Global Production with Export Platforms

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December 28, 2012

Abstract

Most international commerce is carried out by multinational firms, which use their foreign affiliates for the majority of their foreign sales. In this paper, I examine the determinants of multinational firms' location and production decisions and the welfare implications of multinational production. The few existing quantitative general equilibrium models that incorporate multinational firms achieve tractability by assuming away export platforms – i.e. they do not allow foreign affiliates of multinationals to export – or by ignoring fixed costs associated with foreign investment. I develop a quantifiable multi-country general equilibrium model, which tractably handles multinational firms that engage in export platform sales and that face fixed costs of foreign investment. I first estimate the model using German firm-level data to uncover the size and nature of costs of multinational enterprise and show that fixed 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 find that a twenty percent increase in the productivity of US firms 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 find 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 likelihood estimation

*I am grateful to my advisors Jonathan Eaton and Stephen Yeaple for their guidance, encouragement, and support. I am also grateful to Andrés Rodríguez-Clare and Paul Grieco for encouragement and various discussions on the topic. I wish to thank Kerem Cosar, Anca Cristea, Anna Gumpert, Christian Gourieroux, David Jinkins, Corinne Jones, Sung Jae Jun, Konstantin Kucheryavyy, Matthias Lux, Joris Pinkse, and seminar participants at the German Bundesbank, European Trade Study Group, and Cornell-PSU macro conference for helpful comments and suggestions. I thank the German Bundesbank for the hospitality and access to its Microdatabase Direct investment (MiDi). All errors are my own. Correspondence: `fut111@psu.edu`.

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.

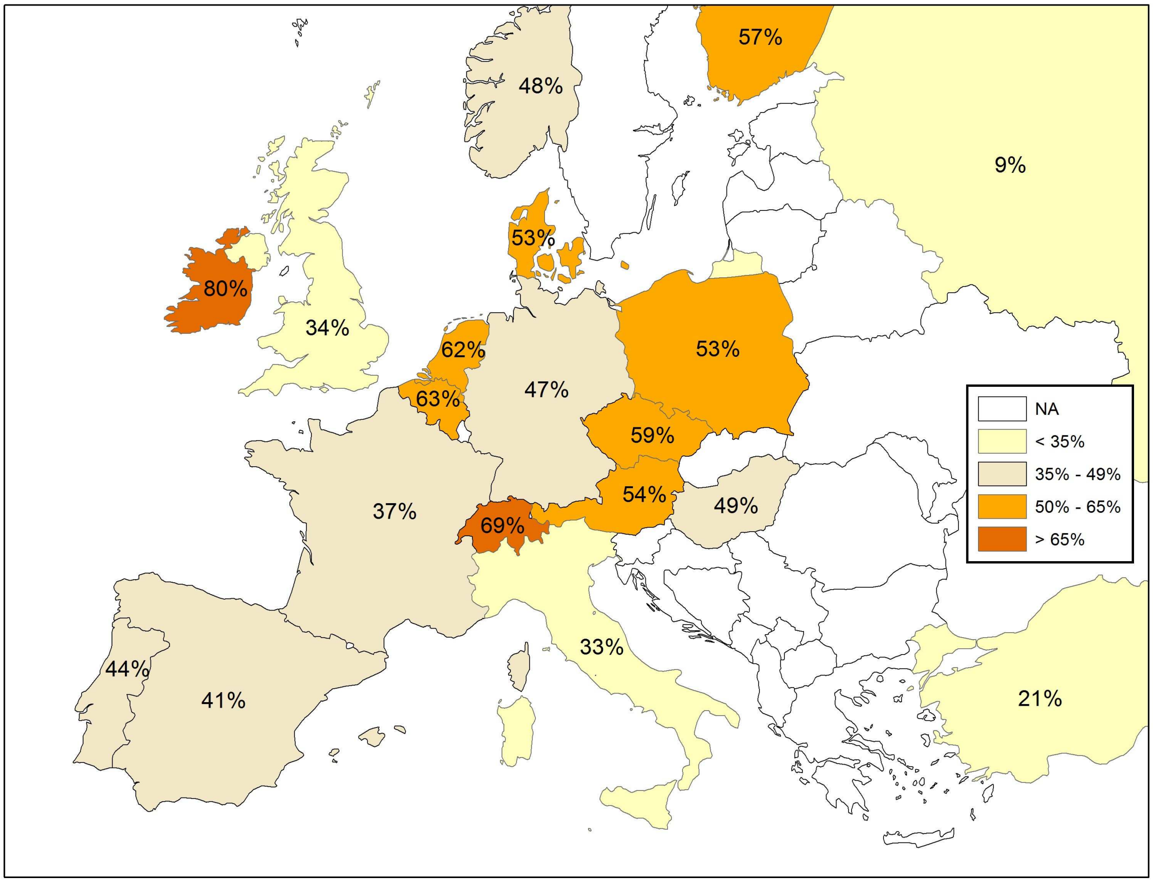

Figure 1: Export platform shares for US multinationals in Europe (year: 2004, source: BEA)

country. Export platform sales account for on average around 40 percent of multinationals' foreign output, a share which is systematically higher for smaller countries. It is implausible to assume that the anticipation of these sales does not affect location or production decisions. My model also incorporates fixed costs of establishing foreign plants, a component of my study which is suggested by many firms' concentrating their production in only a few locations and which constitutes a key feature of much of the existing literature on multinational production. Nevertheless, the few empirical papers that incorporate export platforms ignore fixed costs of establishing foreign plants. I also incorporate multiple products per firm into the framework, an element for which a growing empirical literature provides much descriptive evidence.[2]

The possibility of export platform sales, together with the presence of fixed cost of establishing foreign plants, makes the decision as to which market to serve from which location interdependent across markets. For example, if the firm decides to serve France for a particular product from a local plant, then this decision affects

[2]Evidence on the pervasiveness of multi-product firms is provided by Bernard, Jensen, Redding, and Schott (2007), Bernard, Redding, and Schott (2010), and Arkolakis and Muendler (2010).

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 is primarily concerned with developing solution algorithms to the single firm's problem.

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 endogenously. I assume a market structure characterized by monopolistic competition. For simplicity, I assume there are no fixed costs to exporting.[11] Consequently, every product is sold to every market. I start with the description of demand and then turn to the problem of the firm.

2.1 Demand

I assume standard CES preferences, with the distinction that here each firm has a continuum of products instead of a single product. A good is indexed by a firm ω and a variety υ. I assume a measure 1 of varieties per firm and a fixed measure of firms. If the representative consumer of country j consumes $q_j(\omega, \upsilon)$ units of each variety υ of each firm $\omega \in \Omega$, she gets the following utility:

$$U^j \equiv \left(\int_\Omega \int_0^1 q_j(\omega, \upsilon)^{(\sigma-1)/\sigma} d\upsilon d\omega \right)^{\sigma/(\sigma-1)}. \tag{1}$$

The elasticity of substitution $\sigma > 1$ is identical between varieties inside and outside the firm. Assuming the same elasticity of substitution between varieties within the firm and between varieties from different firms simplifies the pricing decision by the firm. Consumers maximize their utility by choosing their consumption of goods subject to their budget constraint. I denote the aggregate income in country j by Y_j. Utility maximization implies that the quantity demanded in country j of variety υ supplied by firm ω at price $p_j(\omega, \upsilon)$ is

$$q_j(\omega, \upsilon) = p_j(\omega, \upsilon)^{-\sigma} \frac{Y_j}{P_j^{1-\sigma}}, \tag{2}$$

where P_j is the ideal price index in country j:

[11] Fixed costs of exporting (at the firm level) could be incorporated, as in Eaton, Kortum, and Kramarz (2011), but they are omitted for simplicity and would require additional data to be identified.

$$P_j \equiv \left[\int\limits_{\Omega_j} p_j(\omega)^{(1-\sigma)} d\omega \right]^{1/(1-\sigma)}, \tag{3}$$

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

$$p_j(\omega) \equiv \left(\int\limits_0^1 p_j(\omega, \upsilon)^{1-\sigma} d\upsilon \right)^{1/(1-\sigma)}, \tag{4}$$

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, ϕ, a vector of fixed cost levels in every country, η, and a vector of location-specific productivity shifters, ϵ. 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 ν_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 Fréchet and other extreme value distributions.

of a product's productivity in country j is:

$$\Pr(\nu_j \leq x) = \exp\left(-\left(\phi\epsilon_j\right)^{\theta}\left(\gamma_{ij}x\right)^{-\theta}\right).$$

The product of the core productivity level, ϕ, and the plant-specific productivity shifter, ϵ_j, determines the level of the productivity draws in the plant in country j. Larger values of $\phi\epsilon_j$ imply better productivity distributions.[13] The dispersion of the productivity draws is decreasing in θ. All firms from country i may have lower productivity in country l, which is captured by an iceberg loss in production, γ_{il}. These losses may for example occur because of higher costs due to communication challenges, information frictions, or shipments of intermediate products. For technical reasons I impose $\theta > \max(\sigma - 1, 1)$.

At each location, the firm transforms units of labor into goods at a constant marginal cost inversely proportional to productivity. The wage in country j is denoted by w_j. Trade costs to ship goods from country l to m are of the iceberg type and are denoted by τ_{lm}. Given these assumptions about production and shipping technology, it is easy to derive that the costs to serve market m from country $l \in Z$ are distributed as

$$\Pr\left(\frac{w_l\tau_{lm}}{\nu_l} \leq c\right) = 1 - \exp\left(-\left(\frac{\gamma_{il}w_l\tau_{lm}}{\phi\epsilon_l}\right)^{-\theta}c^{\theta}\right).$$

Having its production plants in place, the firm selects, for each product and market, the production location that can supply that market at the minimum cost. Using the known properties of the Fréchet distribution, one can derive that the product-level costs with which the firm will serve market m are distributed according to

$$G_m(c|i,\phi,Z,\epsilon) = 1 - \exp\left(-\sum_{k\in Z}\left(\frac{\gamma_{ik}w_k\tau_{km}}{\phi\epsilon_k}\right)^{-\theta}c^{\theta}\right). \tag{6}$$

With CES preferences and monopolistic competition, the firm charges a constant mark-up, $\frac{\sigma}{\sigma-1}$, for each good over the unit cost of delivering the good to each market. Using the optimal pricing rule, and the distribution of product-level costs, (6), we can write the firm-level price index – defined in (4) – which aggregates the product-level prices that the firm (i,ϕ,Z,ϵ) charges in market m, as

$$p_m(i,\phi,Z,\epsilon) = \kappa^{\frac{1}{1-\sigma}}\phi^{-1}\left(\sum_{k\in Z}(\gamma_{ik}w_k\tau_{km})^{-\theta}\epsilon_k^{\theta}\right)^{-1/\theta}, \tag{7}$$

where $\kappa = \Gamma\left(\frac{\theta+1-\sigma}{\theta}\right)\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}$ is a constant.[14] The total sales of firm (i,ϕ,Z,ϵ) in market m are

[13] The reader familiar with Eaton and Kortum (2002) may recognize the similarity between the country-specific parameter T_j in their paper and the firm-country-specific parameter $\phi\epsilon_j$ in this paper.

