Global Production with Export Platforms

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December 28, 2012

Abstract

Most international commerce is carried out by multinational rms, which use their foreign a liates for the majority of their foreign sales. In this paper, I examine the determinants of multinational rms' location and production decisions and the welfare implications of multinational production. The few existing quantitative general equilibrium models that incorporate multinational rms achieve tractability by assuming away export platforms { i.e. they do not allow foreign a liates of multinationals to export { or by ignoring xed costs associated with foreign investment. I develop a quanti able multi-country general equilibrium model, which tractably handles multinational rms that engage in export platform sales and that face xed costs of foreign investment. I rst estimate the model using German rm-level data to uncover the size and nature of costs of multinational enterprise and show that xed costs of foreign investment are large. Second, I calibrate the model to data on trade and multinational production for twelve European and North American countries. Counterfactual results reveal that multinationals play an important role in transmitting technological improvements to foreign countries as they can jump the barriers to international trade; I nd that a twenty percent increase in the productivity of US rms leads to welfare gains in foreign countries an order of magnitude larger than in a world in which multinational production is disallowed. I demonstrate the usefulness of the model for current policy analysis by studying the pending Canada-EU trade and investment agreement; I nd that a twenty percent drop in the barriers to foreign production between the signatories would divert about seven percent of the production of EU multinationals from the US to Canada.

JEL Codes: F12, F23, L23
Keywords: multinational enterprise, production location decisions, export platform, constrained maximum likelihood9(o)29(-284(m)on)]TJ 0 g 0 G /F4ET q 1G /0 1 64.8 191855 cm [:eiin li74.8l S Q17.21524 5.9776 4.335.72 Tf 4.948

1 Introduction

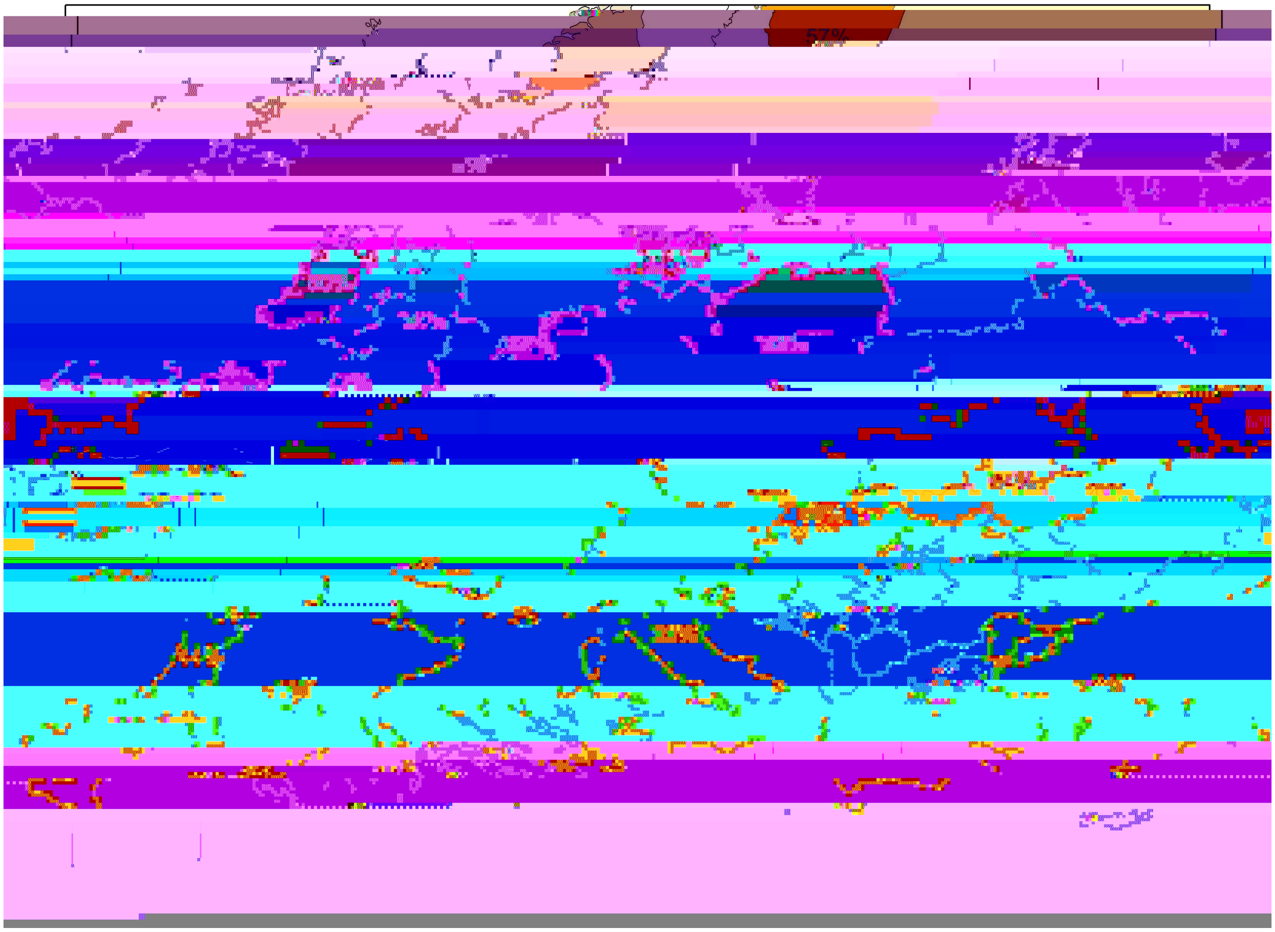
Most international commerce is carried out by multinational firms, which use foreign affiliates for the majority of their foreign sales.[1] In structuring their global operations, these firms confront various costs of multinational production and trade. For instance, whether a firm should pursue a strategy of maintaining many plants to avoid shipping costs or a strategy of consolidating production in a few locations turns on the size of fixed costs of establishing foreign plants relative to the costs of shipping goods. Further, given a set of production locations, the choice of which product to produce where depends on the interaction of comparative advantage and the cost of shipping goods. Taken as a whole, the structure of multinationals' operations must reflect the nature of costs of international commerce. It is therefore interesting that multinationals' global operations reveal a strong home bias: despite the opportunity to move production anywhere, they keep most of their production in the domestic country.

In this paper, I develop a framework that is designed to answer several key questions. First, what are the costs associated with multinational production? How important are the fixed costs of establishing foreign operations relative to the efficiency losses due to remote management? Second, how does the process of globalization, measured as a fall in these costs, affect the structure of global production? Will globalization result in firms' consolidating production in a few favored locations, or will firms expand their global production networks? Third, how does allowing for multinational production affect our understanding of the welfare effects in a general equilibrium trade model?

