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ABSTRACT

The Margins of Multinational Production and the Role of Intra-firm trade

In this paper we ask why the gravity model of international trade also work well for foreign direct investment (FDI) flows or multinational production (MP). We propose a model of trade and horizontal FDI, where the subsidiary is allowed to source inputs from the headquarters. Under certain parameter values, the model will generate gravity relationships for both exports and MP. Matching the model with data using a unique firm-level dataset of both exports and MP reveals the following results. First, intra-firm trade appears to play a crucial role in shaping the geography of MP. Our conclusions are robust to any geographical distribution of fixed costs. Second, counterfactual experiments show that impeding FDI leads to reduced domestic labor demand by the headquarters, suggesting that outwards FDI may have positive effects on home employment.

JEL Classification: F10
Keywords: export, fdi, gravity, intra-firm trade and multinational production

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1 Introduction

The growth in multinational production (MP) is a central element of the economic globalization during the last three decades.[1] World inward foreign direct investment (FDI) flows grew annually by 17 per cent from 1990 to 2006. During the same period, world exports increased by only 8 per cent. By 2006, the value added from multinational production amounted to 10 per cent of world GDP.[2] This remarkable growth has lead researchers to analyze the interaction between multinational activity and trade as well as to understand which forces determine the aggregate flows of MP.

Our work focuses on the firm's location choice of exports and multinational production. At the aggregate level, the gravity relationship is known to fit bilateral trade flows data and it has been recently shown to be consistent with the cross-country pattern of FDI and MP as well (e.g. Barba Navaretti and Venables, 2004). However, it is not clear that the gravity model is a theoretically valid specification for MP. Also, gravity for MP represents a puzzle for existing theories of multinationals: in standard models of horizontal foreign direct investment (HFDI), MP will typically *increase* (i.e. the opposite of gravity) with higher variable trade barriers. HFDI refers to investment in foreign plants that are made to serve consumers in the destination market. So firms will choose FDI in markets where the gains from avoiding trade costs outweigh the costs of maintaining capacity in multiple markets. In models of vertical foreign direct investment (VFDI), where firms exploit cross-country factor price differences by producing inputs in foreign plants and shipping them back to the parent, gravity can emerge due to two-way trade in intermediates. Most studies, however, (e.g. Markusen and Maskus, 1999 and 2002, Blonigen, Davies and Head, 2003, and Brainard, 1997) have shown relatively little evidence, especially among developed

[1] A multinational firm is "an enterprise that controls and manages production establishments (plants) located in at least two countries. It is simply one subspecies of multiplant firm" (Caves, 1996, page 1). There are many ways a firm can organize production on a global scale. In this paper, as will become clear, we focus on horizontal foreign direct investment. Hereinafter we use the terms "foreign direct investment" (FDI) and "multinational production" (MP) interchangeably.

[2] Nominal figures, World Investment Report 2007, UNCTAD, Table I.4.

countries, in support of vertical FDI, whereas there is strong support in favor of the HFDI model.[3]

Recently, some studies (e.g. Antràs, 2003 and Bernard, Jensen and Schott, 2005) have emphasized the importance of intra-firm trade in explaining a large share of world trade. For example, Bernard, Jensen and Schott (2005) find that roughly 40 per cent of U.S. trade flows occur through affiliates of the same multinational. At first sight, this fact seems to contradict the HFDI models. However, intra-firm trade is perfectly consistent with HFDI as long as trade flows from the headquarters to the foreign affiliate. Studies show that there is substantial intra-firm trade in this direction. For example, Hanson, Mataloni, Slaughter (2003) find that for the average U.S. affiliate in their sample, 11 per cent of its total costs are accounted for by imports of intermediate inputs from the U.S. parent. Hence, it seems natural to look for a solution to the FDI gravity puzzle in a context of HFDI and intra-firm trade.