[14] This step is analogous to the calculation of the *overall* price index in Eaton and Kortum (2002) and uses the moment generating function for Fréchet distributed random variables. The calculation is valid under the restriction made earlier that $\theta > \sigma - 1$.

$$s_m(i,\phi,Z,\epsilon) = p_m(i,\phi,Z,\epsilon)^{1-\sigma}\frac{Y_m}{P_m^{1-\sigma}}. \tag{8}$$

The expressions for the firm's price index, (7), and total sales, (8), in market m have intuitive properties: the sales rise in the core productivity level of the firm; furthermore, the firm benefits particularly from having a plant in a country k in which the variable costs to supply market m are low (low $\gamma_{ik}w_k\tau_{km}$), and in which the firm has a large plant-wide productivity shifter (large ϵ_k).

Due to constant returns to scale in the variable production costs, the firm will simply choose for each variety the location with the lowest unit cost to serve a market. We can write the share of products for which the plant in country l is selected to serve country m as

$$\mu_{lm}(i,\phi,Z,\epsilon) = \Pr\left[\underset{j\in Z}{\operatorname{argmin}}\frac{\gamma_{ij}w_j\tau_{jm}}{\nu_j} = l\right] = \begin{cases} \frac{(\gamma_{il}w_l\tau_{lm})^{-\theta}\epsilon_l^{\theta}}{\sum\limits_{k\in Z}(\gamma_{ik}w_k\tau_{km})^{-\theta}\epsilon_k^{\theta}} & \text{if } l\in Z \\ 0 & \text{otherwise} \end{cases}. \tag{9}$$

The share of goods that a firm ships from country l to country m is large if the plant in country l has low costs to serve market m relative to the firm's other plants. If the firm has a plant in country l ($l \in Z$), the product-level cost at which a firm actually supplies market m from location l also has the distribution $G_m(c|i,\phi,Z,\epsilon)$. Consequently, $\mu_{lm}(i,\phi,Z,\epsilon)$ equals not only the share of products that a firm with location set Z ships from location l to market m, but also the corresponding value share. Therefore, the sales from location l to market m for such a firm are

$$s_{lm}(i,\phi,Z,\epsilon) = s_m(i,\phi,Z,\epsilon)\mu_{lm}(i,\phi,Z,\epsilon). \tag{10}$$

The relationship between a firm's plants is described in Proposition 1, whose proof is in the appendix.

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

Next, I proceed to examine the optimal choice of the set of locations, Z.

2.2.2 Choice of production locations

There are various motivations for setting up foreign plants: a foreign plant yields proximity to the local and surrounding markets, may have lower factor costs, and, finally, has a comparative advantage in the production of some of the firm's products. On the other hand, the firm incurs a fixed cost for establishing a foreign plant, 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, η, 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 $\sum_{l \in Z} \eta_l w_l$.

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:

$$E_\epsilon(\pi(i, \phi, Z, \epsilon)) = \frac{1}{\sigma} \sum_m E_\epsilon(s_m(i, \phi, Z, \epsilon)). \tag{11}$$

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:

$$E_\epsilon(\Pi(i, \phi, Z, \epsilon, \eta)) = E_\epsilon(\pi(i, \phi, Z, \epsilon)) - \sum_{k \in Z, k \neq i} \eta_k w_k. \tag{12}$$

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

$$Z(i, \phi, \eta) \in \arg \max_{Z \in \mathcal{Z}^i} E_\epsilon(\Pi(i, \phi, Z, \epsilon, \eta)). \tag{13}$$

While, in general, multiple sets of locations could be optimal for the firm, as long as the fixed cost vector η 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, η, are drawn independently across countries from a distribution denoted by $F^i(\eta)$ 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, ϵ, can be realizations of arbitrary (potentially degenerate) distributions, which are denoted by $G(\phi)$ and $H(\epsilon)$, 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

$$\rho_Z^{i,\phi} = \int_\eta \mathbb{1}\left[Z(i,\phi,\eta) = Z\right] dF^i(\eta). \tag{14}$$

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:

$$X_{ilm} = M_i \int_\phi \sum_{Z' \in \mathcal{Z}^i} \rho_{Z'}^{i,\phi} E_\epsilon(s_{lm}(i,\phi,Z',\epsilon)) dG(\phi). \tag{15}$$

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:

$$P_m = \left[\sum_i M_i \int_\phi \sum_{Z' \in \mathcal{Z}^i} \rho_{Z'}^{i,\phi} E_\epsilon(p_m(i,\phi,Z',\epsilon)^{1-\sigma}) dG(\phi)\right]^{1/(1-\sigma)}. \tag{17}$$

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 $\Delta_k^i = \{Z \in \mathcal{Z}^i \mid k \in Z\}$. 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:

$$w_k L_k = \frac{\sigma - 1}{\sigma} \sum_m X_{km} + \sum_{i \neq k} M_i \int_\phi \int_\eta \sum_{Z \in \Delta_k^i} \mathbb{1}\left[Z(i,\phi,\eta) = Z\right] \eta_k w_k dF^i(\eta) dG(\phi). \tag{18}$$

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.

$$Y_m = w_m L_m + M_m \int_\phi \int_\eta \sum_{Z \in \mathcal{Z}^m} \mathbb{1}\left[Z(i,\phi,\eta) = Z\right] E_\epsilon(\Pi(i,\phi,Z,\epsilon,\eta) dF^i(\eta) dG(\phi) \tag{19}$$

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

Definition 1. *Given* $\tau_{ij}, \gamma_{ij}, F^i(\eta), G(\phi), H(\epsilon), M_i, \mathcal{Z}^i, \forall i, j = 1, ..., N$, *a* **global production equilibrium** *is a set of wages,* w_i, *price indices,* P_i, *incomes,* Y_i, *allocations for the representative consumer,* $q(\omega, \upsilon)$, *prices,* $p_m(i, \phi, Z, \epsilon)$, *and location choices,* $Z(i, \phi, \eta)$, *for the firm, such that*

(i) equation (2) *is the solution of the consumer's optimization problem.*

(ii) $p_m(i, \phi, Z, \epsilon)$ *and* $Z(i, \phi, \eta)$ *solve the firm's profit maximization problem.*

(iii) P_i *satisfies equation* (17).

(iv) The labor market clearing condition, (18), *holds.*

(v) Y_m *satisfies equation* (19).

Since the model is static, utility maximization implies current account balance. However, it is possible that a country runs a trade deficit, which is financed by the profits that this country's multinational firms make abroad.

In the following section I apply this model to data from German multinational firms to identify the determinants of firms' production and location choices. In this first tier of my empirical analysis, I take wages, aggregate income, and price indices in countries as given.

3 Estimation of fixed and variable production costs

This section estimates the barriers to foreign production faced by German multinationals. Subsection 3.1 documents that German firms tend to concentrate their production in only a few countries, and – conditional on being active in a foreign country – produce less in that foreign country than the relative size of the foreign economy (measured in GDP or gross production) would suggest if multinationals were completely footloose. Subsection 3.2 describes the estimation of fixed and variable costs of foreign production with constrained maximum likelihood, whose parameter estimates are presented in Subsection 3.3. Finally, Subsection 3.4 conducts counterfactual analysis to document the quantitative importance of each of these barriers.

[16] This seems to be a reasonable assumption: according to Cummings, Manyika, Mendonca, Greenberg, Aronowitz, Chopra, Elkin, Ramaswamy, Soni, and Watson (2010), in 2007, U.S. residents held 86 percent of the total market value of all U.S. companies' equities either directly as individual investors or indirectly through pension funds and retirement and insurance accounts.

3.1 Data description and preliminary evidence on barriers to foreign production

My analysis in this section is based on firm-level data on German multinational firms in the manufacturing sector. By law, German resident investors are required to report on the activities of foreign affiliates if the affiliate has a balance sheet total above 3 million Euro and the investor has a share of voting rights of 10 percent or more. The information about the foreign affiliates is contained in the Microdatabase Direct Investment (MiDi) which is maintained by the German Bundesbank.[17] I use data for the year 2005 for affiliates that belong to the manufacturing sector and that are majority-owned by a parent firm in the manufacturing sector. I focus on German multinationals' activities in twelve Western European and North American countries.[18] I take the set of countries in which a multinational owns an affiliate (including the home country) as the corresponding data analogue to the set of production plants in the model. I observe the total sales for each affiliate as well as the total sales for the parent company.[19]

The data for manufacturing firms in these host countries contains 1,711 positive firm-country output observations from 665 firms. The United States and France are the most popular destination countries for German multinational firms. Table 10 in Appendix B describes the activities at the country level. Most multinationals concentrate their production in very few countries: the average number of production locations (including the home country) is 2.57. Further, the fraction of multinationals' production that occurs abroad is small relative to the fraction of aggregate production (by all – including foreign – firms) that occurs abroad. I call this phenomenon 'home bias in production.' On average, across all German multinationals, the share of foreign production in total output is 0.29. Table 11 in Appendix B shows that the share of foreign production in total output is rising in the number of foreign affiliates. However, even for firms with more than six production locations, the average share of total output that is produced abroad is only around 50 percent. Suppose a firm's output in country k were proportional to the value of gross production in country k. This would result in an average share of foreign output to global output of 0.44, controlling for the set of locations in which the firm is active.[20] As this figure is larger than the actual foreign output share of firms, 0.29, this finding suggests that, beyond fixed costs, differences in variable production costs drive home bias in production.[21]

Additionally, I use data on gross production and bilateral trade flows from the OECD STAN database

[17] Other research uses of the database include Muendler and Becker (2010), who study the margins of multinational labor substitution for multinational firms, and Buch, Kleinert, Lipponer, and Toubal (2005), who characterize the patterns of German firms' multinational activities.

[18] These countries are Austria, Belgium, Canada, Switzerland, Germany, Spain, France, United Kingdom, Ireland, Italy, Netherlands, and the United States.