Existing quantitative models of trade and multinational production have proven tractable only after excluding many of the strategies that firms actually use or by shutting down mechanisms that are almost universally thought to be important. The framework that I develop to answer these questions is suitable both for structural estimation of global production costs using firm-level data and for aggregate quantitative analysis in general equilibrium. My model incorporates, and so allows me to quantify, a wide range of mechanisms that appear in the theoretical literature. In this model, firms choose from a rich array of production strategies in a multi-country setting in which variable trade and multinational production costs interact with increasing returns at the plant level.

An example of the rich production strategies that can be addressed in my model is the case of export platforms. Export platform sales are exports from a foreign plant to other countries. For US multinationals' affiliates in Europe, Figure 1 documents the proportion of output exported to other countries from the host

[1] A multinational firm is a company with enterprises in more than one country. I define its home country as the country in which the parent company of the enterprises is registered. Usually, this coincides with the country of the multinational firm's headquarters. According to Bernard, Jensen, and Schott (2009), in the year 2000 multinational firms accounted for nearly 80 percent of US imports and exports, respectively, and employed 18 percent of the entire U.S. civilian workforce. Publicly available BEA data shows that, in the manufacturing sector, the sales by U.S. MNEs' majority-owned foreign affiliates are more than twice as large as the aggregate U.S. exports.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the choice regarding which country to serve the Netherlands from, because the fixed cost of establishing a plant in France has already been incurred. I solve the firm's problem in two stages. In the first stage, each firm chooses a set of countries in which to produce and incurs the fixed costs of establishing foreign plants. In the second stage, the firm decides for each product which market to serve from which location. In the countries in which a firm has established a plant, I treat its product-location-specific productivities as random variables, similarly to how Eaton and Kortum (2002) treat a country's productivities. By envisioning each firm as consisting of a continuum of products, I obtain intuitive, closed-form expressions for the output at each of the firm's plants. The firm's output is a function of the locations of the firm's plants, the productivity of each plant, the input costs in the plants' host countries, and the local and foreign market potential of the plants' host countries. Furthermore, the model delivers a probability with which a firm chooses a set of plants, as the fixed cost to establish a plant in a foreign country is stochastic and firm-country-specific.

With this framework, I conduct a two-tier empirical analysis. Using German firm-level data on output at the parent and affiliate levels, I estimate both the variable production costs in foreign countries as well as the distribution of fixed costs to establish a foreign plant. I find that German multinational firms face between 7 percent (Austria) and 42 percent (United States) larger variable production costs abroad than at home. In the data and estimated model, the share of foreign production of multinational firms is on average around 30 percent. If the variable production costs were the same in foreign countries as in Germany, the foreign output share would rise to 68 percent (taking into account firms' re-optimizing their locations). If, instead, variable production costs were at their estimated level and fixed costs to setting up foreign plants were zero (so each firm had a plant everywhere), the foreign output share would become 72 percent. Hence, fixed costs and larger variable production costs abroad are similarly important barriers to foreign production. If both variable production cost differences and fixed costs were eliminated, the foreign output share would rise to 88 percent (which is roughly equal to the share of foreign countries' GDPs in the set of countries considered).

In the second tier of my empirical inquiry, I turn my attention to general equilibrium welfare analysis. I calibrate the general equilibrium outcomes of my model to match data on bilateral trade flows, bilateral shares of foreign production, and the country-specific production cost estimates from German multinational firms. The cost estimates of German multinationals enable me to include both variable foreign production frictions and fixed costs in the analysis that otherwise includes only aggregate data. I solve for the endogenous relative wages and price indices in every country. With the calibrated model, I explore how globalization changes the structure of global production. For example, currently, Canada and the EU are negotiating a trade and investment agreement: CETA. If one supposes that the agreement is signed and yields a twenty percent reduction of variable and fixed production costs between the signatories, then { according to my calibrated model { EU multinationals would divert around seven percent of their production from the US to Canada. These findings hinge on the possibility of export platform sales from Canada to the US. Without this possibility, the location and output decisions of European firms are independent between Canada and the United States. Instead, I find that a Canada-EU trade and investment agreement could induce a strong third-party effect on the United States.

A more complete model of multinational production and trade can revise answers to classic questions in the trade literature. First, I evaluate the welfare gains from trade both in my global production model and in a classical trade model without multinational production offered by Anderson and van Wincoop (2003), which is a special case of my model when multinational production is shut down. Contrary to what one may expect, I find that the gains from trade estimates from this standard trade model without multinational production are very similar to the gains from trade estimates in my global production model. However, multinational production is instrumental for the analysis of gains from foreign technology improvements, a question studied by Eaton and Kortum (2002), among others. Suppose all US firms improve their technology by 20 percent. I find that the welfare gains in foreign countries from such a technology improvement are an order of magnitude larger when multinational production is taken into account.

The model presented in this paper contains elements of Helpman, Melitz, and Yeaple (2004) and Eaton and Kortum (2002). As in Helpman, Melitz, and Yeaple (2004), firms produce differentiated goods and can establish foreign plants at the expense of fixed costs.[3] I extend their framework by incorporating export-platform sales and multi-product firms. As in Eaton and Kortum (2002), countries differ in their comparative advantage in production. In my model, however, each product can be produced only by a single firm, which can also produce in foreign countries, while Eaton and Kortum (2002) instead assume that each firm operates only domestically and that firms from different countries can produce the same product. If multinational production is prohibitively costly, my model collapses with respect to its aggregate predictions to Anderson and van Wincoop (2003), and the product-location-specific productivity draws have no impact.

A vibrant area of ongoing research centers on the gains from multinational production and trade. Ramondo and Rodriguez-Clare (2012) investigate the gains from trade, multinational production, and openness.[4] They find that the gains from trade can be twice as large if multinational production is taken into account than without.[5] Arkolakis, Ramondo, Rodriguez-Clare, and Yeaple (2012) endogenize the allocation between production and innovation in a model of global production with monopolistic competition. A key difference between these papers and my work is that they assume away fixed costs of foreign plants. Their calibrated

[3] Helpman, Melitz, and Yeaple (2004) combine key elements that appeared in Melitz (2003) and Horstmann and Markusen (1992).

[4] Their paper extends the Ricardian trade model by Eaton and Kortum (2002) insofar as it allows the technologies that originated in a country to be used for production abroad.

