Thus, MP in intermediates by i in l is

$$Y_{li}^g = \eta \sum_n \pi_{nli}^g w_n L_n. \tag{10}$$

Total imports by n from l are given by the imports of intermediate goods produced in l with technologies from any other country, $\eta \sum_i \pi_{nli}^g w_n L_n$, plus the imports of country l's input bundle for intermediates used by country l's multinationals operating in country n. For concreteness, we refer to the first type of trade as arm's-length and the second type of trade as intrafirm. To compute intrafirm trade flows, let ω_{nl} be the cost share of the home country's input bundle for the production of intermediates in country n by multinationals from country l. From equation (4), $\omega_{nl} = a(c_l^g d_{nl}/c_{nl}^g)^{1-\xi}$. The value of imports of the input bundle for intermediates by n from l associated with MP by l in n is $\omega_{nl} Y_{nl}^g$. Total imports by country n from $l \neq n$ are then given by the sum of arm's-length trade and intrafirm trade,

$$X_{nl} = \eta \sum_i \pi_{nli}^g w_n L_n + \omega_{nl} Y_{nl}^g. \tag{11}$$

The trade balance condition for country n is

$$\sum_{l \neq n} X_{nl} = \sum_{l \neq n} X_{ln}. \tag{12}$$

Since c_{li}^g is a function of wages $\boldsymbol{w} = (w_1, \ldots, w_I)$ and price indices $\boldsymbol{P}^g = (P_1^g, \ldots, P_I^g)$, then so are $\tilde{c}_{ni}^g$, π_{nli}^g, Y_{nl}^g, and X_{nl}. The price index equations (8) for $s = g$ and the trade balance equations (12) can then be used to determine the equilibrium wages and price indices in this economy.[17]

For the calibration of our model, a key target will be the trade elasticity, defined as the partial elasticity of relative trade flows with respect to relative trade costs, $\partial \ln(\hat{X}_{nl}/\hat{X}_{nn})/\partial \ln d_{nl}$. Quantitative trade models

[17] To compute the equilibrium, we follow an algorithm similar to the one proposed by Alvarez and Lucas (2007). In particular, we use the set of equations associated with (8) for $s = g$ and $n = \{1, \ldots, I\}$ to determine a function $P^g(\boldsymbol{w})$: $I \rightarrow I$. Together with $P^g(\boldsymbol{w})$, eq. (8) for $s = f$ also defines a function $P^f(\boldsymbol{w})$ for the price index of final goods. Using the function $P^g(\boldsymbol{w})$, we can think of the trade balance conditions in (12) as a system of I equations in $\boldsymbol{w}$. This system of equations, together with some normalization of wages, yields an equilibrium wage vector $\boldsymbol{w}$. The functions $P^g(\boldsymbol{w})$ and $P^f(\boldsymbol{w})$ then determine the price indices for intermediate and final goods, respectively, in all countries.

such as those of Eaton and Kortum (2002), Anderson and van Wincoop (2003), and Eaton, Kortum, and Kramarz (2011) all exhibit the useful feature that this elasticity is common across countries and equal to a structural parameter coming from preferences or technology. If we shut down MP in our model, then the trade elasticity would be given by the distribution parameter θ (as in Eaton and Kortum [2002]). In the presence of MP, however, the trade elasticity is not a constant in our model. There are two reasons for this. First, arm's-length and intrafirm trade flows are subject to two different elasticities with respect to trade costs: the distribution parameter θ and the elasticity of substitution between home and host countries' input bundles for MP, $\xi - 1$. Second, if $\rho > 0$, there is positive correlation among the productivity parameters associated with source country i ($z^g_{1i}, z^g_{2i}, \ldots, z^g_{Ii}$), whereas there is no correlation among the productivity parameters associated with production location l ($z^g_{l1}, z^g_{l2}, \ldots, z^g_{lI}$).

An interesting case arises if $\rho = 0$. For this special case, arm's-length trade flows, defined as $\hat{X}_{nl} \equiv X_{nl} - \omega_{nl} Y^g_{nl}$, satisfy a gravity equation similar to that in Eaton and Kortum (2002), except that the technology in each country is "augmented" by the possibility of MP:

$$\hat{X}_{nl} = \frac{\tilde{T}^g_l (c^g_l d_{nl})^{-\theta}}{\sum_k \tilde{T}^g_k (c^g_k d_{nk})^{-\theta}} \eta w_n L_n. \tag{13}$$

Here, $\tilde{T}^g_l \equiv \sum_i T_i (h^g_{li})^{-\theta}$ is an augmented technology parameter for the production of intermediate goods in country l that takes into account the possibility of using technologies from other countries, appropriately discounted by the efficiency losses h^g_{li}. This implies that country l's normalized import share in country n depends only on the trade cost d_{nl} and the price indices P^g_n and P^g_l:

$$\frac{\hat{X}_{nl}/\eta w_n L_n}{\hat{X}_{ll}/\eta w_l L_l} = \left(\frac{d_{nl} P^g_l}{P^g_n}\right)^{-\theta}. \tag{14}$$

This equation is exactly like the one in Eaton and Kortum (2002); see their equation (12). In the case with $\rho = 0$, MP flows also satisfy a gravity-like relationship. In Appendix A, we describe in detail this relationship.[18]

In general, for $\rho \neq 0$ and given that trade data include intrafirm trade (i.e., we have data for X_{nl} and not for $\hat{X}_{nl}$), our calibration procedure will use the trade elasticity as a target, but this will pin down θ only indirectly together with all the other parameters.

[18] Another interesting special case arises when MP costs are zero or separable (i.e., $h^g_{li} = \kappa_l \mu_i$, for all l, i), in which case the trade elasticity is $\theta/(1-\rho)$.

D. Gains from Trade, MP, and Openness

In this paper, we are particularly interested in quantifying the country-level gains from trade, MP, and openness. We first establish some terminology.

The gains from openness for country n (GO_n) are given by the proportional change in country n's real wage, w_n/P_n^f, as we move from a counterfactual equilibrium characterized by isolation, which attains when trade and MP costs are infinite (d_{nl}, $h_{li}^s \to \infty$ for all $n \neq l$, $l \neq i$, and $s = f, g$), to the actual equilibrium.

The gains from trade for country n (GT_n) are given by the proportional change in w_n/P_n^f as we move from the counterfactual equilibrium with MP but no trade (actual h_{li}^s for all l, i and $s = f, g$ but $d_{nl} \to \infty$ for all $n \neq l$) to the actual equilibrium.

Similarly, the gains from MP for country n (GMP_n) are given by the proportional change in w_n/P_n^f as we move from the counterfactual equilibrium with trade but no MP (actual d_{nl} for all n, l but $h_{li}^s \to \infty$ for all $l \neq i$ and $s = f, g$) to the actual equilibrium. The gains from MP can be decomposed into those that arise from MP in intermediates, GMP_n^g, and those that arise from MP in final goods, GMP_n^f, with $GMP_n = GMP_n^f \times GMP_n^g$.

We are interested in comparing GT_n and GMP_n with the gains that would be computed in models with only trade and models with only MP. We label these gains GT_n^* and GMP_n^*, respectively. Formally, GT_n^* is the proportional change in country n's real wage as we move from a counterfactual equilibrium characterized by isolation to an equilibrium with no MP but with the same trade flows as in the actual equilibrium. Analogously, GMP_n^* is the proportional change in country n's real wage as we move from a counterfactual equilibrium characterized by isolation to an equilibrium with no trade but with the same MP flows as in the actual equilibrium.[19]

The following lemma establishes that GT_n^* and GMP_n^* can be calculated as simple formulas from trade and MP shares, respectively.

Lemma 1. The gains from trade and the gains from MP in trade-only and MP-only models, respectively, can be directly calculated from trade and MP shares as follows:

$$GT_n^* = \left(X_{nn} / \sum_j X_{nj} \right)^{-\eta/\theta}, \tag{15}$$

[19] Of course, the trade (MP) costs necessary to yield the same trade (MP) flows as in the actual equilibrium may be different in a trade-only (MP-only) model than in our model with trade and MP.

$$\mathrm{GMP}_n^{g*} = \left(Y_{nn}^g / \sum_j Y_{nj}^g\right)^{-\eta/\theta}, \tag{16}$$

$$\mathrm{GMP}_n^{f*} = \left(Y_{nn}^f / \sum_j Y_{nj}^f\right)^{-1/\theta}, \tag{17}$$

with the total gains from MP given by $\mathrm{GMP}_n^* = \mathrm{GMP}_n^{g*} \times \mathrm{GMP}_n^{f*}$.

The formula for the gains from trade as a function of normalized trade flows in equations (15) is very similar to Eaton and Kortum's (2002) equation (15) and exactly the same as the one in Alvarez and Lucas (2007). The formula is also consistent with the results in Arkolakis, Costinot, and Rodríguez-Clare (2012). The formulas in equations (16) and (17) can be seen as natural extensions of these same ideas for the computation of the gains for MP in MP-only models.

One of the main results of our paper is that GT_n can be higher or lower than GT_n^* because of the substitutability and complementarity forces that exist between trade and MP. If $\mathrm{GT}_n > \mathrm{GT}_n^*$, then we say that trade is an MP complement: the gains from trade are higher than the ones that would be computed in trade-only models because trade also leads to gains by facilitating MP. On the contrary, if $\mathrm{GT}_n < \mathrm{GT}_n^*$, then we say that trade is an MP substitute: the gains from trade are lower than the ones that would be computed in trade-only models because trade decreases the gains from MP. If $\mathrm{GT}_n = \mathrm{GT}_n^*$, then we say that trade is MP independent.

Analogously, if $\mathrm{GMP}_n < \mathrm{GMP}_n^*$, then we say that MP is a trade substitute, while if $\mathrm{GMP}_n > \mathrm{GMP}_n^*$ ($\mathrm{GMP}_n = \mathrm{GMP}_n^*$), then we say that MP is a trade complement (trade independent).

E. *Three Special Cases*

Before we present the calibration of the full model in the next section, it is instructive to consider three special cases for which we can derive analytical results: (1) the case with $a = \rho = 0$ (i.e., no imports of home inputs associated with MP and no correlation across productivity in different locations), (2) the case of symmetric countries, and (3) the case of a rich and a poor country with $a = 0$ and frictionless trade. All proofs are in Appendix A.

1. $a = \rho = 0$

The following proposition establishes that if $a = \rho = 0$, then trade is MP independent.

Proposition 1. Assume that $a = \rho = 0$. Then, trade is MP independent in the sense that $\mathrm{GT}_n = \mathrm{GT}_n^*$. Moreover, $\mathrm{GO}_n = \mathrm{GT}_n^* \times \mathrm{GMP}_n^*$.

To understand this result, recall that our model captures two opposite forces affecting the relationship between trade and MP. First, trade tends to be an MP complement because of the need to import home country intermediate goods by multinationals' foreign subsidiaries. Second, trade tends to be an MP substitute because trade and MP are alternative ways to serve a particular market. The first force is not present if $a = 0$ because in this case, foreign subsidiaries do not demand home country intermediate goods. The second force is not present if $\rho = 0$ because with no correlation across productivities in different locations, there is, in a sense, no longer a technology that can be used in different countries. Proposition 1 implies that if $a = \rho = 0$, then it would be valid to use the trade-only model to compute gains from trade. Moreover, as the last part of the proposition establishes, one can use the trade-only and MP-only models jointly to compute the overall gains from openness since $GO_n = GT_n^* \times GMP_n^*$.

In contrast to the result that trade is MP independent, parameters $a = \rho = 0$ do not imply that MP is trade independent. Let bilateral trade shares be denoted by $\lambda_{nl} \equiv X_{nl}/\sum_j X_{nj}$, and let $\bar{\lambda}_{nn}$ be the domestic trade share in the counterfactual equilibrium with trade but no MP. The following proposition establishes the relationship between GMP_n and GMP_n^* for this case.

PROPOSITION 2. Assume that $a = \rho = 0$. Then

$$GMP_n = GMP_n^*(\lambda_{nn}/\bar{\lambda}_{nn})^{-\eta/\theta}.$$

Two simple examples illustrate this result. In both examples, there are two countries labeled North (N) and South (S). The first example has $T_N > 0$ but $T_S = 0$. The equilibrium in this case entails MP by North in South but no MP by South in North. Since South has no technologies of its own, there would be no trade in the counterfactual equilibrium with no MP; hence, $\bar{\lambda}_{NN} = 1$. But $\lambda_{NN} < 1$ in the actual equilibrium. This implies that $\lambda_{NN} < \bar{\lambda}_{NN}$; hence, from proposition 2, we see that $GMP_N > GMP_N^*$, so MP is a trade complement for North. This example captures the gains from BMP for North, which can satisfy domestic demand at a lower cost by using its superior technologies to produce in South. In the second example, we have frictionless trade and both regions are identical except that South is smaller: $T_N/L_N = T_S/L_S$ and $L_S < L_N$. In this case, the domestic demand share for South increases as we move from the counterfactual equilibrium with no MP to the actual equilibrium with MP (i.e., $\lambda_{SS} > \bar{\lambda}_{SS}$). This implies that $GMP_S < GMP_S^*$, so that MP is a trade substitute for South: As South becomes more productive thanks to MP, it effectively becomes larger and the gains from trade decline.

2. Symmetry

The symmetric case can be solved analytically, but the basic intuition regarding the role of the various parameters carries to the general case with asymmetric countries. We derive intuitive formulas for the gains from trade, MP, and openness and then explore the conditions under which trade (MP) behaves as a substitute or complement for MP (trade). We are also interested in differentiating between the complementarity that arises from the possibility of doing BMP and the one that arises from the use of the home country's input bundle in multinational activities.