[19] I consolidate multiple affiliates in the same country by the same parent company into one entity.

[20] Specifically, I calculate for each firm with location set Z, $\frac{\sum_{k \neq i, k \in Z} y_k}{\sum_{k \in Z} y_k}$, where y_k denotes gross production in manufacturing in country k and i denotes the country of origin of the firm (here Germany). The average of this measure across firms is 0.44 as opposed to 0.29 for the average foreign output share of the firms.

[21] This pattern is robust across various sub-sectors of the manufacturing sector (see Table 12 in Appendix B), with the exception being '*other non-metallic mineral products*' in which the mean share of foreign host countries' production exceeds the mean share of foreign production by German firms from this sector.

to calculate country-specific 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 specification of the model, and then I show how fixed 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 $\tilde{\eta}_{t,k} = \eta_{t,k} w_k$ denote the value of the fixed costs that firm t must pay to erect a production facility in country k. Let $\tilde{w}_k = w_k \gamma_{ik}$ denote the unit input costs in country k of German firms (firms from country i). I add a subscript t to the variables that are firm-specific. I assume that the fixed cost that a firm has to pay to start production in country k, $\tilde{\eta}_{t,k}$, is drawn independently across countries and firms from a log-normal distribution with mean $\mu_{\tilde{\eta}}$ and standard deviation $\sigma_{\tilde{\eta}}$. I set the fixed costs in Germany to zero and normalize the unit input costs in Germany to one. Further, I assume that the location-specific productivity shifter ϵ is drawn from a log-normal distribution, $\log \mathcal{N}(0, \sigma_\epsilon)$, independently across countries and firms, and that the core productivity levels of the German multinationals are drawn from a Pareto distribution with scale parameter μ_ϕ and shape parameter σ_ϕ.

I set the value of the elasticity of substitution between products, σ, to six. This implies a reasonable mark-up of 20 percent above marginal costs. The estimates are robust to various parameters for the dispersion parameter, θ, of the distribution of the country-firm specific productivity shifters. I use a benchmark value of seven for the dispersion parameter ($\theta = 6$ and $\theta = 9$ give very similar results).[22]

3.2.2 Constrained Maximum Likelihood Estimation

Under the new notation with firm subscripts, $\tilde{\eta}_{t,k} = \eta_{t,k} w_k$, $\tilde{w}_k = w_k \gamma_{ik}$, and equations (11) and (12) from the model, the expected profits from selecting location set Z for firm t with core productivity ϕ_t and fixed cost draws $\tilde{\eta}_t$ are:

$$E_\epsilon(\Pi(\phi_t, Z, \epsilon, \tilde{\eta}_t; \sigma_\epsilon, \tilde{w})) = \frac{1}{\sigma} \kappa \phi_t^{\sigma-1} \sum_m \int_\epsilon \frac{Y_m}{P_m^{1-\sigma}} \left(\sum_{k \in Z} (\tilde{w}_k \tau_{km})^{-\theta} \epsilon_k^\theta \right)^{(\sigma-1)/\theta} dH(\epsilon; \sigma_\epsilon) - \sum_{k \in Z, k \neq i} \tilde{\eta}_{t,k}. \quad (20)$$

[22] Ideally I would estimate $\frac{\theta}{\sigma-1}$ from product-level bilateral export data or sales data in a particular country. The distribution of costs to serve market m in (6), together with the optimal pricing rule and the demand function implies that the product-level sales of a particular firm are distributed Fréchet with dispersion parameter $\frac{\theta}{\sigma-1}$. Data for the entire manufacturing sector would be most appropriate to use, as this is my selection criteria for the multinationals and trade data. When using car model sales data in five European countries available from Goldberg and Verboven (2001), I find an estimate of $\widehat{\frac{\theta}{\sigma-1}} = 1.02$.

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 how productive these facilities are after selecting its plants. Following equation (14) from the model, we can write the probability that a firm with core productivity level ϕ_t selects location set Z_t as

$$\Pr(Z = Z_t \mid \phi_t; \tilde{w}, \sigma_\epsilon, \mu_{\tilde{\eta}}, \sigma_{\tilde{\eta}}) = \int_{\tilde{\eta}} \mathbb{1}\{E_\epsilon(\Pi(\phi_t, Z, \epsilon, \tilde{\eta}; \sigma_\epsilon, \tilde{w})) \geq E_\epsilon(\Pi(\phi_t, Z', \epsilon, \tilde{\eta}; \sigma_\epsilon, \tilde{w})) \quad \forall Z' \in \mathcal{Z}^i\} dF(\tilde{\eta}; \mu_{\tilde{\eta}}, \sigma_{\tilde{\eta}}). \tag{21}$$

This is a good place to discuss the timing assumption made in the model. The model attends to the possibility that, after the plants are established, the operations in every country are hit by productivity shocks whose realizations were not known to the firm when the production locations were established. The timing assumption simplifies the computation: the firm chooses its optimal location only conditional on its core productivity level, ϕ_t, the vector of fixed cost draws, $\tilde{\eta}_t$, and other parameters that are common across firms, $(\tilde{w}, \sigma_\epsilon)$, but not also conditional on the firm-country-specific productivity levels.

Since the firm-level data contains only the observations for German multinationals, but not for those firms that decided to operate only domestically, I also specify the probability that firm chooses location set Z_t conditional on choosing to become a multinational (which is the selection criteria of the data):

$$\Pr^*(Z = Z_t \mid \phi_t; \tilde{w}, \sigma_\epsilon, \mu_{\tilde{\eta}}, \sigma_{\tilde{\eta}}) = \frac{\Pr(Z = Z_t \mid \phi; \tilde{w}, \sigma_\epsilon, \mu_{\tilde{\eta}}, \sigma_{\tilde{\eta}})}{1 - \Pr(Z = Z_{\text{domestic}} \mid \phi; \tilde{w}, \sigma_\epsilon, \mu_{\tilde{\eta}}, \sigma_{\tilde{\eta}})}. \tag{22}$$

Aside from the information about the multinational's chosen locations, we observe its total output in each country in which it is active. Given a parameter guess of the unit input costs across countries, we can learn about the country-specific productivities of the multinational from the country-specific output levels. The productivity of firm t in country l is the product of the core productivity level, ϕ_t, and the firm-country specific productivity shifter, $\epsilon_{t,l}$. I denote this expression by $\psi_{t,l} = \phi_t \epsilon_{t,l}$. Let $r_{t,l}(\tilde{w}, Z_t, \psi_t) = \sum_m s_{lm}(i_t, \phi_t, Z_t, \epsilon_t)$ denote the total revenue from sales to all countries of firm t in country l. Plugging in equations (9), (7), (8), and (10), we get the following equation for the output of firm t in country l:

$$r_{t,l}(\tilde{w}, Z_t, \psi_t) = \kappa \sum_m \frac{Y_m}{P_m^{1-\sigma}} \frac{(\tilde{w}_l \tau_{lm})^{-\theta} \psi_{t,l}^\theta}{\left(\sum_{k \in Z_t} (\tilde{w}_k \tau_{km})^{-\theta} \psi_{t,k}^\theta \right)^{\left(\frac{\theta+1-\sigma}{\theta}\right)}}. \tag{23}$$

We have such an equation for every location in which firm t has a production location. Let r_t denote the vector of outputs of firm t in its production locations. Knowing the output of a firm in each of its locations and all other parameters allows us to pin down exactly its productivity level, $\psi_{t,l} = \phi_t \epsilon_{t,l}$, in each of its locations

l. 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 $r : \mathbb{R}^K_{++} \times \mathcal{Z}^i \times \Psi \to \mathbb{R}^K_{++}$ 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 $\Psi = [\psi_{min}, \psi_{max}]^K$ with $\psi_{min} > 0$ and $\psi_{min} < \psi_{max} < \infty$. Then for any triple $\{r_t, \tilde{w}, Z\}$, the vector ψ that solves $r_t - r(\tilde{w}, Z, \psi) = 0$ 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 $\Theta = \{\tilde{w}, \sigma_\epsilon, \mu_{\tilde{\eta}}, \sigma_{\tilde{\eta}}, \mu_\phi, \sigma_\phi\}$ given the observed data on location choice and revenues $\{Z_t, r_t\}_{t=1}^T$ can be written as:

$$L(\Theta; \{Z_t, r_t\}_{t=1}^T) = \prod_{t=1}^T \int \Pr^*(Z = Z_t \mid \phi; \tilde{w}, \sigma_\epsilon, \mu_{\tilde{\eta}}, \sigma_{\tilde{\eta}}) g(r_t \mid Z_t, \phi; \tilde{w}) dG(\phi; \mu_\phi, \sigma_\phi), \tag{24}$$

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, $\epsilon_{t,l} = \frac{\psi_{t,l}}{\phi_t}$. It follows from Proposition 2 that the vector of revenues, r_t, can be inverted to get the vector of plant-specific productivity levels, ψ_t. The firm-location-specific productivity shifter $\epsilon_{t,l}$ is i.i.d. across firms and locations. I rewrite the likelihood function in (24) as

$$L(\Theta; \{Z_t, \psi_t\}_{t=1}^T) = \prod_{t=1}^T \int \Pr^*(Z = Z_t \mid \phi; \tilde{w}, \sigma_\epsilon, \mu_{\tilde{\eta}}, \sigma_{\tilde{\eta}}) \left| J_t(\phi, \tilde{w}) \right| \prod_{l \in Z_t} h\left(\frac{\psi_{t,l}(\tilde{w})}{\phi} \mid \sigma_\epsilon \right) dG(\phi; \mu_\phi, \sigma_\phi), \tag{25}$$

where $h(\cdot \mid \sigma_\epsilon)$ 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):

$$\max_{\Theta,\psi} \quad \log L(\Theta; \{Z_t, \psi_t\}_{t=1}^{T})$$

$$\text{subject to:} \quad r_{t,l}(\tilde{w}, Z_t, \psi_t) = \kappa \sum_m \frac{Y_m}{P_m^{1-\sigma}} \frac{(\tilde{w}_l \tau_{lm})^{-\theta} \psi_{t,l}^{\theta}}{\left(\sum_{k \in Z_t} (\tilde{w}_k \tau_{km})^{-\theta} \psi_{t,k}^{\theta}\right)^{\left(\frac{\theta+1-\sigma}{\theta}\right)}} \tag{26}$$

$$\forall\ t \in \{1, ...T\},\ l \in \{1, ...N\} \text{ such that } l \in Z_t.$$

In summary, I use data on the chosen set of countries, Z_t, for each firm t – the probability of the location choice is the first term of the likelihood function – and the observed output in every country $r_{t,l}$ in which firm t is active – which is the left hand side of the constraints – to estimate the following parameters: the vector of unit input costs, $\tilde{w}$, the vectors that characterize the destination-country-specific distributions of fixed costs, $\mu_{\tilde{\eta}}$ and $\sigma_{\tilde{\eta}}$, the parameters for the core productivity distribution, μ_ϕ and σ_ϕ, and the parameter that characterizes the dispersion of the firm-country level productivity shocks, σ_ϵ. Given the structural parameters and the vector of location-specific outputs, the vector of the firm-country-specific productivity levels, ψ, solves the system of constraints. I control for unobserved heterogeneity in the core productivity levels of the firms and in the country-specific fixed cost draws.