[5] One reason that our results differ is that in their paper, a complementarity between trade and MP is directly built into the input bundle of a multinational firm abroad, which is a function of intermediate shipments from the home country.

models' fit of the data on export platform sales is only successful in special cases.[6] While my model fits the export platform sales of US multinationals well (without having aimed to fit those in the calibration), a restricted version of my model without fixed costs does not. Both fixed and variable costs discourage foreign production, but it is the fixed costs that induce firms to concentrate their production in a few locations.[7]

My findings that multinational firms face significantly larger variable production costs abroad and significant fixed costs of establishing foreign plants are in line with the findings of Irarrazabal, Moxnes, and Opromolla (2009). They use data from Norwegian firms and develop a structural model that extends Helpman, Melitz, and Yeaple (2004) by incorporating intra-firm trade, and they find that a very large share of intra-firm trade is necessary to rationalize the observed output data.[8] Their paper ignores export platform sales, however, which makes the set of production strategies across which a firm can choose much smaller. Without the possibility of export platform sales, the decision to set up an affiliate in Belgium is independent of the decision to set up an affiliate in the Netherlands.[9]

Since in my model firms choose a set of production locations instead of making independent decisions about whether to establish a plant for each country, this paper also joins a literature that studies large discrete choice problems at the firm level.[10] Morales, Sheu, and Zahler (2011) estimate a dynamic trade model in which the costs of serving a foreign market depend on the set of foreign markets the firm had served in the past. This creates an interdependency of the destination markets. Interdependent location choices within the firm also arise in Holmes (2011), who estimates the determinants of the expansion of Walmart stores within the United States. Both papers use moment inequalities to conduct their estimations. By contrast, the parameters in my model are point-identified, which enables me to conduct general equilibrium analysis.

The following section outlines the model. Section 3 estimates country-specific fixed and variable production costs for German multinational firms via constrained maximum likelihood. Section 4 calibrates the

[6] In Ramondo and Rodriguez-Clare (2012), only when the productivity draws for ideas that originated in one country are uncorrelated across countries can the calibrated model come close to matching the data on export platform sales for US multinationals. The calibrated model in Arkolakis, Ramondo, Rodriguez-Clare, and Yeaple (2012) generates much lower export platform sales for US firms than in the data.

[7] Fixed costs and export platforms have been analyzed together only in very restrictive settings. Neary (2002) shows in a theoretical analysis that with export platform sales and fixed costs of establishing foreign plants, the European single-market policy increases foreign direct investment into the EU from outside countries. Ekholm, Forslid, and Markusen (2007) develop a three-country model that incorporates both fixed costs and export platform sales. Other three-country models with fixed costs and complex relationships between domestic and foreign plants have been developed by Yeaple (2003) and Grossman, Helpman, and Szeidl (2006). However, it is impractical to apply their model to the data of many countries. Head and Mayer (2004) apply a model with multiple countries, fixed costs, and sales to surrounding markets to data on Japanese affiliates under the restriction that each firm can only have a single production location. The interdependence between firms' location and production decisions has been reflected in empirical work by Baltagi, Egger, and Pfaffermayr (2008) and Blonigen, Davies, Waddell, and Naughton (2007), who apply spatial econometric methods to data on bilateral FDI and multinational firms' sales and point out significant third-country effects in their estimation results.

[8] Instead of assuming intra-firm trade, I allow the production efficiency of foreign affiliates to differ from the production efficiency at home (e.g., through communication costs with headquarters).

[9] Existing work on structural estimation with data on multinational firms is sparse. Exceptions are Feinberg and Keane (2006) who structurally estimate U.S. multinationals' decisions to invest and produce in Canada, and Rodrigue (2010) who structurally estimates a model of trade and FDI with data on Indonesian manufacturing plants.

[10] The decision as to where to establish facilities and which market to serve from which facility is known as the `Facility Location Problem' in operations research. See Klose and Drexl (2005) for a survey of the literature on the `Facility Location Problem,' which

general equilibrium, and Section 5 conducts the counterfactual exercises described above. Section 6 concludes.

2 A model of global production with export platforms

I develop a model that explains in which countries firms locate their plants, how much they produce in each country, and how much they ship from one country to another. Geography is reflected in three kinds of barriers between countries: variable iceberg trade costs, variable efficiency losses in foreign production, and fixed costs to establish foreign plants. Countries differ in endowments of labor and the mass and distribution of firms. While the technology of local firms is part of the endowments, the set of firms that produce in a country is determined

$$P_j = \left[\int_{\Omega_j} p_j(\omega)^{(1-\sigma)} d\omega \right]^{1/(1-\sigma)}; \tag{3}$$

which is simply the standard CES price index over the firm-level price indices. The price index of firm ω to country j is

$$p_j(\omega) = \left(\int_0^1 p_j(\omega; \nu)^{1-\eta} d\nu \right)^{1/(1-\eta)}; \tag{4}$$

and the expenditure on goods produced by firm ω in country j is

$$s_j(\omega) = p_j(\omega)^{1-\sigma} \frac{Y_j}{P_j^{1-\sigma}}. \tag{5}$$

Next, I proceed to describe the problem of a single firm.

2.2 The firm's problem

Each firm behaves like a monopolist and faces a CES demand function for each of its products. Every firm is infinitesimal and takes aggregate price indices, income, and wages as given. The problem of the firm consists of two stages: first, the firm selects the set of countries in which to establish a plant in order to maximize expected profits; it then learns about the exact quality of each plant, and decides which market to serve from which location for each product. Note that the timing assumption – the firm learns about the quality of each plant after the set of production locations is selected – is not essential, but it simplifies the analysis of firm-level data for reasons that I will discuss in Section 3.

A firm is characterized by its country of origin, i, its core productivity parameter, , a vector of fixed cost levels in every country, , and a vector of location-specific productivity shifters, . All these variables are firm-specific. There are N countries.

2.2.1 Production decisions after the plants are selected

Denote by Z the set of locations the firm has selected for production plants. I assume that a firm always has a plant in its home country. In those countries in which the firm has established a plant, the firm draws a location-specific productivity for each of its products from a Fréchet distribution.[12] Let $_j$ be a random variable that denotes the productivity level in country j for a particular product. The cumulative distribution function

[12] See Kotz and Nadarajah (2000), Chapter 1, for a description of the Frechet and other extreme value distributions.

of a product's productivity in country j is:

$$\mathrm{Pr}(\;_{j}\quad x) = \exp\quad(\;_{j})\;(\;_{ij}\, x)\quad :$$

The product of the core productivity level, , and the plant-speci c productivity shifter, $_j$, determines the level of the productivity draws in the plant in country j. Larger values of $_j$ imply better productivity distributions.[13] The dispersion of the productivity draws is decreasing in . All rms from country i may have lower productivity in country l

which motivates the firm to concentrate its production in as few locations as possible. The firm selects a set of production locations based on its core productivity level, φ, its fixed cost draws, ν, and its country of origin, i. As it is assumed that a firm always has a plant in its home country, in total, there are 2^{N-1} feasible combinations of locations. I denote the set that contains all sets of locations for a firm from country i by $\mathcal{Z}^i$. Fixed costs have to be paid in units of labor from the host country. If the firm chooses the set of locations $Z \in \mathcal{Z}^i$, the firm incurs fixed costs equal to $\sum_{l \in Z} \nu_l w_l$.