Symmetry entails $L_i = L$ and $T_i = T$ for all i, $d_{nl} = d$, and $h^f_{nl} = h^g_{nl} = h$ for all $l \neq n$. In equilibrium, wages, costs, and prices are equalized across countries, $w_n = w$, and $P^s_n = P^s$, for $s = g, f$ and all n. Thus, the cost of the multinational input bundle collapses to $c^g_{li} = m \cdot c^g$ for all $l \neq i$, with $m \equiv [(1-a)h^{1-\xi} + ad^{1-\xi}]^{1/(1-\xi)}$, and $c^g_{ll} = c^g$ for all l. The share of expenditures on the home input bundle done by MP is simply $\omega = a(d/m)^{1-\xi}$.

The equilibrium is characterized as follows (see App. A for formal derivations). In the case of final goods, the situation is straightforward: A country uses some of its own technologies to serve domestic consumers through local production and also to serve foreign consumers through MP. For intermediate goods, there is trade, MP, and BMP: Countries use some of their own technologies to produce at home to serve domestic and foreign consumers (through exports), and they use some of their technologies for MP whose output is sold to local consumers (MP), sent back home, or sold to third markets (BMP).[20] There is also trade associated with the import of the home country's input bundle for MP.

The following proposition shows how access to foreign technologies through trade and MP increases a country's real wage.

Proposition 3. Under symmetry,

$$\mathrm{GO} = [1 + (I-1)h^{-\theta}]^{1/\theta}[\Delta_0 + (I-1)\Delta_1]^{\eta/\theta}, \tag{18}$$

$$\mathrm{GT} = \frac{\mathrm{GO}}{\lim_{d\to\infty}\mathrm{GO}} = \left[\frac{\Delta_0 + (I-1)\Delta_1}{1 + (I-1)\tilde{m}^{-\theta}}\right]^{\eta/\theta}, \tag{19}$$

$$\mathrm{GMP} = \frac{\mathrm{GO}}{\lim_{h\to\infty}\mathrm{GO}} = [1 + (I-1)h^{-\theta}]^{1/\theta}\left[\frac{\Delta_0 + (I-1)\Delta_1}{1 + (I-1)d^{-\theta}}\right]^{\eta/\theta}, \tag{20}$$

[20] The assumption that technologies are draws from a multivariate Fréchet distribution with $\rho \in [0, 1)$ implies that there is some BMP even with symmetric countries; BMP vanishes only when $\rho \to 1$.

where

$$\Delta_0 \equiv [1 + (I - 1)(md)^{-\tilde{\theta}}]^{1-\rho},$$

$$\Delta_1 \equiv [d^{-\tilde{\theta}} + m^{-\tilde{\theta}} + (I - 2)(md)^{-\tilde{\theta}}]^{1-\rho},$$

$$\tilde{m} \equiv \lim_{d\to\infty} m = (1 - a)^{1/(1-\xi)}h,$$

$$\tilde{\theta} \equiv \theta/(1 - \rho).$$

The expression for the gains from openness in equation (18) indicates that a country that opens up to both trade and MP in the intermediate-goods sector benefits from using its own technologies abroad and from access to foreign technologies. When domestic technologies are used (the term Δ_0), production can be carried out in $I - 1$ foreign locations through MP at the cost m and then goods shipped back home at the cost d. Hence, technologies are "fully" discounted by $(md)^{-\tilde{\theta}}$. Foreign technologies can be accessed by importing goods, in which case they are discounted by $d^{-\tilde{\theta}}$ (the first term in Δ_1); by doing MP, in which case they are discounted by $m^{-\tilde{\theta}}$ (the second term in Δ_1); and by doing BMP in $I - 2$ different locations, in which case the full discount $(md)^{-\tilde{\theta}}$ applies (the third term in Δ_1). The term in the first brackets in equation (18) captures the gains from accessing $I - 1$ foreign technologies through (inward) MP in the final-goods sector, at a discount of $h^{-\theta}$.

It is clear that the gains from openness decrease with h as well as d: The higher the trade or MP costs, the lower the gains from openness. Additionally, the parameter ρ appears in GO in association with intermediate goods: As ρ indicates the correlation between technology draws for a given source country across different production locations, it matters only when both trade and MP are allowed. As one would expect, GO decreases with ρ. In the case in which $\rho \to 1$ (so that $z^s_{li} = z^s_{ji}$ for all l, j and $s = g, f$), BMP in intermediate goods vanishes, and trade and MP no longer overlap: If $d > h$, there is MP but no arm's-length trade; in contrast, if $h > d$, there is arm's-length trade but no MP (see App. A).

The expression for GT in equation (19) indicates that a country that opens up to trade benefits through specialization according to Ricardian comparative advantage (which, here, takes into account trade flows associated with BMP) and from the fact that trade facilitates MP by allowing multinational affiliates to import inputs from their home country. The following proposition describes parameter configurations under which trade is an MP complement or an MP substitute.

PROPOSITION 4. Assume that countries are symmetric. (*a*) If $\rho = 0$ and $a > 0$, trade is an MP complement; if $\rho > 0$ and $a = 0$, trade is an MP substitute. (*b*) Assume that $a, \rho > 0$. If $\xi \to 1$, trade is an MP complement; if $h < d$ and $\xi \to \infty$, trade is an MP substitute.

To gain some intuition for these results, start from the case with $a = \rho = 0$, for which we know from proposition 1 that trade is MP independent. As ρ increases above zero, the positive correlation between productivity draws across locations generates substitutability. Alternatively, as a increases above zero, the demand for home country inputs by multinationals introduces complementarity. If both $\rho > 0$ and $a > 0$, then we need to consider the parameter ξ. If ξ is close to one, the low elasticity of substitution between home and host countries' inputs for MP generates no gains from MP if trade is not possible. Hence, trade is an MP complement. Conversely, if ξ is high, then only the cheapest input bundle is used for MP; if $h < d$, then trade does not contribute to decreasing MP costs. This implies that trade is an MP substitute.

Turning to the gains from MP, the first term on the right-hand side of (20) captures the gains associated with final goods, whereas the second term captures the gains associated with intermediate goods. For intermediates, the gains from MP are affected by the substitutability between trade and MP that arises for $\rho > 0$.

PROPOSITION 5. Assume that countries are symmetric. If $\rho = 0$, MP is trade independent; if $\rho > 0$, MP is a trade substitute.

We emphasize two implications of this proposition. First, the value of a does not affect whether MP is trade independent or is a trade substitute. The reason is that while trade facilitates MP by reducing the unit cost of the multinational input bundle ($m < \tilde{m}$ if $a > 0$), MP does not facilitate trade; MP only adds a competing alternative to trade in serving other markets. Second, the result that MP is trade independent for $\rho = 0$ is consistent with lemma 2: Under symmetry, we have $\bar{\lambda}_{nn} = \lambda_{nn}$ because, in this case, MP affects all countries equally and therefore has no effect on trade shares.

3. Two Countries with $a = 0$ and Frictionless Trade

This special case shows that the rich country can experience losses from MP. We consider two countries labeled North (N) and South (S), with $T_N/L_N > T_S/L_S$. This condition implies that wages will tend to be higher in North than in South. We assume that MP generates no demand for home country intermediate goods ($a = 0$) and that trade is frictionless ($d_{NS} = d_{SN} = 1$). Our main result for this case is established in the following proposition.

PROPOSITION 6. Assume $a = 0$ and frictionless trade. There exists $\rho^* \in [0, 1)$ such that North gains from frictionless MP in intermediate goods ($\text{GMP}_N^g > 1$) for $\rho \in [0, \rho^*)$, while it loses for $\rho \in (\rho^*, 1)$ ($\text{GMP}_N^g < 1$).

The reason why MP can have a negative impact on the rich country is that outward MP effectively reduces the demand for a country's exports, worsening its terms of trade. But this negative effect relies on there being strong substitutability between trade and MP as alternative ways of serving foreign markets—hence the need for a high-correlation parameter ρ for this to be a dominant effect. Note that in this example, we have assumed $a = 0$. But in general, with $a > 0$, outward MP would generate an increased demand for home country inputs, and this would make it less likely for the rich country to lose from MP (see Becker and Muendler 2010; Irarrazabal et al. 2013).[21]

III. Calibration

A. *Data Description*

We restrict our analysis to the set of 19 OECD countries considered by Eaton and Kortum (2002): Australia, Austria, Belgium, Canada, Denmark, Spain, Finland, France, United Kingdom, Germany, Greece, Italy, Japan, Netherlands, Norway, New Zealand, Portugal, Sweden, and the United States. Except when mentioned otherwise, all the data are averaged over the period 1996–2001. We use STAN data on manufacturing trade flows from country l to country n as the empirical counterpart for trade in intermediates in the model, X_{nl}. We use UNCTAD data on the gross value of production for multinational affiliates from i in l as the empirical counterpart of bilateral MP flows in the model, $Y_{li} \equiv Y^f_{li} + Y^g_{li}$.[22]

We complement the bilateral-trade and MP data with data on intrafirm trade by multinational firms in manufacturing, and the share of MP in final goods, relative to all MP. These data are available for the United States from the BEA. We also use data from the BEA to compute a measure of BMP for foreign affiliates of US multinationals and for US affiliates of foreign multinationals in the manufacturing sector. Appendix B presents more detail on the data and summary statistics.

B. *Calibration Procedure*

We reduce the number of parameters to calibrate by assuming that bilateral-trade and MP costs in the intermediate-goods sector are a function of distance and whether countries share a border and a language,

[21] It is also important to note that in our model, outward MP generates no profits since there is perfect competition. Such profits would lead to additional gains from MP for rich countries, as in Burstein and Monge-Naranjo (2009) and Arkolakis et al. (2012).

[22] Since the model is one of constant returns to scale and perfect competition, the concept of "firms" is not clearly defined. There is, thus, a gap between model and data since the data on MP come from the activities of multinational firms. On the one hand, this is not a major problem because we use only aggregate MP flows rather than any firm-level data. On the other hand, as we acknowledge in the introduction, there is a discrepancy between the concept of MP in the model, which corresponds to the value of production with technologies from country i in another country l, and the concept of MP in the data, which corresponds to the value of production in country l performed by affiliates of firms headquartered in country i.

respectively:

$$d_{ni} = 1 + (\delta_0^d + \delta_{\text{dist}}^d \text{dist}_{ni}) \times (\delta_{\text{bord}}^d)^{b_{ni}} \times (\delta_{\text{lang}}^d)^{l_{ni}}, \tag{21}$$

$$h_{ni}^g = 1 + (\delta_0^h + \delta_{\text{dist}}^h \text{dist}_{ni}) \times (\delta_{\text{bord}}^h)^{b_{ni}} \times (\delta_{\text{lang}}^h)^{l_{ni}}, \tag{22}$$

for all $n \neq i$, with $d_{nn} = 1$ and $h_{nn}^g = 1$. The variable dist_{ni} is the distance between i and n. The variable b_{ni} (l_{ni}) equals one if countries share a border (a language) and zero otherwise. Thus, for example, if $\delta_{\text{bord}}^d < 1$, then countries that share a border have lower trade costs. We also assume that MP costs in the final-goods sector are proportional to the ones in the intermediate-goods sector:

$$h_{ni}^f = \max[1, \ \mu h_{ni}^g]. \tag{23}$$

Finally, we assume that T_i/L_i varies directly with the share of R&D employment observed in the data (an average over the 1990s from the World Development Indicators). Thus, for example, since the share of R&D employment is 0.9 percent in the United States and 0.3 percent in Greece, we assume that T_i/L_i is three times higher in the United States than in Greece.

The parameters that need to be calibrated, then, are the parameters that determine trade and MP costs in the tradable sector, $\boldsymbol{\Upsilon} \equiv \{\delta_0^d, \delta_0^h, \delta_{\text{dist}}^d, \delta_{\text{dist}}^h, \delta_{\text{bord}}^d, \delta_{\text{bord}}^h, \delta_{\text{lang}}^d, \delta_{\text{lang}}^h\}$; the parameter μ in equation (23); the size parameters, $\boldsymbol{L} \equiv (L_1, L_2, \ldots, L_I)$; the Fréchet parameters, ρ and θ; and the remaining technology parameters $[\alpha, \beta, \xi, a]$.

We calibrate $[\alpha, \beta, \xi]$ as follows. We set the labor share in the intermediate-goods sector, β, to 0.5 and the labor share in the final-goods sector, α, to 0.75, as calibrated by Alvarez and Lucas (2007).[23] This implies that $\eta \equiv (1 - \alpha)/\beta = 0.5$. For the parameter ξ, which captures the degree of complementarity between home and host countries' inputs for MP, we appeal to estimates from the labor literature. Becker and Muendler (2010) estimate cross-wage elasticities of labor demand for German multinationals across multiple production locations. Their results suggest a value of approximately $\xi = 1.5$.[24]

[23] They calibrate the parameter β to match the share of value added in gross output in tradable sectors (agriculture, mining, and manufacturing) and the parameter α to match the fraction of US employment in the nontradable sector (services), using input-output data for the OECD countries in 1993. Jones (2011) also uses $\beta = 0.5$.

[24] They estimate that the effect of a 1 percent increase in German wages on the demand for labor by multinationals in other countries of Western Europe is 1.2. Since the average share of these multinationals' wage bill allocated to German workers is 62 percent, the implied elasticity of substitution is 1.94. They also estimate that the elasticity of German multinationals' labor demand in Germany to wages in Western Europe is 0.2. Given that the average share of these multinationals' wage bill allocated to Western European workers

We choose not to include the parameter ρ in the calibration since this parameter is not well identified from the aggregate data on bilateral trade and MP shares. Instead, we consider two values for ρ: $\rho = 0$ (no correlation) and a central value of $\rho = 0.5$.