The estimation is an implementation of the Mathematical Programming with Equilibrium Constraints (MPEC) procedure proposed by Su and Judd (forthcoming). They show that the estimator is equivalent to a nested fixed-point estimator in which the inner loop solves for the firm-country specific productivity levels, and the outer loop searches over parameters to maximize the likelihood. The estimator therefore inherits all the statistical properties of a nested fixed-point estimator. It is consistent and asymptotically normal as the number of firms tends to infinity and the number of simulation points used to evaluate the integrals rises proportionally to the number of firms.[23] As there are 1,711 positive firm-country output observations, the constrained optimization problem described in (26) has 1,711 equality constraints. In total, the data on the firm-output observations and the firms' location set choices is used to estimate 26 structural parameters. I compute standard errors via bootstrapping and use a logit-smoothed accept-reject simulator to evaluate the probability of location choice described in (21).[24]

3.3 Parameter Estimates

Table 1 displays the parameter estimates. I find that for German multinationals the variable costs of production (unit input costs) are systematically smaller in Germany than in foreign countries, which is not surprising given

[23]As the integrals are evaluated numerically in a finite sample with finite simulation draws, the Simulated Maximum Likelihood Estimator is necessarily biased (after taking logarithms of the Likelihood function). I find in a Monte-Carlo study of my estimation procedure that the bias is very small in practice for this problem.

[24]See Train (2009), Chapter 5, for a description of this and other methods of simulation.

the low foreign output share abroad discussed in Section 3.1. The unit input costs in Germany are normalized to one. The smallest difference 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 differences in production costs reflect both wage-level differences and efficiency losses that occur by producing outside the home country.

Table 1: Maximum Likelihood Estimates

		Unit input costs $\tilde{w}$	Fixed costs $\mu_{\tilde{\eta}}$
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 fixed cost, $\sigma_{\tilde{\eta}}$	2.1902		
	(0.320)		
Scale parameter productivity, μ_ϕ	1.1329		
	(0.017)		
Shape parameter productivity, σ_ϕ	5.1026		
	(0.620)		
S.d. log productivity shock, σ_ϵ	0.1844		
	(0.009)		
Log-Likelihood	-1.21E+004		
Number of firms, T	665		

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

We can give the fixed costs a value interpretation as we observe the firms' 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 contains the results. The model effectively fits the average share of foreign output across firms. Both in the data and in the estimated model the average foreign output share is only around 0.30. If the unit input costs in the foreign countries were the same as in Germany, and there were no fixed costs for setting up foreign plants, then every firm would have a plant in each country and the average foreign output share across firms would be 0.88. The question arises as to whether fixed costs or larger variable production costs abroad are the more important barrier to foreign production. If unit input costs were equalized across countries, and fixed costs were kept at their estimated level, then firms would re-optimize their production locations and output decisions such that the foreign output share would be 0.68. If, instead, fixed costs were eliminated (and unit input costs held at their estimated level), the average foreign output share would rise even further to 0.72. Overall, I find that both fixed costs and differences in unit input costs significantly contribute to home bias in

Table 2: Fixed cost by country

Country	Mean fixed cost of firms who set up a plant in the respective country in million Euro
Austria	7.107
	(1.338)
Belgium	18.063
	(7.515)
Canada	11.718
	(6.497)
Switzerland	5.814
	(2.715)
Spain	7.370
	(2.474)
France	7.037
	(1.423)
United Kingdom	6.653
	(1.966)
Ireland	6.069
	(1.665)
Italy	6.103
	(1.041)
Netherlands	7.499
	(2.332)
United States	6.799
	(1.257)

Notes: Standard errors in parentheses.

production. While both factors have a large quantitative effect, fixed costs are slightly more important.

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

Data	Model	No fixed costs	Same unit input costs as in Germany	No fixed 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 fixed. 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. Specifically, I calibrate trade costs, variable foreign production costs, and fixed costs of setting up foreign affiliates, to data on bilateral trade flows, the values of output of firms from country i in country l, and the estimates of the country-specific variable production costs of German multinationals from the previous section. The estimates of fixed and variable production costs for German multinationals from the previous section enable me to include both variable foreign production frictions and fixed 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 figures on population and educational attainment are for the year 2000.

[25] Unlike bilateral trade flow 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-financial affiliate sales together with information on M&A from Thomson & Reuters to predict the aggregate total sales of (non-financial) affiliates from country i in country l.

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 m that is spent on goods produced in country l ('trade-share') is

$$\xi_{lm} = \frac{X_{lm}}{Y_m}, \tag{27}$$

and the share of output produced by firms from country i in country l ('MP-share') is

$$\kappa_{il} = \frac{\sum_m X_{ilm}}{\sum_m X_{lm}}. \tag{28}$$

As an additional set of moments, I include the relative unit production costs of German firms in various countries that were estimated in Section 3. These are driven both by the foreign efficiency losses, γ, and endogenous relative wages, w. Relative variable production costs for German (j) firms in country l are $\frac{\tilde{w}_l}{\tilde{w}_j} = \frac{w_l \gamma_{jl}}{w_j}$. Note that I do not impose a restriction that multinational firms from other countries have the same variable production costs as German firms in foreign countries. Rather, the variable production costs of German multinationals relative to their production costs at home, are targeted to fit the estimates that were obtained with firm-level data in the previous section.

I estimate the parameters that characterize the trade costs between countries l and m, τ_{lm}; efficiency losses of foreign production, γ_{il}; and the distribution of fixed costs to set up plants in foreign countries as a firm from country i, $F^i(\eta)$. I make the following restrictions on the functional form for trade and foreign production iceberg costs:

$$\begin{aligned}
\tau_{lm} &= \beta^{\tau}_{const}(dist_{lm})^{\beta^{\tau}_{dist}}(\beta^{\tau}_{contig})^{contig_{lm}}(\beta^{\tau}_{lang})^{language_{lm}} \qquad \text{for } l \neq m \\
\gamma_{il} &= \beta^{\gamma}_{const}(dist_{il})^{\beta^{\gamma}_{dist}}(\beta^{\gamma}_{contig})^{contig_{il}}(\beta^{\gamma}_{lang})^{language_{il}} \qquad \text{for } i \neq l.
\end{aligned}$$

Domestic production iceberg costs and trade costs are normalized to one, while fixed costs for the domestic production location are set to zero. For all $l \neq i$, the fixed costs to set up a plant in location l for a firm from i (in units of labor in the destination country) are drawn independently across firms and locations. Formally, $\eta_l \sim \log \mathcal{N}(\ln f_{il}, \beta^f_\sigma)$, where

[26] The construction of MP and bilateral trade shares from the data is described in detail in Appendix B.

$$f_{il} \quad = \quad \beta^f_{const}(dist_{il})^{\beta^f_{dist}}(\beta^f_{contig})^{contig_{il}}(\beta^f_{lang})^{language_{il}} \qquad \text{for } i \neq l.$$

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. As in the previous section, the value for the dispersion parameter of the product level productivity shock distribution, θ, is set to seven, and the elasticity of substitution, σ, is fixed to six. Following Chaney (2008), the core productivity levels for all firms are drawn from a Pareto distribution. Axtell (2001) estimates that US firm sizes are Pareto distributed with shape parameter 1.098. This suggests a shape parameter, $\vartheta = 5.5$, of the Pareto distribution for the core productivity levels, ϕ.[27] As I do not aim to explain an individual firm's data in this section, I abstract from the distribution of firm-location specific productivity shifters from here onwards.[28] This enables me to avoid evaluating numerically large-dimensional integrals without any explanatory power, since only aggregated information is used in this section.

The three sets of moments are stacked into the following vector:

$$d(\beta, w, A) = \begin{bmatrix} \xi(\beta, w, A) - \xi \\ \kappa(\beta, w, A) - \kappa \\ \frac{\tilde{w}(\beta,w,A)}{w_j} - \frac{\tilde{w}}{\tilde{w}_j}. \end{bmatrix}$$

This vector $d(\beta)$ is a 300×1 vector in which each element characterizes the distance between the respective model outcome (given the parameter vector β) and the outcome in the data. The calibration's objective is to minimize the sum of the squared differences between the model outcomes and the data targets for these outcomes. As we vary the parameter vector β, the equilibrium values of wages, profits (income), and price indices change. Note that in order for firms to choose their optimal policy, only the equilibrium wages and the market potential $A_m = \frac{Y_m}{P_m^{1-\sigma}}$ need to be known. Let $A_m(\beta, A, w)$ denote the market potential in country m that comes out of the policy functions of the firms and equations (19) and (17). Searching for an equilibrium, we seek a vector of market potentials A and wages w such that $A_m(\beta, A, w) = A_m \quad \forall m = 1, ..., N$, and the labor market clearing condition, $L^{\mathrm{d}}_l(\beta, A, w) = L_l \quad \forall l = 1, ..., N-1$, which is specified in (18), holds. As in the previous section, this suggests a constrained optimization procedure to calibrate the parameters.

Formally, the calibration solves the following constrained optimization problem:

[27] In the restricted version of my model with only a single production location for each firm (which is true for most firms in practice), the firm size distribution inherits the distribution of the core productivity levels and therefore will be Pareto distributed with shape parameter $\frac{\vartheta}{\sigma-1}$. This value is within one standard error from the point estimate of the shape parameter in the previous section based on German multinationals.