The firm chooses the set of locations that maximizes its expected profits. The expected variable profits from Z are simply the sum of the expected sales to all markets multiplied by the proportion of sales that represents variable profits:

$$E(\pi(i;\varphi;Z;\cdot)) = \frac{1}{\sigma}\sum_m E(s_m(i;\varphi;Z;\cdot)). \tag{11}$$

The total expected profits of set Z are the expected variable profits minus the fixed cost payments associated with the locations contained in the set. I assume that no fixed costs have to be paid for the domestic plant (or that they have been paid in the firm's entry stage that I do not include in this model). The expected total profits from choosing a set of locations Z are thus:

$$E(\Pi(i;\varphi;Z;\nu;\cdot)) = E(\pi(i;\varphi;Z;\cdot)) - \sum_{k \in Z; k \neq i} \nu_k w_k. \tag{12}$$

I write the set of locations that maximizes the expected profits as

$$Z(i;\varphi;\nu) \in \arg\max_{Z \in \mathcal{Z}^i} E(\Pi(i;\varphi;Z;\nu;\cdot)). \tag{13}$$

While, in general, multiple sets of locations could be optimal for the firm, as long as the fixed cost vector ν is drawn from a continuous distribution (where the draws are independent across countries), the set of fixed cost shock vectors for which the firm is indifferent across two or more location sets has measure zero.

In the following subsection, I turn to describing the endowments of each country, the aggregation of the firms' choices, and the global production equilibrium.

2.3 Equilibrium

Country j is endowed with a population L_j and a continuum of heterogeneous firms of mass M_j. I assume that the elements of the fixed cost vector, ν, are drawn independently across countries from a distribution denoted by $F^i(\nu)$ that can differ by the country of origin, i, is continuous, and has the positive orthant as its support.[15]

[15] For instance, the fixed costs to produce domestically are assumed to be zero, which generates differences among the fixed cost contributions across countries.

The core productivity level, φ, and the vector of location-specific productivity shifters, ν, can be realizations of arbitrary (potentially degenerate) distributions, which are denoted by $G(\varphi)$ and $H(\nu)$, respectively.

Now I proceed to aggregate over the individual firms' choices to establish expressions that I use in the definition of the global production equilibrium below. The share of firms from country i with core productivity φ that choose location set Z is

$$\chi^{i,\varphi}_{Z} = \int 1[Z(i,\varphi,\nu) = Z]\, dF^i(\nu): \tag{14}$$

This formulation is used in the derivation of the total sales of firms that originated in country i from country l to country m, X_{ilm}. We can simply integrate over the core productivity levels of the firms from country i, and write their sales as the weighted sum of the sales a firm would make from country l to country m conditional on a location set, where the weights are the probabilities with which the firm actually chooses this location set:

$$X_{ilm} = M_i \int \sum_{Z' \in \Omega^i} \chi^{i,\varphi}_{Z'} E\left(s_{lm}(i,\varphi,Z',\nu)\right) dG(\varphi): \tag{15}$$

Aggregate trade flows from country l to m are then simply the sum of the term X_{ilm} across all countries of origin:

$$X_{lm} = \sum_i X_{ilm}: \tag{16}$$

Following (3), the consumer price index in market m, P_m, consists of the firm-level price indices for market m of firms from all countries. Again, the expression is the integral over the core productivity levels of the firms and a weighted sum of the firms' price indices conditional on their location choice:

$$P_m = \left[\sum_i M_i \int \sum_{Z' \in \Omega^i} \chi^{i,\varphi}_{Z'} E\left(p_m(i,\varphi,Z',\nu)^{1-\sigma}\right) dG(\varphi)\right]^{1/(1-\sigma)}: \tag{17}$$

In order to establish the labor market clearing condition for country k, I define the set of feasible location sets for firms from country i that include a location in country k as $\Omega^i_k = \{Z \in \Omega^i \mid k \in Z\}$. Total labor income in country k is equal to the sum of the wages paid in production in country k by firms from all countries and of the wages paid in plant construction by foreign companies:

$$w_k L_k = \frac{1}{\sigma}\sum_m X_{km} + \sum_{i \neq k} M_i \int\int \sum_{Z \in \Omega^i_k} 1[Z(i,\varphi,\nu) = Z]\, \kappa_k w_k\, dF^i(\nu)\, dG(\varphi): \tag{18}$$

I assume that a representative household owns the domestic firms.[16] The aggregate income in country m is then the sum of the labor payments and the profits by firms that originated in country m:

$$Y_m = w_m L_m + M_m \int \int \sum_{Z \in Z^m} 1[Z(i; \; ; \;) = Z] \, E \, ((\; i; \; ; Z; \; ; \;) dF^i(\;) dG(\;) \tag{19}$$

Now that I have defined the expressions above, I can define the global production equilibrium.

Definition 1. Given $_{ij}; \; _{ij}; F^i(\;); G(\;); H(\;); M_i; Z^i; \forall i; j = 1; ...; N$, a global production equilibrium is a set of wages, w_i, price indices, P_i, incomes, Y_i, allocations for the representative consumer, $q(!; \;)$, prices, $p_m(i; \; ; Z; \;)$, and location choices,

3.1 Data description and preliminary evidence on barriers to foreign production

to calculate country-speci c manufacturing absorption (described in Appendix B), and I use estimates from a standard gravity pure trade model as proxies for bilateral trade costs and price indices.

3.2 Estimation

Next, I complete the empirical speci cation of the model, and then I show how xed and variable production costs can be estimated from location set and output data from German multinationals via constrained maximum likelihood.

3.2.1 Parameterization

Let $\tilde{}_{t;k} = \ _{t;k} w_k$ denote the value of the xed costs that rm t must pay to erect a production facility in country k. Let $\tilde{w}_k = w_k \ _{ik}$ denote the unit input costs in country k of German rms (rms from country i). I add a subscript t

The first term represents expected variable profits from having production facilities in the countries contained in the location set, and the second term represents the fixed costs that the firm would have to pay. Recall that the level of fixed costs is known at the time the firm makes its decision, but the firm only learns

I. Proposition 2 states that given all other parameters, the solution to this system of equations is unique (the proof is in the appendix).