We calibrate the remaining parameters through the following algorithm. Given a value for $\rho \in \{0, 0.5\}$, the values for $[\alpha, \beta, \xi]$ as chosen above, and a set of parameters to calibrate $[\boldsymbol{\Upsilon}, \boldsymbol{L}, a, \mu, \theta]$, we compute the equilibrium and generate the following statistics: a simulated data set with 361 observations (one for each country pair, including the domestic pairs) for the bilateral trade and MP shares, $\lambda_{nl}^{T} \equiv X_{nl}/\sum_j X_{nj}$ and $\lambda_{nl}^{M} \equiv Y_{li}/\sum_j Y_{lj}$, respectively; real GDP levels for all countries, $w_n L_n / P_n^f$; intrafirm trade to MP ratios, $\omega_{li} Y_{li}^g / Y_{li}$; and MP in the intermediate-goods sector as a share of total MP, Y_{li}^g / Y_{li}. We compute averages of the last two variables across country pairs in which the United States is either the home or the host country (i.e., $i =$ US or $l =$ US). We also compute an estimate of the *trade elasticity* (i.e., the partial elasticity of trade flows to trade costs) by running an ordinary least squares (OLS) regression with no intercept on the following gravity equation for normalized trade flows, similar to Eaton and Kortum (2002):

$$\log \frac{\lambda_{nl}^{T}}{\lambda_{ll}^{T}} = -\varepsilon \log\left(\frac{d_{nl} P_l^g}{P_n^g}\right). \tag{24}$$

Notice that for $\rho = a = 0$, this equation is the same as the one in equation (14) and $\varepsilon = \theta$. Otherwise, in general, $\varepsilon \neq \theta$, as we explain in more detail below.

Finally, we compute a measure of the explanatory power of the model for bilateral trade shares given by

$$R^{T} \equiv 1 - \frac{\sum_{n,i;n\neq i}(\lambda_{ni}^{T,\text{data}} - \lambda_{ni}^{T,\text{model}})^2}{\sum_{n,i;n\neq i}(\lambda_{ni}^{T,\text{data}})^2}. \tag{25}$$

We use an analogous formula for the measure of the explanatory power of the model for bilateral MP shares, which we denote by R^M.

This procedure gives us a set of moments that we use to calibrate the parameters $[\boldsymbol{\Upsilon}, \boldsymbol{L}, a, \mu, \theta]$ as follows. First, given $\boldsymbol{\Upsilon}$ and θ, the parameters a and μ are chosen so that the model matches the moments for the importance of intrafirm trade and MP in intermediate goods, respectively, and the vector $\boldsymbol{L}$ matches the real GDP levels (relative to the US levels) in the data. Second, given θ, the parameters in $\boldsymbol{\Upsilon}$ are chosen to minimize $(1 - R^T) + (1 - R^M)$. Finally, the parameter θ is chosen so that the value

is 15 percent, the implied elasticity of substitution is 1.3. The average of these two elasticities is close to 1.5. This is close to the elasticity of substitution between skilled and unskilled workers, which Katz and Murphy (1992) estimate at 1.4.

for ε above is equal to 4.2, an average of the estimates presented by Simonovska and Waugh (2011) for the set of 19 OECD countries that we consider here.[25]

C. Results

Table 1 reports the calibrated parameters, and the vector $\boldsymbol{L}$ is reported in Appendix table C2.

For both calibrations, the effect of distance on trade and MP costs is similar: A 10 percent increase in distance between a country pair increases trade costs by more than 2 percent and MP costs in the tradable-goods sector by more than 3 percent. Both calibrations suggest that a common border decreases trade costs by more than MP costs ($\delta^d_{\text{border}} < \delta^h_{\text{border}}$), whereas the opposite is true for country pairs with a common language ($\delta^d_{\text{lang}} > \delta^h_{\text{lang}}$). These calibrated parameters translate into average MP costs in the tradable sector that are more than 40 percent higher than the average trade costs for the calibration with $\rho = 0$.

We showed in Section II.C that, in general, the trade elasticity is not equal to θ because of the existence of intrafirm trade $(a > 0)$ and the fact that ρ might be different from zero. In fact, our calibration procedure for the case with $\rho = 0.5$ implies that, to generate a trade elasticity of $\varepsilon = 4.2$, we need $\theta = 3.75$. This reveals that the trade elasticity is a biased estimator of θ. The (upward) bias arises because $\rho > 0$ leads to a higher trade elasticity than θ, as now there is an additional channel (besides the standard one in Ricardian trade-only models) through which higher trade costs decrease trade flows; that is, exports can be replaced by MP or BMP. As expected, for the case with $\rho = 0$, the calibrated value of θ is 4.45, which is closer to the value of the trade elasticity ε. Of course, if $a = \rho = 0$, then $\theta = \varepsilon = 4.2$.

The next two tables illustrate how the calibrated model matches the patterns in the data along several dimensions. Table 2 reports statistics from the data and the calibrated model. For bilateral trade and MP shares, we report the mean, the standard deviation, and the correlation coefficient. We also show the average BMP share implied by the model for foreign affiliates of US multinationals and for US affiliates of foreign multinationals. While the average bilateral trade and MP shares generated by the model are similar to the ones in the data, the correlation between the two flows is higher in the model. We comment on the results for BMP below.

Table 3 shows the measure of the model's explanatory power for bilateral trade and MP, R^T and R^M, respectively. Additionally, it presents cor-

[25] Various empirical studies using different estimation strategies find a value for ε in the range of the one calculated by Simonovska and Waugh (2011). See Bernard et al. (2003), Donaldson (2010), Simonovska (2010), Eaton et al. (2011), and Burstein and Vogel (2012).

TABLE 1
Calibrated Parameters

	Model with $\rho = 0.5$		Model with $\rho = 0$	
	Trade	MP	Trade	MP
Cost parameters:				
Distance	.18	.26	.13	.31
Common border	.74	1.45	.65	1.86
Common language	.60	.40	.70	.36
Constant	.89	.95	1.09	1.30
Average costs	2.88	3.39	2.79	4.03
Standard deviation costs	.40	.47	.32	.48
Minimum cost	1.41	1.47	1.51	1.56
Maximum cost	5.49	7.12	4.69	8.45
Intrafirm trade parameter a	.15		.14	
MP cost parameter for final sector μ	1.55		1.11	
Variability parameter in Fréchet θ	3.75		4.40	

TABLE 2
Summary Statistics: Data and Calibrated Model

	Data	Model with $\rho = 0.5$	Model with $\rho = 0$
Bilateral trade shares:			
Average	.021	.021	.021
Standard deviation	.038	.035	.035
Bilateral MP shares:			
Average	.029	.024	.023
Standard deviation	.063	.038	.041
Correlation bilateral trade and MP shares	.701	.804	.793
Average outward BMP shares for the United States	.405	.115	.364
Average inward BMP shares for the United States	.090	.013	.065

relations between magnitudes in the model and data for bilateral trade and MP shares across country pairs, as well as correlations for aggregate exports, imports, outward MP, and inward MP as shares of GDP of the source and the receiving country, respectively.

Both R^2's and correlation coefficients for bilateral trade and MP shares are high, indicating that the model captures the observed bilateral patterns of these two flows fairly well. When we express total exports and total imports as shares of absorption in manufacturing, the correlations between the model and data are still high. Correlations are lower but fairly strong when we compute total outward and inward MP as shares of GDP. The model performs poorly in capturing the level of outward and inward MP shares for the largest countries in the sample (i.e., Germany, Japan, and the United States). Appendix table C2 shows the actual and simulated data for these four variables for each country against country size.

TABLE 3
Model's Goodness of Fit

	Model with $\rho = 0.5$	Model with $\rho = 0$
Model's R^2:		
Bilateral trade shares	.89	.89
Bilateral MP shares	.64	.66
Correlations data and model:		
Bilateral trade shares	.93	.92
Bilateral MP shares	.76	.77
Total exports shares	.76	.71
Total imports shares	.85	.85
Total outward MP shares	.56	.54
Total inward MP shares	.56	.60

Note.—Bilateral MP is the gross value of production for affiliates from country i in l; total outward MP is the total gross value of production for foreign affiliates from country i; total inward MP is the total gross value of production for foreign affiliates in country l. Total exports and imports are expressed as shares of absorption in manufacturing.

The model can generate BMP flow; that is, country i produces in country $l \neq i$ and sells to country $n \neq l$. Let $\kappa_{li} \equiv (\sum_{n \neq l} \pi^g_{nli} X^g_n) / Y^g_{li}$ denote the share of total production of intermediate goods in l by country i that is sold in countries other than l. (Note that κ_{ll} is the export share of domestic firms in country l.) Using BEA data for the manufacturing sector, we can construct BMP shares κ_{li} for the pairs (l, i) in which either $i =$ US or $l =$ US. We refer to the average κ_{li}, for $i =$ US ($l =$ US), as the average outward (inward) BMP share for the United States.

In table 2 we show that the model is reassuringly consistent with the data in the sense that the average outward BMP share for the United States is much higher than its average inward BMP share. This is what we would expect since the United States is the largest country in our sample and has the (second-) highest research intensity (see App. table C2), discouraging the use of the United States as an export platform.

On the one hand, the calibrated model with $\rho = 0$ implies an average outward BMP share for the United States of 36 percent, which is not far from the 40 percent share shown in the data. On the other hand, the calibrated model with $\rho = 0.5$ implies an average outward BMP share for the United States of only 11.5 percent. One way to understand why the model calibrated with $\rho = 0.5$ does poorly in replicating the observed BMP shares is by recalling the result in Section II.E that in a symmetric world, BMP flows go to zero as $\rho \rightarrow 1$. The reason is that in a symmetric world with perfectly correlated productivity draws, for country i to serve market n through l implies paying both the MP cost and the trade cost (uniform across all country pairs by assumption), whereas exporting entails only the trade cost. In principle, moving to an asymmetric world could lead to positive BMP flows even with $\rho \rightarrow 1$, as cheaper countries become export platforms. But this possibility is of little importance in our sample of developed countries.[26] In contrast, a low value for ρ leads to more BMP because it implies that country i may have a particularly good productivity draw in l but not in n; so if l and n are "close" (i.e., d_{nl} is low), then it would be efficient to use l as an export platform to serve n.

Figure 2 shows outward BMP shares for the United States in country l ($\kappa_{l,\mathrm{US}}$) on the horizontal axis and export shares from country l on the vertical axis, in the data and as implied by the calibrated models with $\rho = 0$ and $\rho = 0.5$, respectively.[27] The left panel of figure 2 shows a strong positive relationship between BMP and export shares in the data: An OLS regression with no intercept and robust standard errors yields a coefficient of 0.88 (standard error 0.05) and R^2 of .95. Countries that deviate from this pattern are small economies, such as Belgium, which has a relatively high export share (95 percent) but a lower BMP share than the United States (60 percent), and Sweden, with a BMP share relatively higher than the United States (64 percent) but a lower export share (50 percent). The middle panel of figure 2 shows that, according to the model calibrated with $\rho = 0$, BMP and export shares are closely lined up over the 45-degree line.[28] This means that the export intensity of multinationals is close to that of domestic firms; for example, the export share of US firms in Belgium is close to that of domestic Belgian firms. The right panel of figure 2 shows that the model calibrated with $\rho = 0.5$ also reproduces the positive relationship between US outward BMP shares and export shares but with BMP shares that are too small.

Turning to inward BMP shares, the average BMP share for the United States is 9 percent as reported in table 2, and the export share from the United States is also close to 9 percent. The calibrated model with $\rho = 0$ delivers an average BMP share of 6.5 percent, while the export share from the United States is 7 percent. In contrast, the calibrated model with $\rho = 0.5$ delivers much lower average BMP shares (1.3 percent), but not very different export shares for the United States (8 percent).

These results reveal that the model calibrated with $\rho = 0$ does much better in matching the facts about BMP than the model calibrated with $\rho = 0.5$. Still, we choose to present results for both calibrations below to

[26] The introduction of asymmetric trade costs could make it profitable for the United States to serve country n through some country l that is "close" to n (e.g., the United States could serve France through Belgium). But our calibrated model implies that in most cases, it would make more sense to serve country n directly through MP rather than through some other country l.

[27] Country l's total exports in manufacturing are normalized by the total gross value of production in manufacturing in country l.

[28] Notice that if $a = \rho = 0$, then $\kappa_{li} = \kappa_{ll}$ for all i, l. Since $\kappa_{li} = \sum_{n \neq l} \pi^g_{nli} X_n / \sum_n \pi^g_{nli} X_n$, plugging in for π^g_{nli} from eq. (7) with $a = 0$ and $\rho = 0$, $\kappa_{li} = \sum_{n \neq l} d_{nl}^{-\theta} P_n^{\theta} X_n / \sum_n d_{nl}^{-\theta} P_n^{\theta} X_n$, so that $\kappa_{li} = \kappa_{lj}$ for all i, j.

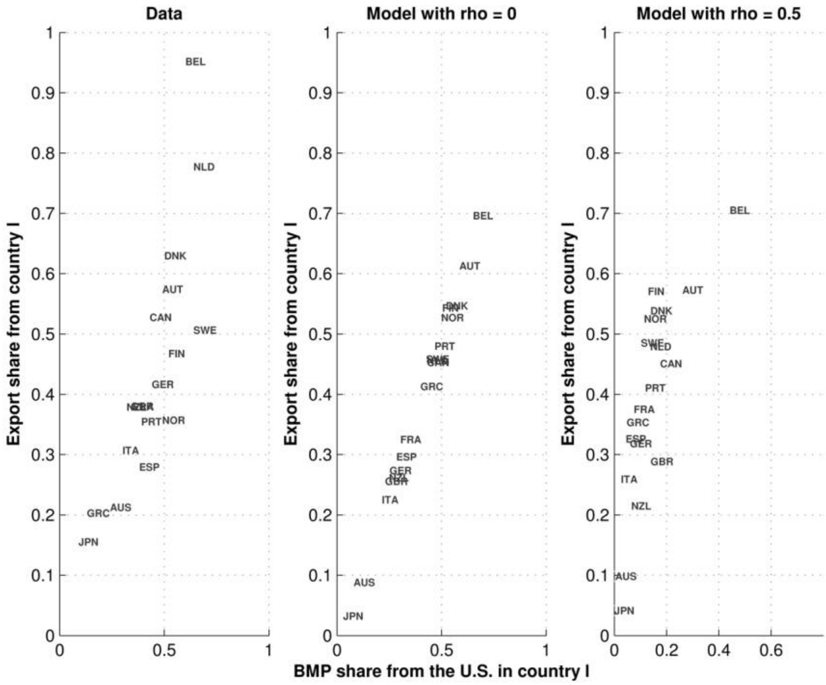

FIG. 2.—BMP shares: data and calibrated model, the United States. Outward bridge multinational production (BMP) shares from the United States to country l against export share from country l to all countries, in manufacturing.

highlight the role of the parameter ρ in shaping the gains from trade and MP implied by the model.