We make three main contributions to the literature. First, we uncover new firm-level facts about MP and how MP activity is related to characteristics of the parent firm, using a unique firm-level dataset of joint exports and FDI decisions, by destination. Second, we extend, in a simple but nontrivial way, existing models of HFDI by introducing intra-firm trade from headquarters to subsidiary. Third, structural estimation of the model confirms the importance of intra-firm trade (which is unobserved in the data), and allows us to reject the competing hypotheses such as those emphasizing geographical differences in fixed costs in MP.

We propose a model of joint export and MP decisions, similar to Helpman, Melitz and Yeaple (2004), but where gravity emerges as an equilibrium outcome because some inputs are shipped from the headquarters to the affiliate. These inputs may be traded goods, headquarters services, as in Helpman (1984), or costs related to monitoring the subsidiary, as in Head and Ries (2008). Because variable trade costs

[3] Contrary to this trend in the literature, Alfaro and Charlton (2007), using four-digit level data, find that the share of vertical FDI (subsidiaries that provide inputs to their parent firms) is larger than commonly found using two-digit level data, even within developed countries.

are incurred in intra-firm trade, MP will become less profitable if variable barriers are high. However, exports also become less profitable as trade costs increase. Therefore, the incentives to establish a foreign plant may increase or decrease as barriers rise. We show that this ambiguity will depend on certain parameters of the model, such as the share of headquarters inputs required by the affiliate. Moreover, we introduce into the model firm- and destination-specific shocks to sales and fixed trade cost to account for some of the stylized facts shown in the empirical section. This is in line with the recent work of Eaton, Kortum and Kramarz (2008) for French firms' export decisions.

Turning to estimation, we use the stochastic structure of the model to derive micro-founded gravity equations for export and MP. We pay extra attention to biases arising due to unobserved selection: for example, MP entrants may have unobserved characteristics that influence both the entry decision and the volume of sales. Our ML estimator deals with this potential bias by incorporating the standard Heckman (1979) selection framework. Firm-level estimation of exports and MP has the advantage of identifying the intensive margin (sales per firm per destination) and the extensive margin (the number of firms per destination) separately. This also allows us to identify the costs that are present in MP and how they shape the geography of MP. Theory predicts that the number of sellers in a destination is influenced by entry costs (fixed or sunk costs) and variable costs. Sales per firm, on the other hand, are only affected by variable costs. This fundamental difference is what enables us to draw conclusions about the scale of variable versus fixed costs in MP. With this information, we can directly test whether gravity for MP is a result of the geographical distribution of fixed costs or a result of variable trade barriers (due to intra-firm trade).

This distinction is important in many respects. In the case of zero intra-firm trade, the creation of plants abroad is associated with the destruction of plants at home. In the case of positive intra-firm trade, on the other hand, firms still face the trade-off between selling through exports or through FDI, but now MP may entail a substantial amount of value added at home. Entering FDI may in fact increase domestic production and employment because the parent firm must supply inputs to its new affiliates. Given the point estimates from our econometric model, we can quantify how domestic production and labor demand responds when firms enter or exit FDI.

Several strong conclusions emerge from the analysis. First, our estimation results show that fixed costs of exporting are increasing in distance whereas fixed costs of conducting FDI are fairly constant. This suggests that fixed costs in multinational operations do not play a role in the dampening of MP with distance. Second, intra-firm trade appears to play a crucial role in shaping the geography of MP. Our estimates highlight an important feature of the data: within firms, MP sales are decreasing with distance, suggesting that marginal MP costs are increasing with distance. This leads us to reject the standard proximity-concentration model where intra-firm trade is zero. This conclusion is robust to any geographical distribution of fixed costs of MP. However, our structural model puts a very high weight on intra-firm trade in generating the spatial pattern of FDI. Specifically, the point estimate of the affiliate's cost share related to purchases from the headquarters is about 9/10. This leads us to conclude that there must be additional forces contributing to dampening MP on the intensive margin. Thus, the estimated cost share can be interpreted as an upper bound on the true cost share. Finally, our counterfactuals indicate that impeding FDI has strong effects on trade flows but the decline in welfare is not particularly large: shutting down FDI completely leads to welfare losses in the range of 0.3 to 2.5 per cent, depending on the elasticity of substitution. Moreover, we do find that the multinationals affected by these barriers cut their home employment by as much as 50 per cent. Hence, reducing barriers to FDI may have positive effects on the domestic labor market because outward FDI entails a substantial amount of economic activity at home.