Proposition 2. Let $r : \mathbb{R}^K_{++} \times Z^i \to \mathbb{R}^K_{++}$ be the stacked vector of revenues as defined in equation (23), where K denotes the number of countries in which firm t has a plant and $\Phi = [\phi_{min}; \phi_{max}]^K$ with $\phi_{min} > 0$ and $\phi_{min} < \phi_{max} < 1$. Then for any triple $\{r_t; \tilde{w}; Z\}$, the vector ϕ that solves $r_t - r(\tilde{w}; Z; \phi) = 0$ is unique.

The likelihood function for each firm consists of the probability of its chosen location set and the density of the plant-specific revenues of the firm conditional on its location set and its core productivity level. I integrate out the core productivity level of each firm, which is observed by the firm but unobserved by the researcher. The likelihood function of the parameters $\theta = \{\tilde{w}; \sigma; \tilde{\mu}; \tilde{\rho}; \ldots\}$ given the observed data on location choice and revenues $\{Z_t; r_t\}_{t=1}^T$ can be written as:

$$L(\theta; \{Z_t; r_t\}_{t=1}^T) = \prod_{t=1}^T \int Pr(Z = Z_t \mid \phi; \tilde{w}; \sigma; \tilde{\mu}; \tilde{\rho}) g(r_t \mid Z_t; \phi; \tilde{w}) dG(\phi; \ldots); \qquad (24)$$

The first factor under the integral – the probability of the location choice – is specified directly in (22). The second factor – the density of the revenues – can be expressed in terms of the density of the plant-specific productivity shifters, $\eta_{t;l} = \frac{\phi_{t;l}}{\phi_t}$. It follows from Proposition 2 that the vector of revenues, r_t, can be inverted to get the vector of plant-specific productivity levels, ϕ_t. The firm-location-specific productivity shifter $\eta_{t;l}$ is i.i.d. across firms and locations. I rewrite the likelihood function in (24) as

$$L(\theta; \{Z_t; \phi_t\}_{t=1}^T) = \prod_{t=1}^T \int Pr(Z = Z_t \mid \phi; \tilde{w}; \sigma; \tilde{\mu}; \tilde{\rho}) |J_t(\phi; \tilde{w})| \prod_{l \in Z_t} h\left(\frac{\phi_{t;l}(\tilde{w})}{\phi} \mid \ldots\right) dG(\phi; \ldots); \qquad (25)$$

where $h(\cdot \mid \cdot)$ denotes the univariate density of the firm-location-specific productivity shifter. The term $|J_t(\phi; \tilde{w})|$ is the determinant of the Jacobian which is included in the likelihood function because of the change of variables from the firm's revenues to the firm's productivity shifters.

Note that the firm-specific productivity shifter is not directly observed; we learn about the firm's productivity level in country k – given the current parameter guess and the observed country-specific output levels of the firm – from a system of equations that contains the output of the firm in each of its locations specified in (23). Therefore, I solve the following constrained optimization problem to estimate the parameters in which the objective function is the logarithm of the likelihood function specified in (25):

the low foreign output share abroad discussed in Section 3.1. The unit input costs in Germany are normalized to one. The smallest di erence in unit input costs is found in Austria, in which German multinationals face only around seven percent larger variable production costs than at home. Within Western European countries, the production costs for German multinationals are largest in Italy and the United Kingdom (33-34 percent higher than in Germany). The production costs in the United States are around 42 percent higher than at home. The di erences in production costs re ect both wage-level di erences and e ciency losses that occur by producing outside the home country.

Table 1: Maximum Likelihood Estimates

		Unit input costs ₩	Fixed costs ~
Country			
Austria		1.076	4.659
		(0.021)	(0.423)
Belgium		1.144	5.609
		(0.038)	(0.500)
Canada		1.324	5.067
		(0.080)	(0.571)
Switzerland		1.264	4.468
		(0.055)	(0.472)
Spain		1.223	3.912
		(0.018)	(0.335)
France		1.229	3.683
		(0.023)	(0.243)
United Kingdom		1.341	3.906
		(0.021)	(0.321)
Ireland		1.127	6.149
		(0.052)	(0.671)
Italy		1.334	3.978
		(0.039)	(0.309)
Netherlands		1.194	5.303
		(0.029)	(0.513)
United States		1.420	3.847
		(0.016)	(0.250)
S.d. log xed cost, ~	2.1902		
	(0.320)		
Scale parameter productivity,	1.1329		
	(0.017)		
Shape parameter productivity,	5.1026		
	(0.620)		
S.d. log productivity shock,	0.1844		
	(0.009)		
Log-Likelihood	-1.21E+004		
Number of rms, T	665		

Notes: Unit input costs in Germany are normalized to one. Standard errors in parentheses.

We can give the xed costs a value interpretation as we observe the rms' output in Euro and, with

CES preferences and monopolistic competition, we can easily determine that variable profits are proportional to output. Fixed costs are identified by observing the actual choice of production locations and variable profits together with the counterfactual scenarios of how variable profits would change if the firm altered its set of production locations. Note that my model does not distinguish between fixed costs to maintain a plant and sunk costs to establish a foreign plant. I use the estimates in Table 1 together with the structure of the model to calculate the mean fixed costs paid by firms that set up a production location in the respective countries. The calculation of the mean fixed cost conditional on having established a plant in the country is described in Appendix C and the results are displayed in Table 2. For most countries the estimated mean fixed cost of plants that were actually established is 6-8 million Euro. The paid fixed cost is estimated to be larger in Canada (12 million) and Belgium (18 million). The larger fixed cost estimates for these countries are in accordance with the data in Table 10 in Appendix B. Belgium has almost the same geographic location as the Netherlands and a similar local and surrounding market potential. While the number of German firms that have production locations in these countries is about the same, the output of plants in Belgium is much larger. This is reflected in the estimation of a lower variable production cost in Belgium and a larger fixed cost to keep the number of entrants at the same level with the Netherlands. Similarly, only a small number of firms have a plant in Canada, but they tend to have very large outputs.

3.4 Decomposing the sources of home bias in production

While the copious literature on the proximity-concentration trade-off has provided evidence for the presence of fixed costs, little is known about their quantitative importance. The parameter estimates above demonstrate both significant fixed costs to starting production in a foreign country and higher variable production costs abroad. In this section, I let firms re-optimize their location decisions as well as their decisions about which market to serve from which location, under different levels of fixed and variable costs.

Table 3

Table 2: Fixed cost by country

Country	Mean xed cost of rms who set up a plant in the

Table 3: Average share of foreign production in the output of German multinationals

Data	Model	No xed costs	Same unit input costs as in Germany	No xed costs and same unit input costs as in Germany
0.288	0.317	0.716	0.676	0.883
	(0.013)	(0.009)	(0.021)	(0.001)

Notes: Trade costs and price indices are held xed. Standard errors in parentheses.