IV. Gains from Trade, MP, and Openness

A. *Gains under Independence*

Before we present the implications of our calibrated model for the measurement of the gains from trade, MP, and openness, it is instructive to compute these gains under the special case with $a = \rho = 0$. We refer to these gains as the gains under independence because, as shown in proposition 1, $a = \rho = 0$ implies that trade is MP independent in the sense that the gains from trade are equal to the gains computed in a trade-only model (i.e., $GT_n = GT_n^*$) and that the gains from openness are simply $GO_n^* \equiv GT_n^* \times GMP_n^*$ (recall that GMP_n^* are the gains from MP computed in an MP-only model). As shown in lemma 1, GT_n^* and GMP_n^* can be computed directly using the data on bilateral trade and MP shares and a value for the parameters η and θ. The parameter η is easily calibrated (see above), while for $a = \rho = 0$, the parameter θ can be recovered from an estimate of the trade elasticity ε (see Sec. III). This implies that the results for GT_n^* are consistent with the formula in Arkolakis, Costinot, and Rodríguez-Clare (2012) as a general result for a class of quantitative trade models. We calculate GT_n^* using the data in Appendix table C4. For GMP_n^*, we use the data on inward MP shares in table C3, and we assume that the share of MP in the intermediate-goods sector in each country is 0.5, as the one observed for the United States. With this assumption and $\eta = 0.5$, $GMP_n^g = [1 - \sum_{i\neq n} Y_{ni}/(w_n L_n)]^{-\eta/\theta}$ and $GMP_n^f = [1 - (1/2)\sum_{i\neq n} Y_{ni}/(w_n L_n)]^{-1/\theta}$.

Table 4 shows the gains from openness, the gains from trade, and the gains from MP, under independence, calculated directly using the data and the parameters $\eta = 0.5$ and $\theta = 4.2$. Table 4 presents the results for a subsample of countries, and table C5 shows results for all countries in our sample.

On average, the gains from openness are almost three times as large as the gains from trade (17 vs. 6.6 percent). For countries with high inward MP shares, such as Portugal and New Zealand, the gains from openness are around five times as large as the gains from trade.

B. *Gains in the Calibrated Model*

The calculations under independence shown above miss the potential gains coming from the interactions between trade and MP. In this subsection, we use our calibrated model to explore the effect of such interactions.

We show results averaged across countries in table 5 and results by country, for a subset of countries, in table 6. Results by country for the entire sample, for $\rho = 0$ and $\rho = 0.5$, respectively, are in Appendix tables C6 and C7. For meaningful comparisons between GT_n and GT_n^* and between GMP_n and GMP_n^*, the variables GT_n^* and GMP_n^* are calcu-

TABLE 4
Gains from Openness, Trade, and Multinational Production: Independence

	GO_n^*	GT_n^*	GMP_n^*	L_n
New Zealand	1.365	1.053	1.296	.7
Denmark	1.137	1.096	1.037	1.2
Portugal	1.290	1.064	1.213	1.4
Canada	1.261	1.081	1.166	4.4
Germany	1.119	1.037	1.079	9.3
Japan	1.022	1.006	1.015	13.4
United States	1.053	1.015	1.037	28.7

Note.—The variables GO_n^*, GT_n^*, and GMP_n^* refer, respectively, to the gains from openness, trade, and multinational production, for country n, under independence. The variable L_n refers to the number of units of equipped labor in country n, as a percentage of OECD(19)'s total.

TABLE 5
Gains from Openness, Trade, and Multinational Production: Average

Average	GO_n	GT_n	GT_n^*	GMP_n	GMP_n^*
	Model with $\rho = 0$				
All sectors	1.148	1.080	1.062	1.086	1.091
Intermediate-goods sector	1.092	1.080	1.062	1.034	1.039
Final-goods sector	1.049	. . .	. . .	1.049	1.049
	Model with $\rho = 0.5$				
All sectors	1.221	1.101	1.074	1.095	1.116
Intermediate-goods sector	1.148	1.101	1.074	1.032	1.051
Final-goods sector	1.061	. . .	. . .	1.061	1.061

Note.—The variables GO_n, GT_n, and GMP_n refer, respectively, to the gains from openness, trade, and multinational production, for country n; GT_n^* and GMP_n^* refer to the gains from trade and multinational production, respectively, from trade-only and MP-only models.

TABLE 6
Gains from Openness, Trade, and Multinational Production: Selected Countries

	GO_n	GT_n	GT_n^*	GMP_n	GMP_n^*	GMP_n^g
	Model with $\rho = 0$					
New Zealand	1.265	1.080	1.038	1.223	1.238	1.077
Denmark	1.199	1.119	1.097	1.102	1.109	1.042
Portugal	1.230	1.115	1.084	1.141	1.152	1.054
Canada	1.202	1.104	1.075	1.123	1.132	1.048
Germany	1.051	1.040	1.036	1.019	1.016	1.010
Japan	1.004	1.004	1.003	1.001	1.001	1.001
United States	1.012	1.010	1.008	1.005	1.004	1.003
	Model with $\rho = 0.5$					
New Zealand	1.320	1.100	1.037	1.221	1.262	1.096
Denmark	1.320	1.150	1.112	1.120	1.141	1.032
Portugal	1.384	1.140	1.082	1.192	1.219	1.063
Canada	1.282	1.127	1.090	1.128	1.157	1.046
Germany	1.079	1.056	1.051	1.018	1.026	1.005
Japan	1.007	1.005	1.005	1.001	1.002	1.000
United States	1.016	1.012	1.011	1.002	1.005	1.000

Note.—The variables GO_n, GT_n, GMP_n, and GMP_n^g refer, respectively, to the gains from openness, trade, multinational production, and multinational production in the intermediate-good sector, for country n; GT_n^* and GMP_n^* refer to the gains from trade and multinational production, respectively, from trade-only and MP-only models.

lated as indicated in lemma 1 using trade and MP shares implied by the calibrated model.

The implied average gains from openness are between 15 and 22 percent. These gains are more than twice as large as the average gains from openness coming from a trade-only model, $GT_n^* = 6$–7 percent, and around twice as large as the ones coming from an MP-only model, GMP_n^*

$= 9.1$–11.6 percent. On average, around two-thirds of the gains from openness are from trade and MP in the intermediate-goods sector.

The calibrated model implies that trade is an MP complement since, on average, $GT_n > GT^*_n$. Adding trade enhances MP by facilitating intrafirm trade and reducing the unit costs of MP: The average unit cost of the multinational input bundle decreases by around 50 percent with respect to the scenario with only MP but no trade, using either version of the calibrated model.

Turning to MP, the calibrated model implies that, on average, MP is a trade substitute since $GMP_n < GMP^*_n$ when $\rho = 0.5$. The substitutability is quite weak when we consider lower values of ρ. In fact, for $\rho = 0$, MP is practically trade independent. As suggested by the analytical results under symmetry in proposition 5, the complementarity forces associated with BMP cannot overcome the substitutability arising from the fact that MP adds a competing alternative to trade in serving foreign markets.

These results imply that while trade-only models tend to underestimate the gains from trade by a significant amount, MP-only models tend to overestimate the gains from MP by a small amount. Another interesting result is that the gains from trade are larger than the gains from MP in the intermediate-goods sector. This implies that, starting at the actual equilibrium, removing the possibility of trade in intermediate goods would generate larger losses than removing the possibility of MP in this sector.

Not surprisingly, as shown in table 6, the gains from openness are larger for smaller countries: The correlation coefficient between L_n and GO_n is around $-.64$ for both calibrations. Trade behaves as an MP complement, $GT_n > GT^*_n$, for all countries. MP behaves as a mild trade substitute, $GMP_n \leq GMP^*_n$, except for Germany and the United States when $\rho = 0$, in which case MP behaves as a trade complement.[29] For a small country such as Canada, for which the model captures (inward) trade and MP flows very well (see tables C3 and C4), the gains from openness are between 20 and 28 percent. This is much larger than the gains calculated using a trade-only model and larger than the ones calculated using an MP-only model. The gains from trade for Canada are around 30 percent higher than those calculated with a trade-only model (with $\rho = 0.5$, $GT_{CAN} = 12.7$ percent and $GT^*_{CAN} = 9$ percent), whereas the gains from MP are lower than those calculated with an MP-only model (with $\rho = 0.5$, $GMP_{CAN} = 12.8$ percent and $GMP^*_{CAN} = 15.7$ percent).

More generally, the gap between GT_n and GT^*_n is increasing in the amount of inward MP (as a share of GDP) in the calibrated model, across countries. Figure 3 illustrates this relationship. For example, countries

[29] On the basis of proposition 2 and the discussion of that proposition in Sec. II.E, this result can be understood by noting that both the United States and Germany have large net outward MP flows, implying large gains from BMP.

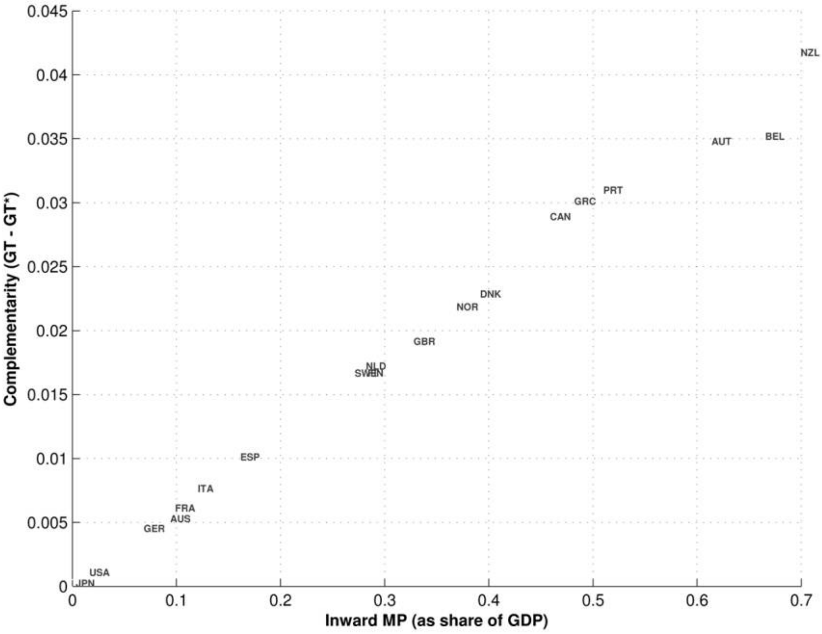

FIG. 3.—Inward multinational production and complementarity. The expression GT − GT* refers to the difference between the gains from trade calculated from the calibrated model with $\rho = 0$ and the gains from trade calculated from a trade-only model.

with inward MP flows near 50 percent of GDP have gains from trade that are around 3 percentage points larger than in trade-only models, whereas this gap falls to 1 percentage point for countries with inward MP flows near 15 percent.

It is noteworthy that Japan and the United States, the two largest countries in our sample, have extremely low gains from MP. In fact, if we restrict our attention to the gains from MP in the intermediate-goods sector and the calibration with $\rho = 0.5$, the United States gains virtually zero from MP ($GMP_n^g = 1$). By doing outward MP, the United States reallocates production from home to foreign countries, in effect sharing its superior technologies with the rest of the world and worsening its terms of trade (see proposition 6). In principle, as explained in Section II.E, there are three forces that could counteract this negative effect: first, gains from inward MP, second, gains from BMP, and, third, increased demand for home production of inputs by foreign affiliates of multinational firms. In the calibrated model, these forces are just strong enough to offset the negative terms of trade effect. It is important to caution, however, that the calibrated model fails to generate the high inward MP flows observed in the data for the largest countries in our sample. Hence, our measures of the gains from MP for these countries are significantly underestimated.

This can be easily seen by comparing GMP_n^* calculated with the observed data (in table 4) and with simulated data (in table 6): While $\mathrm{GMP}_{\mathrm{US}}^*$ calculated from the data is 3.7 percent, the model's calibration delivers around 0.2–0.5 percent (see table C3).

Finally, it is interesting to explore how trade and MP costs affect a country's real income level. We focus on New Zealand, a small and relatively isolated country: Its average inward trade (MP) costs are 4.67 (5.78) versus an average of 2.9 (3.4) for all countries in our sample. We use the calibrated model to quantify the effect on New Zealand if its bilateral inward and outward trade and MP costs became equal to those of Canada or Belgium, two "centrally" located countries. We compute the percentage change in the real wage for New Zealand of moving from the equilibrium in the calibrated model to one of three counterfactual scenarios: (1) a situation in which the trade costs equal those of Canada or Belgium, (2) a situation in which the MP costs equal those of Canada or Belgium, and (3) a situation in which both the trade and MP costs equal those of Canada or Belgium.

The potential gains for New Zealand of having its bilateral trade and MP costs decline to the levels prevailing in Canada or Belgium are very large. Table 7 shows that if trade costs were changed to the level of Canada, New Zealand's real wage would increase by 30 percent, while doing the same for MP costs would increase its real wage by 70 percent. The gains of simultaneously changing trade and MP costs to Canadian levels would increase the real wage in New Zealand by 119 percent. These gains for New Zealand would come mainly from having cheaper access to US technologies through MP in both tradable and nontradable goods. Table 7 shows that New Zealand also would experience significant gains if its trade and MP costs declined to the levels prevailing in Belgium, but not as much as if they declined to the levels prevailing in Canada. Overall, the gains computed in this experiment are quite large compared to

TABLE 7
Gains from Openness, Trade, and Multinational Production: New Zealand

	Percentage Change in Real Wage: New Zealand's Iceberg-Type Costs as in	
	Canada	Belgium
Trade	30	39
Multinational production	70	55
Trade and multinational production	119	75

Note.—Calculation using calibrated model with $\rho = 0$. Change in real wage for New Zealand of moving from the calibrated level of trade and MP costs to a situation in which (1) trade costs equal the ones calibrated for Canada (Belgium), (2) MP costs equal the ones calibrated for Canada (Belgium), and (3) both trade and MP costs equal the ones calibrated for Canada (Belgium).

the gains from trade and MP for New Zealand in table 6. This result is consistent with Eaton and Kortum's (2002) and Waugh's (2010) findings that the gains from trade relative to autarky are small relative to the gains of removing existing trade costs toward a frictionless world.