[28] I set $\epsilon_l = 1 \quad \forall l$ from here onwards.

$$
\begin{aligned}
&\min_{\beta,w,A} d(\beta,w,A)'d(\beta,w,A) \\
&\text{subject to:} \\
&A_m(\beta,w,A) = A_m \quad \forall m = 1,..,N \\
&L_l^{\mathrm{d}}(\beta,w,A) = L_l \qquad \forall l = 1,..,N-1.
\end{aligned}
\tag{29}
$$

As only relative wages matter, I normalize one country's wage and drop one labor market clearing condition. As I have 300 moments as targets and only 13 parameters, an obvious question is how to weight these moments. I decide to be agnostic and give each moment the same weight.

4.3 Calibration results

The parameter estimates are displayed in the second column of Table 4. The iceberg loss in foreign production, γ_{il}, is relatively invariant to the distance between the firm's country of origin, i, and the country of production, l. Instead, fixed costs rise with distance.

Identification of the variable MP cost parameters comes from the moments on variable production costs for German multinational firms in different countries. In Figure 5 in the appendix, I compare German firms' variable production costs in various destination countries implied by the calibrated model with the estimates from the firm-level data in the previous section; the numbers are closely matched. The identification of the fixed cost parameters comes from the moments on bilateral MP shares. Note that the calibration results for the fixed cost parameters imply that the fixed cost is rising in distance between the source and destination country, which was not a pattern of the German firm-level estimates in the previous section. However, data for many more country pairs is used for this section. The estimates reflect that bilateral MP declines with distance.

I also calibrate a restricted version of my model in which the fixed costs to set up foreign plants are set to infinity. As no multinational production arises under this restriction, I call this the 'pure trade model.' It is observationally equivalent to the model by Anderson and van Wincoop (2003) in terms of aggregate trade flows between countries.[29] Using only the trade shares as the targets, I calibrate the same gravity parameters of the trade cost function for this restricted model. The trade cost estimates are very similar across the global production and pure trade models (first column of Table 4). However, the distance coefficient is slightly larger and the constant slightly lower in the pure trade model.

The sum of the squared deviations from the MP and trade shares in the data and calibrated model are displayed under 'Norm MP fit' and 'Norm trade fit' in Table 4. The model of global production in this paper fits trade flows similarly well to a pure trade model and additionally fits multinational production. I present

[29] If fixed costs of exporting were included, the restricted model with no multinational production would be equivalent to Chaney (2008).

Table 4: Calibrated parameters

	Pure trade model	Global production model
Trade cost		
constant, β^{τ}_{const}	0.722	0.789
distance, β^{τ}_{dist}	0.139	0.121
language, β^{τ}_{lang}	0.922	0.929
contiguity, β^{τ}_{contig}	0.934	0.925
Variable MP cost		
constant, β^{γ}_{const}		1.259
distance, β^{γ}_{dist}		0.006
language, β^{γ}_{lang}		0.962
contiguity, β^{γ}_{contig}		0.963
Fixed MP cost		
constant, β^{f}_{const}		0.089
distance, β^{f}_{dist}		0.073
language, β^{f}_{lang}		1.025
contiguity, β^{f}_{contig}		1.105
dispersion, β^{f}_{σ}		0.299
Norm trade fit	0.258	0.262
Norm MP fit		0.158

scatter plots on the model's fit of trade and MP shares in Appendix D.

4.4 Fit of export platform shares

The calibration is targeted to fit bilateral trade and MP shares, as well as the relative variable production costs of German multinationals in various countries. How does the calibrated model perform with respect to moments it did not try to fit? I use data from the BEA on the export platform share of US multinational firms in all countries other than the US included in my estimation to compare the model's predictions with the actual data. The fit is good and displayed in Figure 2. Notice that existing work on multinational production by Ramondo and Rodriguez-Clare (2012) and Arkolakis, Ramondo, Rodriguez-Clare, and Yeaple (2012) get close to fitting the export platform share of US multinationals only under special cases [e.g., uncorrelated productivities across countries for the same idea in Ramondo and Rodriguez-Clare (2012)]. The key difference between the framework in this paper and in their work is that this paper incorporates fixed costs to establish foreign plants. Fixed costs cause firms to concentrate their production in fewer locations, which generates export platform sales. In

Appendix E, I show for a symmetric world how additional production locations lead to lower shares of export platform sales. I also calibrate a restricted model with zero fixed costs to set up a foreign plant. Under this restriction, every firm operates a plant in every country. For this model I use as targets both trade and MP shares, but not the variable production cost estimates for German multinationals.[30] In Appendix F, I present the results for the restricted model with only variable MP costs but no fixed costs. Table 14 in Appendix F shows that the export platform shares are on average 1.4 times larger in the benchmark global production model than in the restricted model without fixed costs.

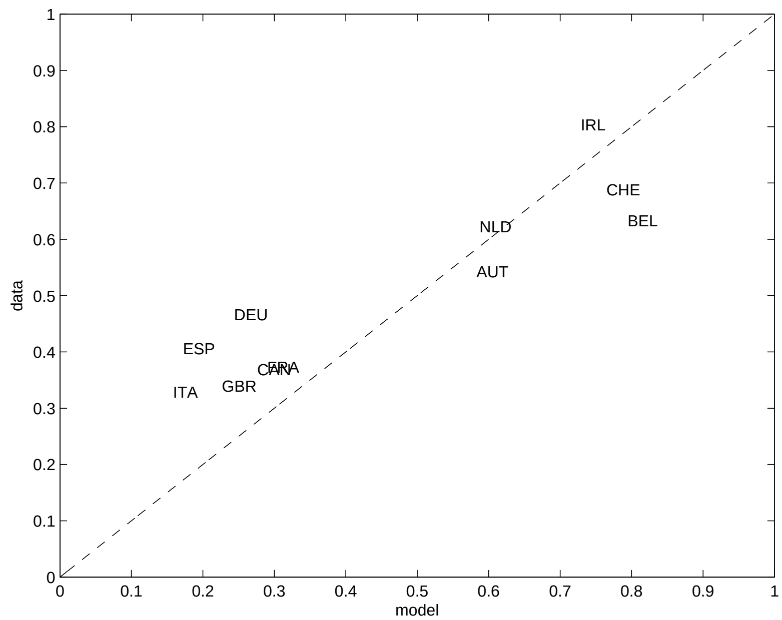

Figure 2: Export platform shares for US multinationals - data and model

[30] These estimates would not be consistent with this kind of model, as they were derived from a model with positive fixed costs to set up foreign plants.

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 effects 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 effects of such an agreement – if it is signed – on the signatories and the U.S.? My setup is particularly suitable for addressing this question. As multinational firms tend to concentrate production in just a few locations and serve the rest of the world via export platform sales, investment liberalization agreements may have particularly strong third-country effects. Third-country effects arise in pure trade models due to the terms of trade effects. With multinational production – in addition to the terms of trade effects – an additional effect arises: the firm can directly move its production locations and volume between countries, so the effect on third countries may be stronger as firms respond to changes in the global bilateral investment cost structure. For instance, a European firm may want to have only one plant in North America. As investment barriers to Canada fall, this firm may move its plant from the United States to Canada. This outcome would be missed by models that do not take into account export platforms, since without export platforms the firm's decision to establish a plant in a country would be independent across countries.

Suppose a deep investment agreement can be reached that lowers both variable and fixed MP costs between the EU countries and Canada by 20 percent. Table 5 displays the difference in the MP-shares before and after the liberalization, as well as the relative change in welfare. The aggregate MP-share of EU countries in Canada would increase from 9 to 32 percent. US firms would react to higher relative Canadian wages and reduce their investment in Canada such that the share of US production in Canada would fall from 21 to 9 percent. Finally, the total foreign production in Canada would increase by a factor of 1.3. Simultaneously, part of the EU countries' increased investment in Canada would crowd out their previous production in the US. EU countries' production share in the US would fall from 5.58 to 5.11 percent. In relative terms, this is a decline by 7 percent. Canadian firms would react to higher relative wages in Canada and increase their activities in the US, but not to the same extent that EU firms would decrease their activities. The overall share of foreign production in the US would fall by 6 percent. Of all countries, Canada would experience the largest welfare gains. The

[31] Comprehensive Economic and Trade Agreement (CETA). Currently discussed measures to remove investment barriers between the EU and Canada include harmonization in taxes and regulation, opening of capital markets, the removal of barriers to executive labor mobility, and improvement in access to information for foreign investors. More information from the Canadian government can be found here: `http://www.international.gc.ca/trade-agreements-accords-commerciaux/agr-acc/eu-ue/negotiations-negoiations.aspx?lang=eng&view=d`. More information from the EU commission can be found here: `http://ec.europa.eu/enterprise/policies/international/cooperating-governments/canada/index_en.htm`.

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 affected much in terms of aggregate welfare.

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

	Difference in inward MP-shares		Rel. welfare
	Canada	United States	
Canada	-10.56	0.05	102.45
EU countries	23.23	-0.47	100.07 - 100.19
Switzerland	-0.19	0.01	99.90
United States	-12.48	0.41	99.95

Notes: Counterfactual: Reduction in variable and fixed MP costs between EU and Canada by 20 percent. First two columns: Differences in MP shares, κ_{il}, before and after the counterfactual change (column: destination l, row: source i).

As a comparison to the potential effects from CETA, which is currently under negotiation, I also compute the potential effects from a hypothetical EU-US agreement that would lower variable and fixed foreign production costs between the signatories by the same proportion. As expected, the effects 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 in the appendix contains the predicted outcomes for such an EU-US agreement.

I proceed with the analysis of a classic question in the trade literature, which has been studied by Eaton and Kortum (2002) among others: how large are the benefits of foreign technology?

5.2 The benefits of foreign technology

It has been widely documented that countries' technologies evolve over time.[32] How much do countries benefit from foreign technology improvement, and how do our estimates of these gains differ between models that allow for multinational production and those that do not? To answer these questions, I follow Eaton and Kortum (2002) and study what happens to welfare in foreign countries if all US firms improve their core productivity levels by 20 percent.[33] Similarly to their paper, I find that in a pure trade model the percentage gains decay dramatically with distance and size (see the results in Table 6). With multinational production, an additional source of gains for foreign countries arises: multinational firms use the better technology in their foreign plants and crowd out some of the production of less productive domestic firms. Hence, the average productivity in

[32] For example, by Bernard and Jones (1996) and Levchenko and Zhang (2011).
[33] The core productivity level of the firms is Pareto distributed; I multiply the draws for US firms by 1.2.

foreign countries rises, which in turn lowers those countries' consumer price indices. Interestingly, in the global production model, the welfare gain from a US technology improvement in foreign countries is about an order of magnitude larger than in the pure trade model. Still, Canada – as the neighboring country – benefits most from a US technology improvement, as the costs both to ship goods and to produce abroad rise with distance.