4 Calibration

In the second tier of my empirical inquiry, I focus on general equilibrium welfare analysis. In this section, I calibrate the key parameters to the general equilibrium outcomes of the model using data for many countries. Speci cally, I calibrate trade costs, variable foreign production costs, and xed costs of setting up foreign a liates, to data on bilateral trade ows, the values of output of rms from country i in country l, and the estimates of the country-speci c variable production costs of German multinationals from the previous section. The estimates of xed and variable production costs for German multinationals from the previous section enable me to include both variable foreign production frictions and xed costs in the analysis. I solve for the endogenous relative wages and price indices in every country.

4.1 Data

The analysis incorporates the same 12 Western European and North American countries as the previous section. Data on multinational production comes from Ramondo, Rodriguez-Clare, and Tintelnot (in process).[25] Gross manufacturing production and bilateral trade data comes from OECD STAN. Figures on labor endowments are drawn from the Penn World Tables, and statistics on educational attainment levels by country are from Barro and Lee (2010). Data on trade and multinational production (MP) are averages across the years 1996 to 2001, and the gures on population and educational attainment are for the year 2000.

[25] Unlike bilateral trade ow data, data on production activities of multinationals in foreign countries is documented only sporadically. They use available data from UNCTAD, BEA, Bundesbank and other sources on non- nancial a liate sales together hs ucti01o

4.2 Calibration procedure

The model delivers predictions for MP and trade shares, which I use as moments to calibrate the parameters.[26]

The share of expenditures by consumers from country

$$f_{il} = {}^{f}_{const} \, (dist_{il})^{{}^{f}_{dist}} \, ({}^{f}_{contig})^{contig_{il}} \, ({}^{f}_{lang})^{language_{il}} \quad \text{for } i \neq l:$$

The mass of firms in country i, M_i, is set proportional to the product of population size and average years of schooling in country i, while the size of the labor force, L_i, is set proportional to the population in country i

$$\min_{;w;A} d(\; ;w;A \;)^0 d(\; ;w;A \;)$$

subject to:

$$A_m(\; ;w;A \;) = A_m \quad 8m = 1;:::;N$$

$$L_l^d(\; ;w;A \;) = L_l \quad 8 = 1;:::;N$$

Appendix E, I show for a symmetric world how additional production locations lead to lower shares of export

5 General equilibrium counterfactuals

I proceed by conducting counterfactual analysis based on the calibrated global production model. In each counterfactual, the general equilibrium is resolved for the new parameter values. I begin with an analysis of an important current policy issue.

5.1 Potential e ects from a Canada-EU trade and investment agreement

The EU and Canada are currently negotiating a trade and investment agreement: CETA.[31] What would be the e ects of such an agreement { if it is signed { on the signatories and the U.S.? My setup is particularly suitable welfare gains in EU countries would be positive but moderate in size and larger for smaller countries. The US and Switzerland would experience small welfare losses. The US economy is large enough that even though the diversion of EU investment from the US to Canada would be substantial, it would not be a ected much in terms of aggregate welfare.

Table 5: Counterfactual changes of lower EU-Canada MP costs

	Di erence in inward MP-shares		Rel. welfare
	Canada	United States	

tries.[35] Thus, the gains from foreign technology improvements are dramatically underestimated if multinational production is omitted from the analysis.

Table 7: Gains from Trade

	Global Production model			Pure Trade model
	Welfare change	Real pro t change	Real wage change	Welfare / Real wage change

Overall, this section suggests that if one wants to evaluate the gains from trade, the use of a pure trade model that ignores multinational production provides results that are close to those from a more general model with trade and multinational production. Furthermore, firms benefit from trade, as trade enables them to economize on fixed costs and to exploit comparative advantage in production. I continue by comparing the outcomes from the benchmark calibrated model with a hypothetical world in which costs of multinational production are prohibitive.

5.3.2 The gains from multinational production

I define as the gains from multinational production the change in real income, Y_j / P_j, one finds when going from a version of my model with infinite costs to multinational production to the model with the calibrated and lowers a multinational's marginal cost curve. On the other hand, the aggregate price index falls, which lowers demand, and multinational firms bear the burden of fixed costs for multinational production. Note that if fixed costs were zero, real profits would rise unambiguously. Furthermore, in a world in which countries are asymmetric in the ratio of labor size to mass of firms, real profits may rise in the country with a particularly

5.3.4 Remarks

While the gains in real wages due to multinational production are similar to the gains in real wages due to trade, the welfare gains from multinational production are much smaller, since real profits fall substantially due to the fixed costs of establishing foreign plants. Note that the welfare gains from multinational production may increase considerably if free entry is taken into account. Lower real profits under multinational production would lead to less entry and henceforth less expenditures on entry costs, which can substantially change the calculation of the welfare gains from multinational production. In future research it would be interesting to incorporate free entry into my model and estimation. Conceptually, this extension is straightforward. For many potential applications free entry does not matter, but it is likely to affect the calculation of the overall gains from multinational production.

induces a rm-delocation e ect. My framework can be used to quantitatively investigate the implications of such policies or other changes to the economic environment.

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Appendices

Appendix A Propositions

Proposition 1. The rm-level sales to each market increase as additional production locations are added to the set of existing locations. However, there is a cannibalization e ect across production locations. That is, a rm that adds a production location decreases the sales from the other locations.

Proof. Let $Z^1 \quad Z^2$. The proposition consists of two parts. Part (i) states, $s_m(i; \; ; Z^1; \;) > s_m(i; \; ; Z^2; \;) \quad 8m$. Proof: Substituting equation (7) into (8) yields

$$s_m(i; \; ; Z; \;) = \quad {}^{1}\frac{Y_m}{P_m^{1}} \left(\sum_{k 2 Z} (\; {}_{ik} w_k \; {}_{km}) \quad {}_k \right)^{(\quad 1)=} ;$$

which increases as additional locations are added to Z since $\quad > \quad 1$. Part (ii) states, $s_{lm}(i; \; ; Z^1; \;) < s_{lm}(i; \; ; Z^2; \;)$ if $l 2 Z^2 \quad 8m$. Proof: Substituting equations (9), (8) and (7) into (10) yields

$$s_{lm}(i; \; ; Z; \;) = \begin{cases} {}^{1}\frac{Y_m}{P_m^{1}} \dfrac{(\; {}_{il} w_l \; {}_{lm}) \quad {}_l}{\left(\sum_{k 2 Z} (\; {}_{ik} w_k \; {}_{km}) \quad {}_k\right)^{(\frac{\quad +1}{\quad})}} & \text{if } l 2 Z \\ 0 & \text{otherwise.} \end{cases}$$

The denominator increases as additional locations are added to Z since $\quad > \quad 1$. ■

Proposition 2. Let $r : R^K_{++} \quad Z \quad {}^i \quad ! \quad R^K_{++}$ be the stacked vector of revenues as de ned in equation (23), where K denotes the number of countries in which rm t has a plant and $\quad = [\quad {}_{min} ; \quad {}_{max}]^K$ with $\quad {}_{min} > 0$ and $\quad {}_{min} < \quad {}_{max} < 1$. Then for any triple $f r_t ; w; Z g$, the vector that solves $r_t \quad r(w; Z; \;) = 0$ is unique.