V. Conclusion

It is reasonable to think that countries, specially small ones, benefit greatly from their interaction with the rest of the world. Whereas much attention has been devoted to trade as the main channel for such benefits, we argue in this paper for the need to investigate other channels as well. We have taken a step in this direction by developing and calibrating a multicountry general equilibrium Ricardian model of trade and MP. An important consideration in building this model has been to allow for both the forces that make trade and MP substitutes and the forces that make them complements, as the empirical evidence suggests. The calibration reveals that the gains from openness are much higher than the gains from trade and also higher than the gains from MP. On net, trade behaves as a complement to MP, while MP behaves as a mild substitute for trade. As a result, for countries with large inward MP flows, the gains from trade can be much higher than those calculated in models with only trade. For example, the gains from trade implied by our model for New Zealand are between 8 and 10 percent, whereas trade-only models imply gains of around 4 percent. The reason is that our model captures the indirect gains from trade associated with its role in facilitating MP. In contrast, the gains from MP calculated in our calibrated model are slightly lower than the gains computed in MP-only models. The reason is that in our model, the substitutability forces associated with the fact that trade and MP are competing ways of serving a foreign market dominate the complementarity forces created by BMP.

Appendix A

Proofs and Other Results

Expenditure Shares and Price Indices

We show that some important results from Eaton and Kortum (2002) can be applied to our setup. In particular, we derive expressions for the expenditure share in country n devoted to goods produced with technologies from country i and the CES price indices in country n, for both final and intermediate goods. This will prove the results in equations (6), (7), and (8).

Since final goods are identical (i.e., they enter preferences symmetrically) except for their productivity parameters, we follow Alvarez and Lucas (2007) and drop index u, labeling final goods by $Z^f \equiv (z_1^f, \ldots, z_I^f)$. Similarly, we label intermediate goods by $Z^g \equiv (\mathbf{z}_1^g, \ldots, \mathbf{z}_I^g)$. In a competitive equilibrium, prices are $p_n^f(Z^f) = \min_i c_{ni}^f / z_{ni}^f$ and $p_n^g(Z^g) = \min_{i,l} c_{li}^g d_{nl} / z_{li}^g$.

Consider, first, the case of intermediate goods and let $p_{ni}^g \equiv \min_l c_{li}^g d_{nl} / z_{li}^g$. The probability that p_{ni}^g is lower than p is

$$G_{ni}^g(p) = 1 - \Pr(z_{li}^g \le c_{li}^g d_{nl}/p \text{ for all } l).$$

Under the assumption that z_{li}^g are draws from the multivariate Fréchet distribution in equation (5), we have

$$\begin{aligned} G_{ni}^g(p) &= 1 - \exp\left\{-T_i\left[\sum_l (c_{li}^g d_{nl}/p)^{-\theta/(1-\rho)}\right]^{1-\rho}\right\} \\ &= 1 - \exp[-T_i(\tilde{c}_{ni}^g)^{-\theta} p^\theta], \end{aligned}$$

where $\tilde{c}_{ni}^g \equiv [\sum_l (c_{li}^g d_{nl})^{-\theta/(1-\rho)}]^{-(1-\rho)/\theta}$. Since p_{ni}^g is independent across i, the reasoning in Eaton and Kortum (2002) can be immediately applied to show that country n will buy goods produced with country i's technologies for a measure of goods equal to $T_i(\tilde{c}_{ni}^g)^{-\theta} / \sum_j T_j (\tilde{c}_{nj}^g)^{-\theta}$.

Of the goods purchased by country n that are produced with country i technologies, what share is produced in country l? This is equal to the probability that, for a specific good, country l is the cheapest location for i to serve market n. This is equivalent to $c_{li}^g d_{nl}/z_{li}^g \le c_{ji}^g d_{nj}/z_{ji}^g$, or $z_{ji}^g \le z_{li}^g (c_{ji}^g d_{nj})/(c_{li}^g d_{nl})$ for all $j \ne l$. Without loss of generality, assume that $l = 1$. The probability that $z_{ji}^g \le a_{nji} z_{1i}^g$ for all $j \ne 1$ where $a_{nji} \equiv (c_{ji}^g d_{nj})/(c_{1i}^g d_{n1})$ is given by $\int_0^\infty F_1(z, a_{n2i}z, \ldots, a_{nIi}z; T_i)\,dz$. But

$$\begin{aligned} &F_1(z, a_{n2i}z, \ldots, a_{nIi}z; T_i) \\ &= [(c_{1i}^g d_{n1})^\theta (\tilde{c}_{ni}^g)^{-\theta}]^{1-[1/(1-\rho)]} T_i \theta z^{-\theta-1} \exp[-(c_{1i}^g d_{n1})^\theta T_i (\tilde{c}_{ni}^g)^{-\theta} z^{-\theta}] \end{aligned}$$

and

$$\int_0^\infty \theta (c_{1i}^g d_{n1})^\theta T_i (\tilde{c}_{ni}^g)^{-\theta} z^{-\theta-1} \exp[-(c_{1i}^g d_{n1})^\theta T_i (\tilde{c}_{ni}^g)^{-\theta} z^{-\theta}]\,dz = 1.$$

This implies that

$$\int_0^\infty F_1(z, a_{n2i}z, \ldots, a_{nIi}z; T_i)\,dz = \frac{(c_{1i}^g d_{n1})^{-\theta/(1-\rho)}}{\sum_l (c_{li}^g d_{nl})^{-\theta/(1-\rho)}}, \qquad \text{(A1)}$$

and, hence, of the goods that country n buys that are produced with country i technologies, the share that is produced in country l is given by the expression in (A1).

Combining the two previous results, we conclude that the share of intermediate goods bought by country n that are produced in country l with country i technologies is given by the right-hand side of equation (7). The corresponding result for final goods is derived simply by letting $d_{nl} \to \infty$ for $n \ne l$.

The previous result relates to shares of goods, whereas we are interested in expenditure shares. Just as in Eaton and Kortum (2002), however, the price distribution of the goods that country n buys is independent of the production location and is also independent of the origin of the technology with which the good is produced. This implies that all the adjustment is on the "extensive margin" and that the share of goods that country n buys from country l that is produced with country i technologies is also the share of the total expenditures by country n that is allocated to those goods. To see this, focus on intermediate goods and condition on market n and technologies from country i. The probability that $p^g_{ni} \leq p$ and that l is the least-cost production location to reach n is the probability that $d_{nl} c^g_{li} / z^g_{li} \leq p$ and $d_{nj} c^g_{ji} / z^g_{ji} \geq d_{nl} c^g_{li} / z^g_{li}$ for all j, or $z^g_{li} \geq d_{nl} c^g_{li} / p$ and $z^g_{ji} \leq z^g_{li} (d_{nj} c^g_{ji}) / (d_{nl} c^g_{li})$ for all j. Without loss of generality, assume that $l = 1$ and again let $a_{nji} \equiv (d_{nj} c^g_{ji}) / (d_{n1} c^g_{1i})$. We want to compute $\int_{d_{n1} c^g_{1i}/p}^{\infty} F_1(z, a_{n2i} z, \ldots, a_{nIi} z; T_i)\, dz$. A procedure similar to the one used to get equation (A1) establishes that

$$\int_{d_{n1} c^g_{1i}/p}^{\infty} F_1(z, a_{n2i} z, \ldots, a_{nIi} z)\, dz$$

$$= \frac{(d_{n1} c^g_{1i})^{-\theta/(1-\rho)}}{\sum_l (c^g_{li} d_{nl})^{-\theta/(1-\rho)}} \{1 - \exp[-T_i (\tilde{c}^g_{ni})^{-\theta} p^\theta]\}.$$

To get the distribution of prices in market n conditional on the good produced in country 1 with technology i, we need to divide by $(c^g_{1i} d_{n1})^{-\theta/(1-\rho)} / \sum_l (c^g_{li} d_{nl})^{-\theta/(1-\rho)}$. This yields a probability equal to

$$G^g_{ni}(p) = 1 - \exp[-T_i (\tilde{c}^g_{ni})^{-\theta} p^\theta]. \tag{A2}$$

Since this expression does not depend on country 1, it implies that for market n and conditioning on country i technologies, the distribution of p for goods that actually are produced in l is the same for $l = 1, 2, \ldots, I$. But independence of productivity draws across i allows us to apply the results from Eaton and Kortum (2002) to establish that the distribution of prices for goods that n actually buys from i is $G^g_n(p) = 1 - \exp[-T_i (\tilde{c}^g_{ni})^{-\theta} p^\theta]$ for all i. This implies that the average price of goods is the same, regardless of where they are produced and of the origin of the technology. As a consequence, expenditure shares for n across (l, i) combinations are the same as the shares of goods bought by n across (l, i) combinations. This finally establishes that expenditure shares for intermediates are given by the expressions in (7). The result in equation (6) is simply obtained by letting $d_{nl} \to \infty$ for $n \neq l$. This same reasoning establishes that the price index for final and intermediate goods is given by equation (8).

Expenditures on Intermediate Goods

Here, we establish that total expenditures on intermediate goods is just a constant fraction of total expenditures on final goods. First note that $P_n Q_n$ is the total cost of the intermediate goods *used in production* in country n. We first calculate the total cost of the intermediate goods *produced* in country n. This is $w_n L^g_n + P^g_n Q^g_n$, plus the intrafirm imports of foreign multinationals located in n, $\sum_{i \neq n} \omega_{ni} Y^g_{ni}$, minus the exports of the domestic input bundle for intermediates to country n's subsidiaries abroad, $\sum_{i\neq n}\omega_{in}Y_{in}^{g}$. Hence, the total cost of intermediate goods produced in country n is

$$w_n L_n^g + P_n^g Q_n^g + \sum_{i\neq n}\omega_{ni}Y_{ni}^g - \sum_{i\neq n}\omega_{in}Y_{in}^g.$$

In equilibrium, this must be equal to the value of intermediate goods produced in country n. Hence,

$$w_n L_n^g + P_n^g Q_n^g + \sum_{i\neq n}\omega_{ni}Y_{ni}^g - \sum_{i\neq n}\omega_{in}Y_{in}^g = \sum_i Y_{ni}^g. \tag{A3}$$

But $Y_{ni}^g = \sum_j \pi_{jni}^g P_j^g Q_j$ implies $\sum_i Y_{ni}^g = \sum_i\sum_j \pi_{jni}^g P_j^g Q_j$. Together with $X_{jn} = \sum_i \pi_{jni}^g P_j^g Q_j + \omega_{jn}Y_{jn}^g$, we have

$$\sum_i Y_{ni}^g = \sum_i \pi_{nni}^g P_n^g Q_n + \sum_{j\neq n}(X_{jn} - \omega_{jn}Y_{jn}^g).$$

Substituting into equation (A3) and simplifying, we get

$$w_n L_n^g + P_n^g Q_n^g + \sum_{i\neq n}\omega_{ni}Y_{ni}^g = \sum_i \pi_{nni}^g P_n^g Q_n + \sum_{i\neq n} X_{in}.$$

Using the trade balance condition (12) to substitute $\sum_{i\neq n}X_{in}$ for $\sum_{i\neq n}X_{ni}$, using equation (11), and simplifying, yields

$$w_n L_n^g + P_n^g Q_n^g = P_n^g Q_n, \tag{A4}$$

where we have used that $\sum_i\sum_j \pi_{nij}^g = 1$.

Now, we know that

$$\frac{L_n^f}{Q_n^f} = \left(\frac{\alpha}{1-\alpha}\right)\frac{P_n^g}{w_n} \tag{A5}$$

and

$$\frac{L_n^g}{Q_n^g} = \left(\frac{\beta}{1-\beta}\right)\frac{P_n^g}{w_n}. \tag{A6}$$

Equations (A4) and (A6) imply that $Q_n^g = (1-\beta)Q_n$, and combining this with $Q_n^f + Q_n^g = Q_n$, we have

$$Q_n^f = \beta Q_n. \tag{A7}$$

Plugging $Q_n^g = (1-\beta)Q_n$ back into equation (A4), we get $w_n L_n^g = \beta P_n^g Q_n$, and using $L_n^g + L_n^f = L_n$, we have

$$w_n(L_n - L_n^f) = \beta P_n^g Q_n. \tag{A8}$$

From equations (A5) and (A7), we get $w_n L_{fn} = [\alpha/(1-\alpha)]\beta P_n^g Q_n$. Using equation (A8), we then have $L_n^f = [\alpha/(1-\alpha)](L_n - L_n^f)$, and, hence, $L_n^f = \alpha L_n$. Plugging into equation (A8), we finally get $(1-\alpha)w_n L_n = \beta P_n^g Q_n$, or $P_n^g Q_n = \eta w_n L_n$.

MP Gravity

In the case with $\rho = 0$, MP flows also satisfy a gravity-like relationship. Using equation (10) and some manipulation, we have

$$Y_{li}^g = \frac{T_i(c_{li}^g)^{-\theta}}{\sum_j \sum_k T_j(c_{kj}^g d_{lk})^{-\theta}} \Psi_l, \tag{A9}$$

where

$$\Psi_l \equiv \sum_n \left(\frac{d_{nl} P_l^g}{P_n^g}\right)^{-\theta} \eta w_n L_n.$$

The first term on the right-hand side of equation (A9) captures the "relative competitiveness" of country *i*'s technologies in country *l*, while Ψ_l can be interpreted as country *l*'s market potential.[30] We can then write

$$\frac{Y_{li}^g/\Psi_l}{Y_{ii}^g/\Psi_i} = \left(\frac{\tilde{h}_{li}^g P_i^g}{P_l^g}\right)^{-\theta}, \tag{A10}$$

where $\tilde{h}_{li}^g \equiv c_{li}^g / c_{ii}^g$ is an average relative cost of producing in country *l* rather than in country *i* with country *i*'s technologies. The term $\tilde{h}_{li}^g$ in equation (A10) plays the analogous role of the term d_{nl} in equation (14).