Table 6: Gains from US technology improvement

	Relative to benchmark		Relative to US gains	
	Pure trade model	Global production model	Pure trade model	Global production model
Austria	1.0009	1.0319	0.45	14.52
Belgium	1.0005	1.0205	0.26	9.34
Canada	1.007	1.0630	3.53	28.69
Switzerland	1.0007	1.0203	0.37	9.26
Germany	1.0003	1.0155	0.15	7.07
Spain	1.0005	1.0310	0.26	14.11
France	1.0003	1.0170	0.17	7.76
United Kingdom	1.0006	1.0299	0.32	13.60
Ireland	1.0022	1.0460	1.12	20.93
Italy	1.0004	1.0240	0.18	10.92
Netherlands	1.0006	1.0286	0.32	13.03
United States	1.1987	1.2195	100.00	100.00

Notes: Counterfactual: Productivity improvement of all firms that originated in the United States by 20 percent. Columns 3 and 4: Welfare gains by country in percent relative to welfare gains in the United States.

The United States also gains more from its firms' technology improvement when multinational production is allowed (US welfare increases by a factor of 1.219 instead of 1.198). Without multinational production, the change in real profits is proportional to the change in real wages. With multinational production, US multinational firms can benefit from the relatively cheaper labor in foreign countries and receive larger profits, which raises the US consumer's income. Note that the US welfare gains exceed 20 percent under a unilateral technology improvement for US firms; by contrast, if all countries had improved their firms' technology by 20 percent, every country's welfare would have simply risen by 20 percent (not displayed in the table). As a consequence, for different initial conditions, e.g. after the increase in productivity of US firms, the welfare gains for the US from a technology improvement in all countries other than the US could be negative as the US profits would decline.[34]

To summarize, in the global production model, since the level of technology used in a country's production is endogenous, an overall improvement to the US firms' technology improves the technology used in foreign countries' production. In other words, multinational firms enhance the spread of technology to foreign coun-

[34] In Appendix G I present levels of parameters for which my model can be solved analytically and show that whether the welfare gain of the country whose firms improved their technology exceeds the rate of technology improvement depends on the increase in global market share due to the technology improvement.

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

5.3 The gains from trade, multinational production, and openness

I continue by studying the gains from trade, multinational production, and openness. I use the calibrated model as a starting point and address how welfare, wages, and profits change when the costs of trade, the costs of multinational production, or the costs of both trade and multinational production are set to prohibitively high levels. I start by comparing the benchmark calibrated model with a hypothetical world in which costs of international trade are infinite.

5.3.1 The gains from trade

I define as the gains from trade in the global production model the change in welfare from the model with the benchmark parameters to a model with infinite trade costs.[36] While the trade in goods is prohibited in this counterfactual world without trade, I allow for the flow of remittances between countries; if trade is prohibited, current account balance implies that for each country the total inflows equal the total outflows of profits.

I compare my model's predictions with those from a workhorse model in multi-country trade analysis, such as Anderson and van Wincoop (2003) and Eaton and Kortum (2002), which abstract away from multinational production. How do the gains from trade in these pure trade models differ from the gains from trade in this model, which includes trade and multinational production? Suppose a researcher would use the same starting point, that is, observe the trade flows that are implied by my global production model and then use a pure trade model to evaluate the gains from trade. Following Arkolakis, Costinot, and Rodriguez-Clare (2012), the gains from trade for country j in a pure trade model such as that of Anderson and van Wincoop (2003) can simply be calculated as $\xi_{jj}^{\frac{1}{1-\sigma}}$. I use $\sigma = 6$ for both models, which implies both a reasonable mark-up for firms and is in the range of estimates for the trade elasticity in pure trade models.[37]

The results in Table 7 display two striking patterns: first, they suggest that the gains from trade are slightly larger in a pure trade model than in a model with trade and MP (though the difference is small). As expected, smaller countries benefit more in both models from trade openness than do larger countries. Second, for each country the increase in real profits because of trade is about more than four times larger than the increase in real wages. Trade enables firms to exploit comparative advantage, concentrate their production in a few locations, and economize on fixed costs. Without trade, firms need to incur fixed costs for every market

[35] The gains from foreign technology improvements may be even larger when spillovers are included. Poole (forthcoming) finds evidence for knowledge transfers from multinational to domestic firms in Brazilian matched worker-establishment data. Alfaro and Chen (2012) estimate that around 2/3 of the gains from multinational production arise through technology spillovers.

[36] Welfare in country j is equal to real income, $\frac{Y_j}{P_j}$.

[37] The survey by Anderson and van Wincoop (2004) finds that most estimates of the trade elasticity in the literature range from five to ten.

Table 7: Gains from Trade

	Global Production model			Pure Trade model
	Welfare change	Real profit change	Real wage change	Welfare / Real wage change
Austria	1.193	1.585	1.154	1.208
Belgium	1.344	1.837	1.296	1.379
Canada	1.098	1.356	1.068	1.108
Switzerland	1.317	1.843	1.268	1.342
Germany	1.060	1.175	1.043	1.068
Spain	1.050	1.188	1.031	1.054
France	1.075	1.232	1.053	1.084
United Kingdom	1.059	1.201	1.040	1.066
Ireland	1.306	1.795	1.263	1.324
Italy	1.043	1.155	1.027	1.048
Netherlands	1.189	1.524	1.151	1.208
United States	1.012	1.035	1.008	1.013

Notes: A number in this table represents the outcome from the benchmark model divided by the outcome from the same model with no trade.

they want to serve, as this requires them to establish a local plant. Further, each product needs to be produced locally even though, if trade were available, a plant in another country would have comparative advantage in producing some of these products.

How do prohibitive trade costs affect the share of production in each country that is conducted by foreign firms? Generally, the outcome is unclear; on the one hand, infinite trade costs eliminate the surrounding market potential of foreign plants, which reduces the total market potential of the foreign plant, since the share of export platform sales is large. With fixed costs to establish foreign plants, a lower market potential – ceteris paribus – should lead to fewer foreign plants being established. On the other hand, without trade, multinational production is the only means of serving a foreign market. I find that the level of multinational production increases when trade is prohibited. Another feature of a world without trade is that not all varieties are sold to every market, just as with fixed costs of establishing foreign plants not every firm is a multinational. This explains why the gains from trade are still large in my global production model, and multinational production can only insufficiently substitute for trade. My findings differ from those Ramondo and Rodriguez-Clare (2012), whose calibrated model indicates that the gains from trade were systematically larger in a world with MP than in a world without MP. However, in their model, aside from the absence of increasing returns at the plant level, the input bundle of a multinational firm abroad is a CES aggregate of the local input bundle in the country of the affiliate and the input bundle in the home country. Therefore, the availability of trade improves the cost structure of the foreign affiliates in their model.[38]

[38] See the paper by Head and Ries (2004) for an overview of intra-firm trade; if firms produce single final products – as assumed in Ramondo and Rodriguez-Clare (2012) – it is sensible to interpret the intra-firm trade from the home country to the foreign affiliate as shipments of intermediates. If firms produce multiple final products – as assumed in my paper – these intra-firm sales can arise simply from the comparative advantage of the home country in producing some of the firms' products.

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 parameters. The relative changes in the outcomes for welfare, real wages, and real profits are displayed in Table 8.

Table 8: Gains from Multinational Production

	Global Production model		
	Welfare change	Real profit change	Real wage change
Austria	1.017	0.740	1.073
Belgium	1.015	0.746	1.069
Canada	1.021	0.779	1.069
Switzerland	1.018	0.731	1.075
Germany	1.006	0.879	1.031
Spain	1.011	0.817	1.049
France	1.008	0.857	1.038
United Kingdom	1.011	0.832	1.047
Ireland	1.021	0.684	1.088
Italy	1.009	0.844	1.042
Netherlands	1.011	0.783	1.056
United States	1.002	0.956	1.012

Notes: A number in this table represents the outcome from the benchmark model divided by the outcome from the same model with no multinational production.

I find that the welfare gains from multinational production are smaller than the welfare gains from trade. Note that real wages and real profits respond quite differently to the availability of multinational production. The changes in real wages from allowing multinational production are comparable to the changes in real wages from allowing trade, which reflects that multinational production substantially lowers the price index; compared to the changes in real wages from allowing trade, they are larger for some countries (e.g. US), and lower for others. However, the welfare gains are systematically lower as real profits fall. Note that the effect of multinational production on real profits is ambiguous. On the one hand, multinational production raises production efficiency 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 large ratio of firms to labor size. In the calibrated model, the mass of firms is roughly proportional to the labor force, as human capital differences between the selected countries are small. Real profits in smaller countries tend to fall more than in larger countries because of the availability of multinational production. Therefore, fixed costs are vital not only for explaining firm-level global production choices and matching the aggregate data on export platform sales, but also for understanding the overall gains and distributional effects from multinational production.

In the next section, I describe the gains from openness.

5.3.3 The gains from openness

Finally, I evaluate how welfare changes if both trade and multinational production are shut down, so that each country operates in autarky. Non-surprisingly, as neither trade nor multinational production can substitute for the absence of the other, the welfare losses of autarky are more substantial than if only trade or multinational production were shut down. The results are displayed in Table 9. For most countries, the change in real wages is similar to the change in welfare, as real profits are roughly unchanged. Real profits tend to increase through the availability of trade, and tend to fall through the availability of multinational production. As expected, small countries benefit substantially more from openness than do large countries.

Table 9: Gains from Openness

	Global Production model		
	Welfare change	Real profit change	Real wage change
Austria	1.262	0.918	1.331
Belgium	1.440	1.058	1.516
Canada	1.154	0.880	1.208
Switzerland	1.414	1.015	1.494
Germany	1.083	0.947	1.110
Spain	1.076	0.870	1.117
France	1.104	0.939	1.137
United Kingdom	1.089	0.896	1.127
Ireland	1.400	0.938	1.492
Italy	1.065	0.891	1.100
Netherlands	1.245	0.965	1.301
United States	1.018	0.970	1.027

Notes: A number in this table represents the outcome from the benchmark model divided by the outcome from the same model with no multinational production and no international trade.

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.

6 Conclusion

My paper contributes to the literature on international trade and multinational firms by developing a new framework that is less restrictive in its assumptions about where multinational firms can produce and sell, and what cost structure they face. In particular, my model accounts for both export platform sales and fixed costs of establishing foreign plants. Existing quantitative models of trade and multinational production have proven tractable only after excluding many of the strategies that firms actually use or shutting down mechanisms that are almost universally thought to be important. My framework can be used for a wide range of possible empirical applications with either firm-level or aggregate data.