Proof. The proof shows that the conditions for the univalence theorem of Gale and Nikaido (1965) are satis ed. Clearly $r(w; Z; \;)$ is di erentiable with respect to and is a closed rectangular region. It is left to show that Jacobian matrix of the mapping r is a P-Matrix at all $\quad 2 \quad$.

I simplify the expression in equation (23) in the following way. I drop the constants and de ne $\quad = \frac{\quad +1}{\quad}$, and $y_m = \frac{Y_m}{P_m^{1}}$. Given the assumptions made in the text, $0 < \quad < 1$. I denote $c_{lm} = (w_l \; {}_{lm}) \quad$. Further, I drop the rm index t. Then $r_{t;l}$ becomes

$$r_l(c; Z; \;) = \sum_m y_m \frac{c_{lm} \quad {}_l}{\left(\sum_{k 2 Z} c_{km} \quad {}_k\right)}$$

Note that

55N89 :.906oi-1.26 Tf 16 Td [( )]1t6 Td [(55N89 :.906oi-1.26 Tf 16 Td [( )]1t6 Td [(55N89 :.906m7 1 7 [(l)-6(m)]TJ/F11 9.9626 $^{1} c \; {}_{lm} \; c$

$$\frac{@r_l}{@ \; {}_l} = \sum_m y_m \quad c \; {}_{lm} c_{lm} \; {}_l^{2} \quad {}^{1} + \; c_{lm} \; {}_l \quad {}^{1}$$

and for $k \neq l$

$$\frac{\partial r_l}{\partial_k} = \sum_m y_m \frac{c_{km\,k}^{\;1} c_{lm\,l}}{\left(\sum_{k \in Z} c_{km\,k}\right)^{+1}} < 0$$

It is easy to see that at all $\in$, $|\frac{\partial r_l}{\partial_l}|_l > \sum_{k \neq l} |\frac{\partial r_l}{\partial_k}|_k \ \forall l$, hence the Jacobian matrix of r has a dominant diagonal in the sense of Gale and Nikaido (1965). This along with the fact that $\frac{\partial r_l}{\partial_l} > 0 \ \forall l$ implies that the Jacobian matrix of

Table 11: Foreign production shares by number of production locations

Number of production locations	Number of rms	Mean share of foreign production	Mean share of foreign gross production
2	474	0.26	0.37
		(0.20)	(0.24)
3	102	0.32	0.54
		(0.18)	(0.19)
4	40	0.35	0.65
		(0.19)	(0.13)
5	23	0.39	0.71
		(0.16)	(0.10)
6	14	0.46	0.75
		(0.15)	(0.08)
7	12	0.48	0.80
		(0.06)	(0.07)
all	665	0.29	0.44
		(0.20)	(0.25)

Notes: Statistics for German MNE activities in 12 Western European and North American countries. Standard deviations in parantheses. Source: MiDi database.

$$TradeShare_{lm} = \frac{X_{lm}}{Absorption_m}$$

B.2.2 MP shares

Let Y_{il} denote the value of output produced in country l by rms originating from country i. The construction of the MP shares takes into account that the set of countries included in this study is only a subset of the entire global economy (though an important part of it, with good local coverage, e.g. Western Europe and North America). Further, the total production of rms at home is not directly observed. I therefore take data on

Table 12: Foreign production shares by sectors

Sector	Number of rms	Mean Number of production locations	Mean share of foreign production	Mean share of foreign host countries production
Manufacture of ...				
textiles	15	2.27	0.34	0.39
		(0.80)	(0.22)	(0.25)
Publishing, printing, and reproduction of recorded media	22	2.36	0.26	0.37
		(0.66)	(0.25)	(0.23)
chemicals and chemical products	85	3.05	0.33	0.45
		(1.79)	(0.22)	(0.26)
rubber and plastic products	67	2.73	0.32	0.45
		(1.21)	(0.21)	(0.25)
other non-metallic mineral products	23	2.65	0.39	0.34
		(1.19)	(0.24)	(0.21)
basic metals	31	2.35	0.22	0.40
		(0.66)	(0.14)	(0.24)
metal products	72	2.32	0.27	0.43
		(0.78)	(0.17)	(0.23)
machinery and equipment	138	2.49	0.25	0.46
		(1.16)	(0.17)	(0.26)
electrical machinery and apparatus	34	2.79	0.26	0.48
		(1.65)	(0.17)	(0.26)
radio, television, and communication equipment and apparatus	15	2.33	0.24	0.51
		(0.72)	(0.16)	(0.28)
medical, precision, and optical instruments, watches, and clocks	49	2.33	0.30	0.54
		(0.75)	(0.20)	(0.24)
motor vehicles, trailers and semi-trailers	57	2.82	0.30	0.48
		(1.28)	(0.21)	(0.25)
all	665	2.57	0.29	0.44
		(1.20)	(0.20)	(0.25)

Notes: Statistics for German MNE activities in 12 Western European and North American countries. Standard deviations in parantheses. Statistics are displayed for sectors with more than 10 German multinationals. Source: MiDi database.

Appendix C Calculation of individual level parameters

The estimation in Section 3 delivers a distribution of xed costs faced by the observed multinational rms. With these estimates I derive the distribution of xed costs for each multinational rm conditional on its observed location choice, Z_t, and the location-speci c productivity vector, $_t$. We can then calculate the mean value of xed costs that were actually paid to set up a plant in the respective countries. To my knowledge, Revelt and Train (2000) were the rst to use such a procedure to infer information about the tastes of each sampled customer from the estimates of the distribution of tastes in the population with a nonlinear - mixed logit - discrete choice model.