Proof of Lemma 1

A trade-only model is obtained from our model with $h_{li}^f, h_{li}^g \to \infty$ for all $l \neq i$. In this case, equation (11) implies that trade flows satisfy Eaton and Kortum's (2002) gravity equation,

$$X_{nl} = \frac{T_l(c_l^g d_{nl})^{-\theta}}{\sum_k T_k(c_k^g d_{nk})^{-\theta}} \sum_j X_{nj}.$$

If $h_{li}^g \to \infty$ for all $l \neq i$, then equation (8) implies that $\sum_k T_k(c_k^g d_{nk})^{-\theta} = \gamma^\theta (P_n^g)^{-\theta}$; hence, using

$$c_n^g = B w_n^\beta (P_n^g)^{1-\beta}, \tag{A11}$$

we have

$$w_n/P_n^g = (\gamma B)^{-1/\beta} T_n^{1/\beta\theta} \left(X_{nn} / \sum_j X_{nj}\right)^{-1/\beta\theta}. \tag{A12}$$

If $h_{li}^f \to \infty$ for all $l \neq i$, then (8) implies that $P_n^f = \gamma T_n^{-1/\theta} c_n^f$, and together with

$$c_n^f = A w_n^\alpha (P_n^g)^{1-\alpha}, \tag{A13}$$

[30] Rearranging eq. (14) and substituting into the expression for Ψ_l, we get $\Psi_l = (\hat{X}_{ll}/\eta w_l L_l)^{-1} \sum_n \hat{X}_{nl}$. If there is no intrafirm trade, then trade balance implies $\sum_n X_{nl} = \eta w_l L_l$, so $\Psi_l = (X_{ll}/\eta w_l L_l)^{-1} \eta w_l L_l$: larger and more open countries have a higher market potential.

this implies that $w_n/P_n^f = (\gamma A)^{-1}T_n^{1/\theta}(w_n/P_n^g)^{1-\alpha}$. Using equation (A12), we finally get

$$w_n/P_n^f = \tilde{\gamma}T_n^{(1+\eta)/\theta}\left(X_{nn}/\sum_j X_{nj}\right)^{-\eta/\theta},$$

where $\tilde{\gamma} \equiv (\gamma A)^{-1}(\gamma B)^{-\eta}$. This establishes the result for the real wage in the closed economy in equation (3), and it also shows that the gains from trade in a trade-only economy are given by equation (15).

A similar procedure leads to the formula for the gains from MP in an MP-only model, which obtains from our model as $d_{nl} \to \infty$ for all $n \neq l$. In particular, equations (7) and (10) imply that $Y_{li}^g = [T_i(c_{li}^g)^{-\theta}/\sum T_j(c_{lj}^g)^{-\theta}]\sum_j Y_{lj}$. Together with equations (8) and (A11), this implies that

$$w_n/P_n^g = (\gamma B)^{-1/\beta}T_n^{1/\beta\theta}\left(Y_{nn}^g/\sum_j Y_{nj}^g\right)^{-1/\beta\theta}. \quad \text{(A14)}$$

But equation (8) implies $P_n^f = \gamma(\tilde{T}_n^f)^{-1/\theta}c_n^f$, where $\tilde{T}_n^f \equiv \sum_i T_i(h_{ni}^f)^{-\theta}$. Together with equations (A13) and (A14), we get

$$w_n/P_n^f = \tilde{\gamma}(\tilde{T}_n^f)^{1/\theta}T_n^{\eta/\theta}\left(Y_{nn}^g/\sum_j Y_{nj}^g\right)^{-\eta/\theta}. \quad \text{(A15)}$$

Finally, from equation (6), we see that

$$\frac{Y_{nn}^f}{\sum_j Y_{nj}^f} = \frac{T_n(c_n^f)^{-\theta}}{\sum_i T_i(c_{ni}^f)^{-\theta}} = \frac{T_n}{\tilde{T}_n^f}. \quad \text{(A16)}$$

Plugging (A16) into (A15), we finally get

$$w_n/P_n^f = \tilde{\gamma}T_n^{(1+\eta)/\theta}\left(Y_{nn}^f/\sum_j Y_{nj}^f\right)^{-1/\theta}\left(Y_{nn}^g/\sum_j Y_{nj}^g\right)^{-\eta/\theta}.$$

From this equation, we get (16), (17), and $\text{GMP}_n^* = \text{GMP}_n^{g*} \times \text{GMP}_n^{f*}$. QED

Proof of Proposition 1

Given $\rho = 0$, equations (10) and (8) imply that $Y_{li}^g = \gamma^{-\theta}T_i(c_{li}^g/P_l^g)^{-\theta}\Psi_l$, where $\Psi_l \equiv \sum_n(d_{nl}P_l^g/P_n^g)^{-\theta}\eta w_n L_n$. Hence,

$$Y_{ll}^g = \gamma^{-\theta}(c_l^g/P_l^g)^{-\theta}T_l\Psi_l. \quad \text{(A17)}$$

With equation (A11), this implies that

$$w_l/P_l^g = (\gamma B)^{-1/\beta}T_l^{1/\beta\theta}(Y_{ll}^g/\Psi_l)^{-1/\beta\theta}. \quad \text{(A18)}$$

Letting $\tilde{T}_n^f \equiv \sum_i T_i(h_{ni}^f)^{-\theta}$ and using (A13), we get

$$P_n^f = \gamma(\tilde{T}_n^f)^{-1/\theta}Aw_n^\alpha(P_n^g)^{1-\alpha}.$$

This implies that $w_n/P_n^f = (\gamma A)^{-1}(\tilde{T}_n^f)^{1/\theta}(w_n/P_n^g)^{1-\alpha}$. Using equation (A18), we get

$$w_n/P_n^f = \tilde{\gamma} T_n^{\eta/\theta}(\tilde{T}_n^f)^{1/\theta}(Y_{nn}^g/\Psi_n)^{-\eta/\theta}. \tag{A19}$$

But from equation (14), given $a = 0$, and using balanced trade, we get

$$\Psi_n = \left(\sum_j X_{nj}/X_{nn}\right)\eta w_n L_n. \tag{A20}$$

When $\eta w_n L_n = \sum_i Y_{ni}^g$ and we plug into equation (A19), the real wage is then

$$\begin{aligned} w_n/P_l^f = \tilde{\gamma} T_n^{(1+\eta)/\theta}\left(Y_{nn}^f/\sum_j Y_{nj}^f\right)^{-1/\theta} \times \left(Y_{nn}^g/\sum_j Y_{nj}^g\right)^{-\eta/\theta} \\ \times \left(X_{nn}/\sum_j X_{nj}\right)^{-\eta/\theta}, \end{aligned} \tag{A21}$$

where we have used equation (A16) to substitute out $\tilde{T}_n^f$ for actual MP flows in final goods (this equation is always valid, not only when $d_{nl} \to \infty$ for all $n \neq l$). This immediately implies that

$$\begin{aligned} \mathrm{GO}_n &\equiv \frac{w_n/P_n^f}{\lim_{h_{li}^g, h_{li}^f, d_{nl} \to \infty} w_n/P_n^f} \\ &= \left(Y_{nn}^f/\sum_j Y_{nj}^f\right)^{-1/\theta} \times \left(Y_{nn}^g/\sum_j Y_{nj}^g\right)^{-\eta/\theta} \times \left(X_{nn}/\sum_j X_{nj}\right)^{-\eta/\theta} \\ &= \mathrm{GMP}_n^{f*} \times \mathrm{GMP}_n^{g*} \times \mathrm{GT}_n^*. \end{aligned}$$

(Note that the limit h_{li}^g, h_{li}^f, $d_{nl} \to \infty$ is taken for all $l \neq i$ and $n \neq l$; the same applies for all such limits below.)

To compute GT_n, we need to obtain w_n/P_n^f as $d_{nl} \to \infty$. Clearly, this implies that $X_{nn}/\sum_j X_{nj} \to 1$. But what happens to $Y_{nn}^f/\sum_j Y_{nj}^f$ and $Y_{nn}^g/\sum_j Y_{nj}^g$? First, we know that $Y_{nn}^f/\sum_j Y_{nj}^f = T_n/\tilde{T}_n^f$, so that MP shares for final goods are independent of trade costs. We now show that something very similar happens for MP shares for intermediate goods, and $Y_{ll}^g/\sum_j Y_{lj}^g = T_l/\tilde{T}_l^g$, where $\tilde{T}_l^g \equiv \sum_i T_i(h_{li}^g)^{-\theta}$. From equation (A17) we have

$$\frac{Y_{ll}^g}{\sum_j Y_{lj}^g} = \frac{\gamma^{-\theta}(c_l^g/P_l^g)^{-\theta} T_l \Psi_l}{\eta w_l L_l}.$$

With equation (8) for $s = g$ and $a = \rho = 0$ and equation (A20), this implies that

$$\frac{Y_{ll}^g}{\sum_j Y_{lj}^g} = \frac{T_l}{\tilde{T}_l^g} \frac{\tilde{T}_l^g (c_l^g)^{-\theta}}{\sum_k \tilde{T}_k^g (c_k^g d_{lk})^{-\theta}} \frac{\sum_j X_{lj}}{X_{ll}} = \frac{T_l}{\tilde{T}_l^g},$$

where the last result comes from the fact that, with $a = \rho = 0$, equation (7) implies that

$$X_{ll} = \frac{\tilde{T}_l^g (c_l^g)^{-\theta}}{\sum_k \tilde{T}_k^g (c_k^g d_{nk})^{-\theta}} \sum_j X_{nj}.$$

Since neither $Y_{nn}^f / \sum_j Y_{nj}^f$ nor $Y_{ll}^g / \sum_j Y_{lj}^g$ is dependent on trade costs, we conclude that

$$\text{GT}_n \equiv \frac{w_n / P_n^f}{\lim_{d_{nl} \to \infty} w_n / P_n^f} = \left(X_{nn} / \sum_j X_{nj} \right)^{-\eta/\theta} = \text{GT}_n^*.$$

QED

Proof of Proposition 2

Here, we compare GMP_n with $\text{GMP}_n^* \equiv \text{GMP}_n^{f*} \times \text{GMP}_n^{g*}$. First, note that neither trade flows nor MP flows in intermediate goods depend on MP in final goods. Hence,

$$\text{GMP}_n^f \equiv \frac{w_n / P_n^f}{\lim_{h_{li}^f \to \infty} w_n / P_n^f} = \left(\frac{T_n}{\tilde{T}_n^f} \right)^{-1/\theta}$$
$$= \left(\frac{Y_{nn}^f}{\sum_j Y_{nj}^f} \right)^{-1/\theta} = \text{GMP}_n^{f*}.$$

Next, the gains from MP in intermediates, GMP_n^g, are determined by $\text{GMP}_n^{g*} = (Y_{nn}^g / \sum_j Y_{nj}^g)^{-\eta/\theta}$ together with the way in which $X_{nn} / \sum_j X_{nj}$ changes as we take $h_{li}^g \to \infty$. Let $\lambda_{nn} \equiv X_{nn} / \sum_j X_{nj}$ and $\bar{\lambda}_{nn}$ the domestic demand share for the counterfactual equilibrium with $h_{li}^g \to \infty$. Then

$$\text{GMP}_n^g \equiv \frac{w_n / P_n^f}{\lim_{h_{li}^g \to \infty} w_n / P_n^f}$$
$$= \left(Y_{nn}^g / \sum_j Y_{nj}^g \right)^{-\eta/\theta} \left(\frac{\lambda_{nn}}{\bar{\lambda}_{nn}} \right)^{-\eta/\theta}$$
$$= \text{GMP}_n^{g*} \left(\frac{\lambda_{nn}}{\bar{\lambda}_{nn}} \right)^{-\eta/\theta}.$$

Since the second term on the right-hand side is, in general, not equal to one, this implies that $\text{GMP}_n^g \neq \text{GMP}_n^{*g}$. Finally, we have $\text{GMP}_n = \text{GMP}_n^f \times \text{GMP}_n^g$. Hence, $\text{GMP}_n \neq \text{GMP}_n^*$. QED

Characterization of the Symmetric Equilibrium

Under symmetry, we can explicitly solve for trade and MP shares, as well as for the real wage. Using the results for the expenditure shares in equation (6), we have

$$y^f \equiv \frac{Y_{ni}^f}{w_n L_n} = \frac{h^{-\theta}}{1 + (I-1) h^{-\theta}}$$

for $i \neq n$, while for $i = n$,

$$\frac{Y^f_{nn}}{w_n L_n} = \frac{1}{1 + (I-1)h^{-\theta}}. \tag{A22}$$

Similarly, using equation (7), we have

$$y^g \equiv \frac{Y^g_{ni}}{\eta w_n L_n} = y^g_1 + y^g_{B,0} + y^g_{B,1}$$

for $i \neq n$. The term y^g_1 captures MP for goods destined to stay in the domestic market, $y^g_{B,0}$ is MP for goods that go back to the country where the technology originates, and $y^g_{B,1}$ is MP for goods that go to a third market. Both $y^g_{B,0}$ and $y^g_{B,1}$ take place through BMP. The respective formulas are

$$y^g_1 = \frac{\Delta_1^{-\rho/(1-\rho)} m^{-\tilde{\theta}}}{\Delta_0 + (I-1)\Delta_1},$$

$$y^g_{B,0} = \frac{\Delta_0^{-\rho/(1-\rho)} (md)^{-\tilde{\theta}}}{\Delta_0 + (I-1)\Delta_1},$$

$$y^g_{B,1} = \frac{(I-2)\Delta_1^{-\rho/(1-\rho)} (md)^{-\tilde{\theta}}}{\Delta_0 + (I-1)\Delta_1},$$

where Δ_0, Δ_1, and $\tilde{\theta}$ are defined in the text. This implies that

$$\frac{Y^g_{nn}}{\eta w_n L_n} = \frac{\Delta_0^{-\rho/(1-\rho)} + (I-1)\Delta_1^{-\rho/(1-\rho)} d^{-\tilde{\theta}}}{\Delta_0 + (I-1)\Delta_1}. \tag{A23}$$