Multinational firms have been characterized as footloose and free to reorganize their global operations as the global economic environment changes [Caves (1996)].[39] My estimates on the variable efficiency losses to foreign production and increasing returns at the plant-level suggest that the view of footloose multinationals is inaccurate. Differences in variable production costs across countries and fixed costs of establishing foreign plants turn out to be similarly important barriers to foreign production for German multinational firms.

General equilibrium analysis reveals that multinational firms play an instrumental role in the transmission of technology improvements to foreign countries. As multinationals have the ability to re-optimize their production locations and output decisions when the cost structure across countries changes, trade and investment agreements can have a significant third-country effect, which would be missed if multinational firms are excluded from the analysis or modeled in a more restrictive way. My findings accord with the common perception that countries compete for multinational firms and that small countries would be hurt disproportionately if a country nearby were to improve the conditions for multinationals from other countries, as this policy-change

[39]See also *The Economist* on March 25, 2004: "Footloose firms: Are global companies too mobile for workers' good?"

induces a firm-delocation effect. 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 firm-level sales to each market increase as additional production locations are added to the set of existing locations. However, there is a cannibalization effect across production locations. That is, a firm that adds a production location decreases the sales from the other locations.*

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

$$s_m(i, \phi, Z, \epsilon) = \kappa\phi^{\sigma-1} \frac{Y_m}{P_m^{1-\sigma}} \left(\sum_{k \in Z} (\gamma_{ik} w_k \tau_{km})^{-\theta} \epsilon_k^\theta \right)^{(\sigma-1)/\theta},$$

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

$$s_{lm}(i, \phi, Z, \epsilon) = \begin{cases} \kappa\phi^{\sigma-1} \frac{Y_m}{P_m^{1-\sigma}} \frac{(\gamma_{il} w_l \tau_{lm})^{-\theta} \epsilon_l^\theta}{\left(\sum_{k \in Z} (\gamma_{ik} w_k \tau_{km})^{-\theta} \epsilon_k^\theta \right)^{\left(\frac{\theta+1-\sigma}{\theta}\right)}} & \text{if } l \in Z \\ 0 & \text{otherwise.} \end{cases}$$

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

Proposition 2. *Let $r : \mathbb{R}_{++}^K \times \mathcal{Z}^i \times \Psi \rightarrow \mathbb{R}_{++}^K$ 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 $\Psi = [\psi_{min}, \psi_{max}]^K$ with $\psi_{min} > 0$ and $\psi_{min} < \psi_{max} < \infty$. Then for any triple $\{r_t, \tilde{w}, Z\}$, the vector ψ that solves $r_t - r(\tilde{w}, Z, \psi) = 0$ is unique.*

Proof. The proof shows that the conditions for the univalence theorem of Gale and Nikaido (1965) are satisfied. Clearly $r(\tilde{w}, Z, \psi)$ is differentiable with respect to ψ and Ψ is a closed rectangular region. It is left to show that Jacobian matrix of the mapping r is a P-Matrix at all $\psi \in \Psi$.

I simplify the expression in equation (23) in the following way. I drop the constants and define $\alpha = \frac{\theta+1-\sigma}{\theta}$, and $\tilde{y}_m = \frac{Y_m}{P_m^{1-\sigma}}$. Given the assumptions made in the text, $0 < \alpha < 1$. I denote $c_{lm} = (\tilde{w}_l \tau_{lm})^{-\theta}$. Further, I drop the firm index t. Then $r_{t,l}$ becomes

$$r_l(c, Z, \psi) = \sum_m \tilde{y}_m \frac{c_{lm} \psi_l^\theta}{\left(\sum_{k \in Z} c_{km} \psi_k^\theta \right)^\alpha}$$

Note that

$$\begin{aligned} \frac{\partial r_l}{\partial \psi_l} &= \sum_m \tilde{y}_m \frac{-\alpha\theta c_{lm} c_{lm} \psi_l^{2\theta-1} + \theta c_{lm} \psi_l^{\theta-1} \left(\sum_{k \in Z} c_{km} \psi_k^\theta \right)}{\left(\sum_{k \in Z} c_{km} \psi_k^\theta \right)^{\alpha+1}} \\ &= \sum_m \tilde{y}_m \frac{(1-\alpha)\theta c_{lm} c_{lm} \psi_l^{2\theta-1} + \theta c_{lm} \psi_l^{\theta-1} \left(\sum_{k \neq l, k \in Z} c_{km} \psi_k^\theta \right)}{\left(\sum_{k \in Z} c_{km} \psi_k^\theta \right)^{\alpha+1}} \\ &> 0 \end{aligned}$$

and for $k \neq l$

$$\frac{\partial r_l}{\partial \psi_k} = \sum_m \tilde{y}_m \frac{-\alpha\theta c_{km}\psi_k^{\theta-1} c_{lm}\psi_l^{\theta}}{\left(\sum_{k \in Z} c_{km}\psi_k^{\theta}\right)^{\alpha+1}} < 0$$

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

Then the univalence theorem of Gale and Nikaido (1965) implies, whenever $r(\tilde{w}, Z, a) = r(\tilde{w}, Z, b)$, where $a, b \in \Omega$, then $a = b$. ■

Appendix B Data

B.1 German multinationals data

All parent companies and majority-owned affiliates are from the manufacturing sector. Table 10 provides descriptive statistics on the multinational firms' activities in the countries included in my dataset. Table 11 documents the average foreign production share by the number of production locations.

Table 10: Descriptive Statistics German multinationals activities

Country	Number	Mean output	Median output
Austria	91	76.3	34
Belgium	45	235.3	37
Canada	36	536.0	28.5
Switzerland	70	58.3	17
Germany	665	625.8	98
Spain	117	191.9	32
France	191	107.7	30
United Kingdom	121	119.4	23
Ireland	18	36.3	19.5
Italy	100	65.0	27.5
Netherlands	46	83.1	25
United States	211	569.0	26

Notes: Output in million Euro. Source: MiDi database.

B.2 Aggregate data

This appendix describes the construction of the trade and MP shares. All data comes from Ramondo, Rodriguez-Clare, and Tintelnot (in process). The trade data is for the manufacturing sector only, while the MP data covers the entire non-financial sector of the economy. I implicitly assume that the MP in the service sector is proportional to the MP in the trade sector. The same assumption is made by Arkolakis, Ramondo, Rodriguez-Clare, and Yeaple (2012). All data are averages over the years 1996-2001.

B.2.1 Trade shares

$$Absorption_m = GrossProduction_m + TotalWorldImports_m - TotalWorldlExports_m - TotOtherImports_m$$

where $TotOtherImports_m$ represents the total imports by country m from countries not included in the analysis.

Table 11: Foreign production shares by number of production locations

Number of production locations	Number of firms	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 firms 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 firms at home is not directly observed. I therefore take data on gross non-financial production in the respective country, and subtract the MP from 50 other source countries contained in Ramondo, Rodriguez-Clare, and Tintelnot (in process), which has the same sectoral coverage. This gives me an estimate of the value of local production, Y_{ii}:

$$MPShare_{jl} = \frac{Y_{jl}}{\sum_{i \in C} Y_{il}}$$

where C denotes the set of countries included in the analysis.

Table 12: Foreign production shares by sectors

Sector	Number of firms	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 fixed costs faced by the observed multinational firms. With these estimates I derive the distribution of fixed costs for each multinational firm conditional on its observed location choice, Z_t, and the location-specific productivity vector, ψ_t. We can then calculate the mean value of fixed costs that were actually paid to set up a plant in the respective countries. To my knowledge, Revelt and Train (2000) were the first 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 β denote the parameter vector of estimates in Section 3. The productivity vector across plants of firm t, ψ_t, can be calculated given r_t and β. The density of the fixed cost draws across countries conditional on having chosen a plant in country l can be written as

$$u(f \mid Z_t, \psi_t, \beta) = \frac{Pr(Z_t \mid \psi_t, f) z(f \mid \beta)}{\int_f Pr(Z_t \mid \psi_t, f) z(f \mid \beta) df},$$

where

$$Pr(Z_t \mid \psi_t, f) = \int_\phi Pr(Z_t \mid \phi, f) k(\phi \mid \psi) d\phi,$$

and

$$k(\phi \mid \psi_t) = \frac{g(\phi) \left| \frac{\mathrm{d}\psi_t/\phi}{\mathrm{d}\psi_t} \right| \prod_{l \in Z_t} h(\frac{\psi_{t,l}(\tilde{w},\sigma_\epsilon)}{\phi} \mid \beta)}{\int_{\phi'} g(\phi') \left| \frac{\mathrm{d}\psi_t/\phi'}{\mathrm{d}\psi_t} \right| \prod_{l \in Z_t} h(\frac{\psi_{t,l}(\tilde{w},\sigma_\epsilon)}{\phi'} \mid \beta) d\phi'},$$

and

$$Pr(Z_t \mid \phi, f) = \mathbb{1}\{E_\epsilon(\Pi|\phi, Z_t, \epsilon, f; \beta) \geq E_\epsilon(\Pi|\phi, Z', \epsilon, f; \beta) \quad \forall Z'\}.$$

The mean of fixed costs for firm t is

$$\bar{f}^t = \int f u(f \mid Z_{t,l}, \psi_t, \beta) df,$$

and the average fixed cost in country l of firms that actually have a plant there is

$$= \frac{\sum_{t=1}^T \bar{f}_l^t \mathbb{1}\{l \in Z_t\}}{\sum_{t=1}^T \mathbb{1}\{l \in Z_t\}}.$$