Let denote the parameter vector of estimates in Section 3. The productivity vector across plants of rm t, $_t$, can be calculated given r_t and . The density of the xed cost draws across countries conditional on having chosen a plant in country l can be written as

$$u(f \mid Z_t; \ _t; \ ) = \frac{Pr(Z_t \mid \ _t; f) z(f \mid \ )}{\int_f Pr(Z_t \mid \ _t; f) z(f \mid \ ) df};$$

where

$$Pr(Z_t \mid \ _t; f) = \int Pr(Z_t \mid \ ; f) k(\ \mid \ ) d \ ;$$

and

$$k(\ \mid \ _t) = \frac{g(\ ) \frac{d \ _t = }{d \ _t} \prod_{l \in Z_t} h(\frac{_{t;l} (w; \ )}{} \mid \ )}{\int_0 g(\ ^0) \frac{d \ _t = \ ^0}{d \ _t} \prod_{l \in Z_t} h(\frac{_{t;l} (w; \ )}{^0} \mid \ ) d} \ ) = $$ (1 Q BT /F10 6.973

D.2 Bilateral MP shares

Figure 4: Bilateral MP shares - data and model

D.3 Variable production costs for German rms

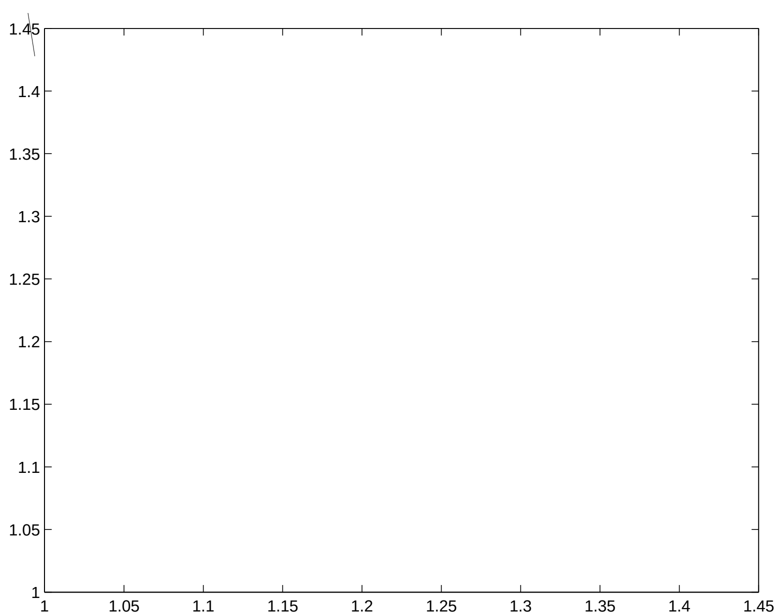

Figure 5: Variable production costs for German rms

Appendix E Number of production locations and export platform shares

Commonly, the intuition is that additional production locations lower the average export platform shares of the rm. The export platform share of a plant is the plant's ratio of export to total sales. However, in general it is not true that any other additional plant decreases the export platform sales ratio of an existing plant: while it is true that the export platform sales decrease, it also matters by how much the local sales decrease. This section shows in a numerical example for a symmetric world that the export platform shares increase with fewer production locations. The numerical results are robust according to many di erent parameters. Nevertheless, it is crucial that trade costs between foreign countries are larger than domestic trade costs, which seems to be a plausible assumption.

I specify the following parameter values: = 6, = 7, $_{lm}$ = 1:6, $_{il}$ = 1:2. Figure 6 displays the export platform shares for plant $l \neq i$ as the number of plants increase. The export platform shares fall from 40 percent for a rm with just 2 plants to 29 percent for a rm with 12 plants. [40]

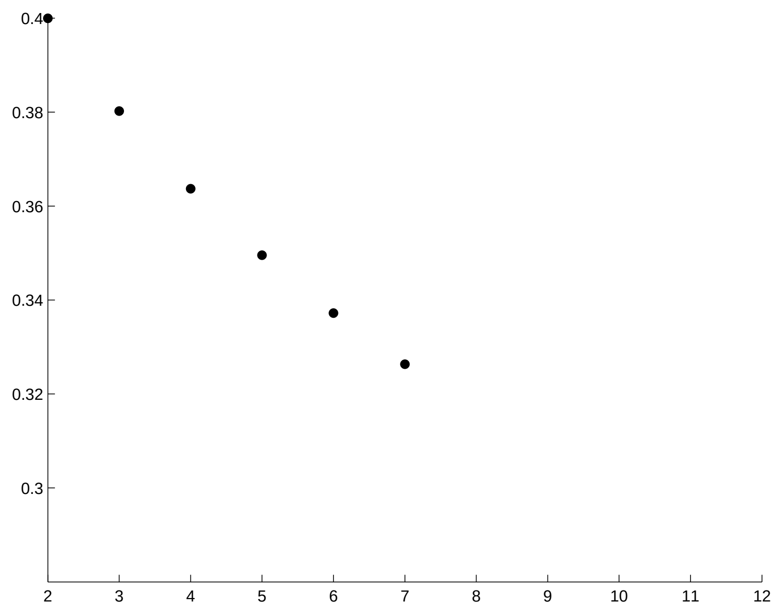

Figure 6: Export platform shares - Numerical example

Appendix F Results for a model with export platforms but without xed costs

Here, I present the results for a calibrated model without xed costs to establish foreign plants. Missing xed

Table 13: Calibrated parameters - restricted global production model without fixed cost

	Parameters
Trade cost	
constant, $_{const}$	0.786
distance, $_{dist}$	0.118
language, $_{lang}$	0.925
contiguity, $_{contig}$	0.936
Variable MP cost	
constant, $_{const}$	1.870
distance, $_{dist}$	0.025
language, $_{lang}$	1.011
contiguity, $_{contig}$	0.847
Norm trade t	0.221
Norm MP t	0.339

Table 14: Export platform shares - Data and Models

	Data	Global Production Model	Restricted Global Production Model

Appendix G Special case: gains from technology improvements

Section 5.2 on the bene ts of foreign technology has two main results. The rst result is that starting from the calibrated model, the magnitude of the gains in foreign countries is much larger if multinational production

Appendix H Potential e ects from an EU-US trade and investment agreement

As a comparison to the potential e ects from CETA, which is currently under negotiation, I also compute the potential e ects from a hypothetical EU-US agreement that would lower variable and xed foreign production costs between the signatories by the same proportion. As expected, the e ects on the non-signatory partners from such an agreement would be even larger: the share of EU multinationals' production in Canada would fall from 9 to 6 percent, and the welfare in Canada would fall by almost half of a percent.

Table 15 contains the predicted outcomes for an EU-US agreement that lowers both variable and xed MP costs between the EU countries and Canada by 20 percent. The structure of this table is analogous to Table 5 in the main text.

Table 15: Counterfactual changes of lower EU-US MP costs

	Di erence in inward MP-shares		Rel. welfare
	Canada	United States	
Canada	1.93	-0.23	99.54
EU countries	-2.84	7.06	100.82 - 101.78
Switzerland	0.08	-0.03	99.68
United States	0.83	-6.80	100.91

Notes: Counterfactual: Reduction in variable and xed MP costs between EU and US by 20 percent. First two columns: Di erences in MP shares, $_{il}$, before and after the counterfactual change (column: destination l, row: source i).