The equilibrium trade share is given by

$$x \equiv \frac{X_{nl}}{\eta w_n L_n} = x_{0,B} + x_1 + x_{1,B} + \omega y^g$$

for $l \neq n$. The term $x_{0,B}$ captures the imports of goods produced abroad (in l) with the importer's (country n) own technologies through BMP; the term x_1 is the standard component associated with imports from a country that used that country's technology for production (country l uses its technologies to export to n); the term $x_{1,B}$ captures imports of goods produced with country l technologies in countries other than l (BMP); and the term ωy^g captures imports of the input bundle from l for domestic operations of country l multinationals. The formulas for $x_{0,B}$ and $x_{1,B}$ are the same as the formulas for $y^g_{B,0}$ and $y^g_{B,1}$, respectively, while $x_1 = y^g_1 (d/m)^{-\tilde{\theta}}$. This implies that

$$\frac{X_{nn}}{\eta w_n L_n} = \frac{\Delta_0^{-\rho/(1-\rho)} + (I-1)\Delta_1^{-\rho/(1-\rho)} m^{-\tilde{\theta}}}{\Delta_0 + (I-1)\Delta_1}. \tag{A24}$$

It is easy to see from these results that the total value of BMP as a share of total MP is

$$\kappa \equiv \frac{y^g_{B,0} + y^g_{B,1}}{y^f + y^g}.$$

In the limit as $\rho \to 1$, technology draws become the same across production locations, and $\kappa \to 0$. Further, when $h > d$, $y^g \to 0$ and there is only trade, $x = d^{-\theta}/[1 + (I-1)d^{-\theta}]$. On the contrary, when $h < d$, trade is just associated with MP flows, $x = \omega m^{-\theta}/[1 + (I-1)m^{-\theta}] = \omega y^g$.

Proof of Proposition 3

We want to compute GO, GT, and GMP under symmetry. We start by computing the real wage when there is trade and MP and under isolation. We know that $w_i = w$, for all i, and that the price index for intermediate goods collapses to

$$P^g = (\gamma B)^{1/\beta}[\Delta_0 + (I-1)\Delta_1]^{-1/\beta\theta} T^{-1/\beta\theta} w.$$

The price index for final goods is

$$P^f = \gamma[1 + (I-1)h^{-\theta}]^{-1/\theta} T^{-1/\theta} A w^{\alpha} (P^g)^{1-\alpha}.$$

With the result for P^g above, the real wage is then

$$\frac{w}{P^f} = \tilde{\gamma}^{-1} T^{(1+\eta)/\theta}[1 + (I-1)h^{-\theta}]^{1/\theta}[\Delta_0 + (I-1)\Delta_1]^{\eta/\theta}, \tag{A25}$$

where $\tilde{\gamma} \equiv (\gamma A)(\gamma B)^{\eta}$. The real wage under isolation is obtained by letting $d \to \infty$ and $h \to \infty$ in equation (A25). Hence,

$$\text{GO} \equiv \frac{w/P^f}{\lim_{h,d\to\infty} w/P^f} = [1 + (I-1)h^{-\theta}]^{1/\theta}[\Delta_0 + (I-1)\Delta_1]^{\eta/\theta}.$$

To calculate GT, we need to calculate the real wage when there is only MP. When we let $d \to \infty$ in equation (A25), the real wage with only MP is

$$\lim_{d\to\infty} w/P^f = \tilde{\gamma}^{-1}[1 + (I-1)h^{-\theta}]^{1/\theta}[1 + (I-1)\tilde{m}^{-\theta}]^{\eta/\theta} T^{(1+\eta)/\theta},$$

where $\tilde{m}$ is as defined in the text. Hence,

$$\text{GT} \equiv \frac{w/P^f}{\lim_{d\to\infty} w/P^f} = \left[\frac{\Delta_0 + (I-1)\Delta_1}{1 + (I-1)\tilde{m}^{-\theta}}\right]^{\eta/\theta}.$$

Similarly, when we let $h \to \infty$ in equation (A25), the real wage when there is only trade is

$$\lim_{h\to\infty} w/P^f = \tilde{\gamma}^{-1}[1 + (I-1)d^{-\theta}]^{\eta/\theta} T^{(1+\eta)/\theta},$$

and, hence,

$$\text{GMP} \equiv \frac{w/P^f}{\lim_{h\to\infty} w/P^f} = [1 + (I-1)h^{-\theta}]^{1/\theta}\left[\frac{\Delta_0 + (I-1)\Delta_1}{1 + (I-1)d^{-\theta}}\right]^{\eta/\theta}.$$

It is easy to check that the first term on the right-hand side is GMP^f and the second term is GMP^g. QED

Proof of Proposition 4

From proposition 3, lemma 1, and equation (A24), we have $\text{GT}/\text{GT}^* = (B'/B^*)^{-\eta/\theta}$, where $B^* \equiv \Delta_0^{-\rho/(1-\rho)} + (I-1)\Delta_1^{-\rho/(1-\rho)} m^{-\tilde{\theta}}$ and $B' \equiv 1 + (I-1)m^{-\theta}$. Again, Δ_0, Δ_1, $\tilde{\theta}$, and $\tilde{m}$ are defined as in the text.

Part *a*: For $\rho = 0$, $B^* = 1 + (I-1)m^{-\theta}$. But $a > 0$ implies that $\tilde{m} > m$ and, hence, $\tilde{m}^{-\theta} < m^{-\theta}$, so $1 + (I-1)\tilde{m}^{-\theta} < 1 + (I-1)m^{-\theta}$ and $B^* > B'$. Then, $\text{GT} > \text{GT}^*$ and trade is an MP complement. For $\rho > 0$ and $a = 0$, we have $\tilde{m} = m$. Hence, using the definitions for Δ_0 and Δ_1, we get

$$\begin{aligned} B^* - B &= \Delta_0^{-\rho/(1-\rho)} + (I-1)\Delta_1^{-\rho/(1-\rho)} m^{-\tilde{\theta}} - 1 - (I-1)m^{-\theta} \\ &= [1 + (I-1)(md)^{-\tilde{\theta}}]^{-\rho} - 1 + (I-1)m^{-\theta} \\ &\quad \times \{[(d/m)^{-\tilde{\theta}} + 1 + (I-2)d^{-\tilde{\theta}}]^{-\rho} - 1\}. \end{aligned}$$

This is negative if $\rho > 0$.

Part *b*: For $a > 0$, $\lim_{\xi \to 1} \tilde{m} \to \infty$. Thus, $\lim_{\xi \to 1} \text{GT} = [\Delta_0 + (I-1)\Delta_1]^{\eta/\theta}$. Thus, for trade to be an MP complement when $\xi \to 1$, we need to show that $[\Delta_0 + (I-1)\Delta_1]^{\eta/\theta} > \text{GT}^*$. But this is equivalent to $B^* > 1$. Using the definitions for Δ_0 and Δ_1, we have

$$B^* = [1 + (I-1)(md)^{-\tilde{\theta}}]^{-\rho} + (I-1)m^{-\tilde{\theta}}[d^{-\tilde{\theta}} + m^{-\tilde{\theta}} + (I-2)(md)^{-\tilde{\theta}}]^{-\rho}.$$

For $\rho = 0$, $B^* = 1 + (I-1)m^{-\theta} > 1$. For $0 < \rho < 1$ and $d = 1$, $B^* = [1 + (I-1)m^{-\tilde{\theta}}]^{1-\rho} > 1$. Since B^* is increasing in d, it follows that $B^* > 1$ for all d.

Now, consider again the case with $a > 0$ and let $\xi \to \infty$. We want to show that if $h < d$, then trade is an MP substitute, or $\text{GT} < \text{GT}^*$. We have $\lim_{\xi \to \infty} \tilde{m} = h$ and $\lim_{\xi \to \infty} m = \min[h, d] = h$. Then $\text{GT} < \text{GT}^*$ in the limit when $\xi \to \infty$ is equivalent to

$$\begin{aligned} 1 + (I-1)h^{-\theta} > {} & [1 + (I-1)(hd)^{-\tilde{\theta}}]^{-\rho} \\ & + (I-1)h^{-\tilde{\theta}}[d^{-\tilde{\theta}} + h^{-\tilde{\theta}} + (I-2)(hd)^{-\tilde{\theta}}]^{-\rho}. \end{aligned}$$

The first term on the right-hand side of this inequality is smaller than one, so it is sufficient to show that

$$h^{-\theta} > h^{-\tilde{\theta}}[d^{-\tilde{\theta}} + h^{-\tilde{\theta}} + (I-2)(hd)^{-\tilde{\theta}}]^{-\rho}.$$

If $d \to \infty$, then the right-hand side is $h^{-\theta}$. Since the right-hand side is increasing in d, then it must be lower than $h^{-\theta}$ for any finite d. QED

Proof of Proposition 5

From proposition 3, lemma 1, and equation (A23), we have

$$\frac{\text{GMP}^g}{\text{GMP}^{g*}} = \left[\frac{1 + (I-1)d^{-\theta}}{\Delta_0^{-\rho/(1-\rho)} + (I-1)\Delta_1^{-\rho/(1-\rho)} d^{-\tilde{\theta}}}\right]^{-\eta/\theta}.$$

It is obvious that $\mathrm{GMP}^{g*} = \mathrm{GMP}^{g}$ for $\rho = 0$. We want to show that $\mathrm{GMP}^{g*} > \mathrm{GMP}^{g}$ for $0 < \rho < 1$. From the definitions of Δ_0 and Δ_1 in the text, $\mathrm{GMP}^{g*} > \mathrm{GMP}^{g}$ is equivalent to

$$1 + (I-1)d^{-\theta} > [1 + (I-1)(md)^{-\tilde{\theta}}]^{-\rho} + (I-1)[1 + (m/d)^{-\tilde{\theta}} + (I-2)m^{-\tilde{\theta}}]^{-\rho} d^{-\theta}.$$

This is clearly true for $0 < \rho < 1$. QED

Proof of Proposition 6

The formula for expenditure shares of intermediate goods in equation (7) implies that, under frictionless trade and with $a = 0$, we have

$$\pi^{g}_{SSS} = \frac{T_S(\tilde{c}^{g}_{S})^{-\theta}}{T_N(\tilde{c}^{g}_{N})^{-\theta} + T_S(\tilde{c}^{g}_{S})^{-\theta}} \cdot \frac{(c^{g}_{S})^{-\tilde{\theta}}}{(\tilde{c}^{g}_{S})^{-\tilde{\theta}}},$$

$$\pi^{g}_{SSN} = \frac{T_N(\tilde{c}^{g}_{N})^{-\theta}}{T_N(\tilde{c}^{g}_{N})^{-\theta} + T_S(\tilde{c}^{g}_{S})^{-\theta}} \cdot \frac{(hc^{g}_{S})^{-\tilde{\theta}}}{(\tilde{c}^{g}_{N})^{-\tilde{\theta}}},$$

where $\tilde{c}^{g}_{N} \equiv [(c^{g}_{N})^{-\tilde{\theta}} + (h^{g}c^{g}_{S})^{-\tilde{\theta}}]^{-1/\tilde{\theta}}$, $\tilde{c}^{g}_{S} \equiv [(h^{g}c^{g}_{N})^{-\tilde{\theta}} + (c^{g}_{S})^{-\tilde{\theta}}]^{-1/\tilde{\theta}}$, and $\tilde{\theta} \equiv \theta/(1-\rho)$. Analogous expressions hold for π^{g}_{NNN} and π^{g}_{NNS}. The trade balance condition then entails

$$(1 - \pi^{g}_{SSS} - \pi^{g}_{SSN})\eta w_S L_S = (1 - \pi^{g}_{NNN} - \pi^{g}_{NNS})\eta w_N L_N.$$

No MP in intermediates ($h^{g} \to \infty$) implies that $\pi_{SSN} = 0$, $\tilde{c}^{g}_{N} = c^{g}_{N}$, and $\tilde{c}^{g}_{S} = c^{g}_{S}$, so the trade balance condition implies that (just as in Alvarez and Lucas [2007])

$$w_N/w_S = \nu^{1/(1+\theta\beta)},$$

where $\nu \equiv (T_N/L_N)/(T_S/L_S)$. The real wage in North is then

$$\lim_{h^{g}\to\infty} \frac{w_N}{P^{f}_{N}} = [T_N + T_S(h^{f})^{-\theta}]^{1/\theta}(T_N + T_S\nu^{\zeta})^{\eta/\theta}, \tag{A26}$$

where $\zeta \equiv \theta\beta/(1+\theta\beta)$. As one would expect, this does not depend on ρ (since there is no MP).