Appendix D Fit of the calibrated global production model

D.1 Bilateral trade shares

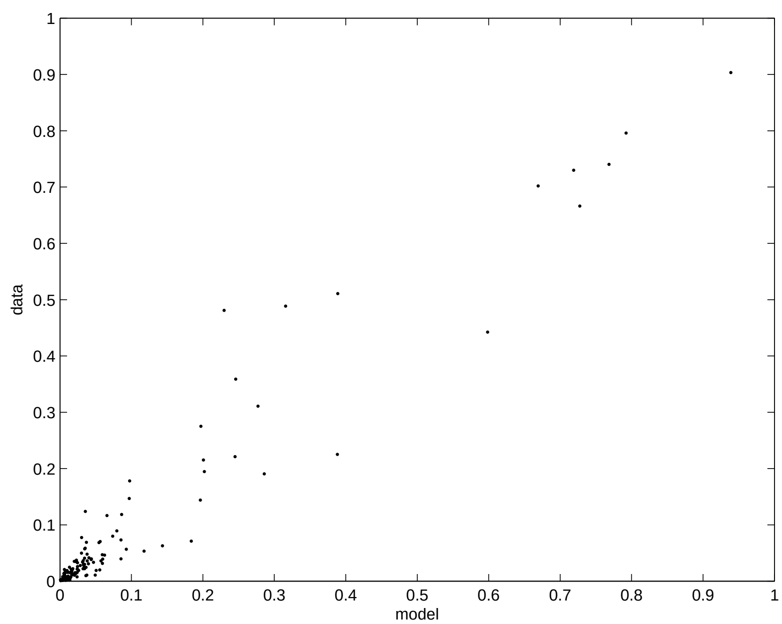

Figure 3: Bilateral trade shares - data and model

D.2 Bilateral MP shares

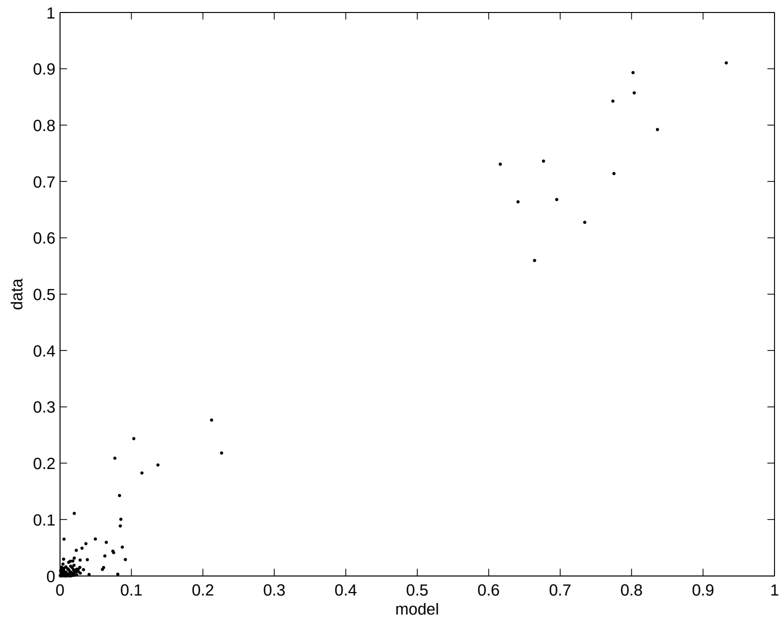

Figure 4: Bilateral MP shares - data and model

D.3 Variable production costs for German firms

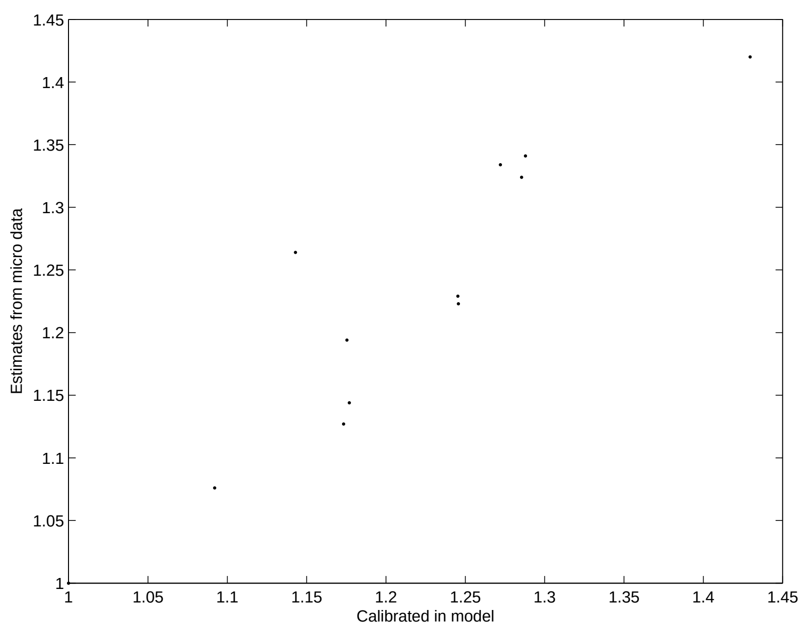

Figure 5: Variable production costs for German firms

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 firm. 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 different 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: $\sigma = 6$, $\theta = 7$, $\tau_{lm} = 1.6$, $\gamma_{il} = 1.2$. 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 firm with just 2 plants to 29 percent for a firm with 12 plants.[40]

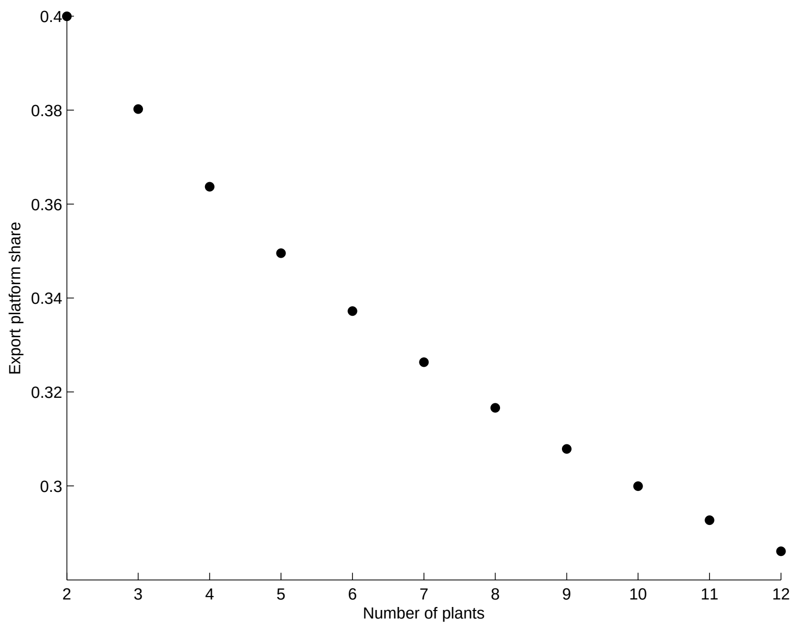

Figure 6: Export platform shares - Numerical example

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

Here, I present the results for a calibrated model without fixed costs to establish foreign plants. Missing fixed costs imply that every firm establishes a plant in every country, which is obviously contrary to the firm-level evidence presented in Section 3. I calibrate the model to match aggregate trade and MP shares (the variable production cost estimates for German multinationals are not included as targets, because those were estimated from a model with both fixed and variable costs).

One can observe that this restricted model fits the MP data much worse; it does a slightly better job at fitting the bilateral trade data, but the sum of the two fitting norms is considerably higher. The share of export platform sales are on average 1.4 times lower than in the full model with fixed cost.

[40]The export share of the domestic plant falls from 49 to 35 percent.

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

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

Table 14: Export platform shares - Data and Models

	Data	Global Production Model	Restricted Global Production Model
Austria	0.54	0.58	0.45
Belgium	0.63	0.79	0.74
Canada	0.37	0.28	0.23
Switzerland	0.69	0.76	0.67
Germany	0.47	0.25	0.16
Spain	0.41	0.17	0.10
France	0.37	0.29	0.19
United Kingdom	0.34	0.23	0.14
Ireland	0.80	0.73	0.62
Italy	0.33	0.16	0.09
Netherlands	0.62	0.59	0.48

Notes: Global Production model: Full model characterized in the main text. Restricted Global Production Model: Model without fixed costs as described in the appendix.

Appendix G Special case: gains from technology improvements

Section 5.2 on the benefits of foreign technology has two main results. The first result is that starting from the calibrated model, the magnitude of the gains in foreign countries is much larger if multinational production is taken into account. The second result is that with multinational production the gains from a technology improvement by factor $x > 1$ may yield welfare gains to that country by factor $y > x$. In order to demonstrate the economics behind the second results, I develop an analytic example in this section. In the example, I show that the size of the welfare gains of the country whose technology improved turns on how much the country's firms can increase their world market share in production.

Proposition 3. *Consider a symmetric world with identical size of the labor force in every country and $\tau_{lm} = 1$, $\gamma_{il} = 1$, $\eta_{il} = 0$, $\forall i, l, m$. Suppose $\sigma = 6$, $M_i = L = 1$, $N = 3$, $x = 1.2$. Then, an increase in productivity to one country by factor x raises its welfare by factor $y > x$.*

I only show the key expressions. Detailed derivations are available from the author upon request. I abstract away from firm heterogeneity (it does not matter for the results) and denote the productivity of all firms in country i by $\phi(i)$.

Welfare under the old scenario, $\phi(i) = \phi\ \forall i$, is:

$$\frac{Y_1}{P} = \frac{\frac{\sigma}{\sigma-1}L}{N^{-1/\theta}\left(\sum_i M_i \kappa \phi(i)^{\sigma-1}\right)^{1/(1-\sigma)}}$$

Welfare under the new scenario, $\phi'(1) = x\phi$, $\phi'(j) = \phi\ \forall j = 2, ..., N$, is:

$$\frac{Y_1'}{P'} = \frac{\frac{(\sigma-1+N\lambda_1')}{\sigma-1}L}{N^{-1/\theta}\left(\sum_i M_i \kappa \phi'(i)^{\sigma-1}\right)^{1/(1-\sigma)}}$$

where λ_i denotes the market share of firms from country i in the expenditures of each country:

$$\lambda_i = \frac{M_i \phi(i)^{\sigma-1}}{\sum_k M_k \phi(k)^{\sigma-1}}$$

Note that the equilibrium price index will always change at a rate less than the factor of technology improvement to country 1's firms, x. However, if the market share of country 1 goes up enough, which depends on the size of σ, the ratio of the two welfare expressions may exceed x. Plugging in the numbers, $\lambda_1' = 0.5544$ instead of the old $\lambda_1 = 1/3$. Relative price index: $\frac{P'}{P} = 0.9226$ and the welfare change in country 1 is 1.2036. For a lower value of σ, the welfare in country 1 would have increased less.

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

As a comparison to the potential effects from CETA, which is currently under negotiation, I also compute the potential effects from a hypothetical EU-US agreement that would lower variable and fixed foreign production costs between the signatories by the same proportion. As expected, the effects 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 fixed 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

	Difference 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 fixed MP costs between EU and US by 20 percent. First two columns: Differences in MP shares, κ_{il}, before and after the counterfactual change (column: destination l, row: source i).