Now, consider the case with frictionless MP in intermediates ($h^{g} = 1$). The trade balance condition now implies that

$$w_N/w_S = \delta \equiv (L_S/L_N)^{1/(1+\tilde{\theta}\beta)},$$

while the final-goods price index in North is

$$P^{f}_{N} = [T_N + T_S(h^{f})^{-\theta}]^{-1/\theta}(T_N + T_S)^{-\eta/\theta}(1 + \delta^{\tilde{\theta}\beta})^{-\eta/\tilde{\theta}} w_N.$$

Hence,

$$\lim_{h^{g}\to 1} w_N/P^{f}_{N} = [T_N + T_S(h^{f})^{-\theta}]^{1/\theta}(T_N + T_S)^{\eta/\theta}(1 + \delta^{\tilde{\theta}\beta})^{\eta/\tilde{\theta}}. \tag{A27}$$

The results in equations (A26) and (A27) imply that $GMP_N^g \gtrless 1$ is equivalent to

$$(T_N + T_S)^{\eta/\theta}(1 + \delta^{\tilde{\theta}\beta})^{\eta/\tilde{\theta}} \gtrless (T_N + T_S \nu^{\zeta})^{\eta/\theta}.$$

This is equivalent to

$$f(\rho) \equiv [1 + l^{\theta\beta/(1-\rho+\theta\beta)}]^{1-\rho}(\nu + l) - \nu - l\nu^{\zeta} \gtrless 0,$$

where $l \equiv L_S/L_N$. But

$$f(0) = l^{1+\zeta}[l^{-\zeta} + \nu/l + 1 - (\nu/l)^{\zeta}].$$

On the one hand, since $0 < \zeta < 1$, $\nu/l + 1 > (\nu/l)^{\zeta}$, for any ν/l, implying that $f(0) > 0$. On the other hand,

$$\lim_{\rho\to 1} f(\rho) = l - l\nu^{\zeta} = l(1 - \nu^{\zeta}).$$

Since $v > 1$, this expression is negative. It is easy to show that $f'(\rho) < 0$ for $\rho \in [0,\ 1)$, implying that there is a $\rho^* \in [0,\ 1)$ such that $f(\rho^*) = 0$. Hence, we conclude that $GMP_N^g > 1$ for $\rho < \rho^*$ and $GMP_N^g < 1$ for $\rho > \rho^*$. QED

Appendix B

Data

The UNCTAD measure of MP includes both local sales in n and exports to any other country, including the home country i. Of the 342 country pairs, the number of observations for which we have available data drops to 216. For a detailed description of the UNCTAD MP data, see Ramondo (2012). The data are averages over the period 1996–2001.

Total expenditures on intermediate goods in the model are given by $\eta w_n L_n$, while in the data, we compute a measure of total expenditures on manufacturing from all the countries in our sample. This measure is computed as gross production in manufacturing in country n, plus total imports of manufacturing goods into country n from the remaining countries in the sample, minus total manufacturing exports from country n to the rest of the world. Data on these three variables for each country are from the STAN database (an average over the period 1996–2001). Total expenditures on final goods in the model are $w_n L_n$, while in the data, we use GDP for country n plus total imports into country n from the remaining 18 OECD countries in the sample, minus total exports from country n to the rest of the world. Data on GDP are from the World Development Indicators, in current dollars, and total exports and imports are from 2005 United Nations trade date by Robert Feenstra and Robert Lipsey (available from the National Bureau of Economic Research).

We use intrafirm imports by multinationals' foreign affiliates from their home country as the empirical counterpart for imports of the national input bundle from the home country for MP, normalized by gross production of affiliates from i in n, $\omega_{ni} Y_{ni}^g/(Y_{ni}^g + Y_{ni}^f)$. We combine data on intrafirm exports from US parent companies to their affiliates abroad with data on imports done by foreign affiliates located in the United States from their parent firms, an average over the period 1999–2003.

For the empirical counterpart of the bilateral share of MP in intermediate goods, $Y_{ni}^{g}/(Y_{ni}^{g}+Y_{ni}^{f})$, we use data on gross production of affiliates from country i in n in the manufacturing sector as the share of total gross production for affiliates of multinational firms from i in n. The relevant data on bilateral MP in manufacturing are also for i = US or n = US, an average over the period 1999–2003.

We are able to compute BMP in manufacturing when the United States is the source country, again as an average over the period 1999–2003. The BEA divides total sales of American affiliates produced in country l into sales to the local market, to the United States, and to other foreign markets. This is the empirical counterpart for $\sum_{n\neq l}\pi_{nli}^{g}X_{n}^{g}/Y_{li}^{g}$ from i = US in a country l belonging to the OECD(19). We average out across l's and obtain an average bilateral BMP share for the US affiliates in the OECD(19). A similar procedure yields the average bilateral BMP share for US affiliates of foreign multinationals. The caveat is that the data for affiliates of foreign multinationals in the United States for the manufacturing sector are available for only seven countries in our sample. Hence, we also compute and present the BMP share for all sectors.

Bilateral distance is the distance in kilometers between the largest cities in the two countries. Common language is a dummy equal to one if both countries have the same official language or if more than 20 percent 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. The source for these data is the Centre d'Etudes Prospectives et Informations Internationales.

Appendix C

Additional Tables

TABLE C1
Summary Statistics: Data

	Mean	Standard Deviation	Observations
Distance (in thousands of kilometers)	6.006	6.009	342
Common language	.110	.310	342
Common border	.090	.280	342
Bilateral trade share	.021	.038	342
Bilateral MP share	.029	.063	216
Bilateral intrafirm share*	.072	.072	34
Bilateral MP share in manufacturing*	.480	.130	33

* Flows from/to the United States.

TABLE C2
Data and Model's Variables

	R&D Employment	Real GDP per Worker	L_n	T_n
Australia	.007	.81	.12	.09
Austria	.005	.79	.05	.03
Belgium	.007	.88	.06	.04

TABLE C2 (*Continued*)

	R&D Employment	Real GDP per Worker	L_n	T_n
Canada	.006	.80	.15	.11
Denmark	.006	.79	.04	.03
Spain	.004	.69	.16	.07
Finland	.012	.73	.03	.05
France	.006	.77	.25	.18
Great Britain	.005	.70	.24	.15
Germany	.006	.73	.32	.23
Greece	.003	.55	.05	.02
Italy	.003	.87	.28	.09
Japan	.010	.63	.46	.52
Netherlands	.005	.81	.09	.06
Norway	.008	.87	.04	.03
New Zealand	.005	.63	.03	.01
Portugal	.003	.54	.05	.02
Sweden	.008	.70	.05	.05
United States	.009	1.00	1.00	1.00

NOTE.—R&D employment is calculated as a share of total employment. Real GDP per worker, L_n, and T_n are calculated relative to the United States; L_n and T_n are from the calibrated model with $\rho = 0$. R&D employment and real GDP per worker are from the data.

TABLE C3
MULTINATIONAL PRODUCTION SHARES: DATA AND MODEL

	DATA		MODEL WITH $\rho = 0$		MODEL WITH $\rho = 0.5$	
	Outward MP	Inward MP	Outward MP	Inward MP	Outward MP	Inward MP
Australia	.15	.29	.08	.09	.08	.12
Austria	.06	.36	.23	.61	.23	.58
Belgium	.66	.56	.42	.67	.42	.63
Canada	.28	.51	.17	.46	.18	.45
Denmark	.19	.14	.20	.39	.23	.42
Spain	.03	.27	.08	.16	.10	.23
Finland	.51	.25	.31	.28	.39	.29
France	.16	.21	.17	.10	.20	.12
Great Britain	.10	.45	.21	.33	.22	.32
Germany	.40	.28	.16	.07	.20	.09
Greece	.01	.08	.09	.48	.10	.56
Italy	.04	.14	.07	.12	.08	.18
Japan	.17	.06	.01	.003	.02	.01
Netherlands	1.11	.62	.19	.28	.22	.33
Norway	.19	.10	.22	.37	.26	.39
New Zealand	.03	.73	.11	.70	.10	.64
Portugal	.04	.60	.08	.51	.09	.58
Sweden	.35	.40	.24	.27	.28	.30
United States	.17	.14	.09	.02	.11	.02
Average	.24	.33	.17	.31	.18	.33

NOTE.—Outward MP is the total gross value of production for foreign affiliates from country i. Inward MP is the total gross value of production for foreign affiliates in country l. Flows are normalized by a country's GDP.

TABLE C4

Trade Shares: Data and Model

	Data		Model with $\rho = 0$:	Model with $\rho = 0.5$:
	Imports	Exports	Imports = Exports	Imports = Exports
Australia	.24	.11	.09	.10
Austria	.53	.38	.64	.60
Belgium	.92	.82	.72	.72
Canada	.48	.54	.48	.48
Denmark	.54	.48	.56	.55
Spain	.27	.20	.31	.35
Finland	.30	.39	.52	.54
France	.30	.30	.32	.36
Great Britain	.34	.27	.26	.30
Germany	.26	.34	.27	.31
Greece	.32	.08	.44	.39
Italy	.21	.22	.25	.29
Japan	.05	.10	.03	.04
Netherlands	.62	.76	.47	.49
Norway	.42	.28	.53	.53
New Zealand	.35	.28	.28	.24
Portugal	.40	.28	.51	.44
Sweden	.40	.49	.45	.48
United States	.12	.09	.07	.08
Average	.37	.34	.38	.38

Note.—Trade shares are for manufacturing. Trade flows are normalized by the country's total manufacturing expenditures (gross value of production minus total exports plus imports from the countries in the sample, in manufacturing).

TABLE C5

Gains from Openness, Trade, and Multinational Production: Independence

	GO_n^*	GT_n^*	GMP_n^*	L_n
Australia	1.118	1.033	1.082	3.3
Austria	1.209	1.093	1.106	1.5
Belgium	1.599	1.343	1.191	1.6
Canada	1.261	1.081	1.166	4.4
Denmark	1.137	1.096	1.037	1.2
Spain	1.116	1.039	1.074	4.7
Finland	1.116	1.044	1.069	1.0
France	1.103	1.044	1.056	7.1
Great Britain	1.197	1.051	1.139	7.0
Germany	1.119	1.037	1.079	9.3
Greece	1.069	1.048	1.020	1.4
Italy	1.064	1.028	1.035	7.9
Japan	1.022	1.006	1.015	13.4
Netherlands	1.368	1.122	1.220	2.7
Norway	1.091	1.066	1.024	1.1
New Zealand	1.365	1.053	1.296	.7
Portugal	1.290	1.064	1.213	1.4
Sweden	1.190	1.062	1.121	1.6
United States	1.053	1.015	1.037	28.7

Note.—The variables GO_n^*, GT_n^*, and GMP_n^* refer, respectively, to the gains from openness, trade, and multinational production, for country n, under independence. The variable L_n refers to number of units of equipped labor in country n, as a percentage of OECD(19)'s total.

TABLE C6

Gains from Openness, Trade, and Multinational Production: $\rho = 0$

	GO_n	GT_n	GT_n^*	GMP_n	GMP_n^*	GMP_n^g	L_n
Australia	1.032	1.016	1.011	1.022	1.022	1.010	3.3
Austria	1.310	1.157	1.123	1.179	1.197	1.067	1.5
Belgium	1.363	1.189	1.154	1.200	1.224	1.075	1.6
Canada	1.202	1.104	1.075	1.123	1.132	1.048	4.4
Denmark	1.199	1.119	1.097	1.102	1.109	1.042	1.2
Spain	1.080	1.053	1.043	1.040	1.039	1.018	4.7
Finland	1.154	1.103	1.087	1.072	1.074	1.033	1.0
France	1.066	1.050	1.044	1.025	1.023	1.013	7.1
Great Britain	1.118	1.054	1.034	1.086	1.087	1.034	7.0
Germany	1.051	1.040	1.036	1.019	1.016	1.010	9.3
Greece	1.204	1.098	1.068	1.133	1.141	1.052	1.4
Italy	1.060	1.040	1.033	1.030	1.029	1.014	7.9
Japan	1.004	1.004	1.003	1.001	1.001	1.001	13.4
Netherlands	1.143	1.090	1.073	1.073	1.073	1.032	2.7
Norway	1.184	1.111	1.089	1.096	1.101	1.040	1.1
New Zealand	1.265	1.080	1.038	1.223	1.238	1.077	.7
Portugal	1.230	1.115	1.084	1.141	1.152	1.054	1.4
Sweden	1.136	1.087	1.070	1.069	1.070	1.031	1.6
United States	1.012	1.010	1.008	1.005	1.004	1.003	28.8

Note.—The variables GO_n, GT_n, GMP_n, and GMP_n^g refer, respectively, to the gains from openness, trade, multinational production, and multinational production in the intermediate-good sector, for country n; GT_n^* and GMP_n^* refer to the gains from trade and multinational production, respectively, from trade-only and MP-only models. The variable L_n refers to the number of units of equipped labor in country n, as a percentage of OECD(19)'s total.

TABLE C7

Gains from Openness, Trade, and Multinational Production: $\rho = 0.5$

	GO_n	GT_n	GT_n^*	GMP_n	GMP_n^*	GMP_n^g	L_n
Australia	1.048	1.025	1.014	1.028	1.035	1.015	3.5
Austria	1.427	1.172	1.129	1.179	1.216	1.049	1.6
Belgium	1.478	1.202	1.185	1.184	1.250	1.047	1.7
Canada	1.282	1.127	1.090	1.128	1.157	1.046	4.4
Denmark	1.320	1.150	1.112	1.120	1.141	1.032	1.3
Spain	1.141	1.079	1.059	1.056	1.068	1.023	4.8
Finland	1.236	1.131	1.110	1.071	1.091	1.017	1.0
France	1.102	1.070	1.062	1.026	1.035	1.009	7.2
Great Britain	1.162	1.078	1.048	1.083	1.105	1.036	7.0
Germany	1.079	1.056	1.051	1.018	1.026	1.005	9.4
Greece	1.346	1.125	1.067	1.184	1.210	1.065	1.5
Italy	1.107	1.062	1.046	1.043	1.053	1.019	8.1
Japan	1.007	1.005	1.005	1.001	1.002	1.000	13.4
Netherlands	1.234	1.122	1.095	1.087	1.104	1.028	2.8
Norway	1.295	1.141	1.106	1.108	1.129	1.029	1.1
New Zealand	1.320	1.100	1.037	1.221	1.262	1.096	.8
Portugal	1.384	1.140	1.082	1.192	1.219	1.063	1.5
Sweden	1.214	1.114	1.090	1.075	1.095	1.023	1.7
United States	1.016	1.012	1.011	1.002	1.005	1.000	27.5

Note.—The variables GO_n, GT_n, GMP_n, and GMP_n^g refer, respectively, to the gains from openness, trade, multinational production, and multinational production in the intermediate-good sector, for country n; GT_n^* and GMP_n^* refer to the gains from trade and multinational production, respectively, from trade-only and MP-only models.

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