Besides Helpman, Melitz and Yeaple (2004) and Eaton, Kortum and Kramarz (2008), our paper is related to Kleinert and Toubal (2006a) who compare a model with symmetric firms and parent-affiliate trade and a model with heterogeneous firms where the fixed cost of FDI is increasing in distance.[4] These authors derive (in partial equilibrium) reduced-form gravity equations for total affiliate sales, number of affiliates and average affiliate sales, and estimate them using aggregate data. They find that the number of affiliates is decreasing in distance between the source and the host country while average affiliate sales do not vary significantly with distance. Compared to their paper, we focus on a general equilibrium model with heterogeneous firms and parent-affiliate trade. Moreover, we do not assume any particular structure on fixed costs. Our overall estimation strategy is different as it involves micro-gravity equations at the firm level. Our structural approach allows us to estimate the degree of intra-firm trade and perform counterfactuals.

Our paper is also related to Ramondo and Rodríguez-Clare (2008), who extend the Eaton and Kortum (2002) model of trade by introducing MP and diffusion of ideas. In their model bilateral trade and MP flows can be correlated either because of a positive correlation between trade and MP costs or because of parent-affiliate trade. They estimate their model on aggregate data.

Another important contribution is Feinberg and Keane (2006), who build a dynamic structural model of U.S multinational corporations and Canadian affiliates to study the growth of MNC-based trade. They assume that parents and affiliates produce different goods, each of which can be used as intermediate into the production process of the other. They model only the marginal (intensive margin) production and trade decisions of the MNC, while we also model and estimate entry into exports and MP. They suggest that the growth in intrafirm trade might be due to technical change and, in particular, to improvements in logistics management.

The rest of the paper is organized as follows: in Section 2 we introduce some firm-level facts about exports and FDI. In Section 3 we lay out our model, and in Section 4 we describe the estimation strategy. Section 5 presents results and counterfactuals. Section 6 concludes.

[4] In the appendix of their paper they also consider a model with heterogeneous firms and parent-affiliate trade.

2 Data and Firm-Level Facts

We now introduce the firm-level dataset used in this study and show some producer-level facts on exports and MP activity. First, we show the relationship between total exports and total affiliate sales versus distance (controlling for market size) and decompose it into an extensive and intensive margin. The extensive margin of FDI is the main feature of the data that calls for the introduction of intra-firm trade into the model. We then exploit the FDI information in the data to replicate some facts that Eaton, Kortum and Kramarz (2008) have shown for exports. These facts emphasize the importance of fixed cost of entry into export markets and of heterogeneity of firms' productivity, and also call for the presence of firm- and destination-specific entry and sales shocks.

2.1 Data

Firm-level data for the Norwegian manufacturing sector are drawn from *Statistics Norway's Capital Database*, a panel of all joint-stock companies in the period 1993-2004. We choose to work on the 2004 cross-section, the most recent available to us, which includes approximately $8,000$ firms. The database provides detailed information on inputs and output and covers about 90 per cent of Norwegian manufacturing revenue.[5] Firm-level trade data, by destination country, come from customs declarations. About 40 per cent of the total number of firms are exporters and, among exporting firms, the average number of destinations served is 6.9. Total manufacturing exports amount to approximately 140 billion NOK, or 29 per cent of Norwegian manufacturing revenue in 2004. Information on firms' foreign operations is gathered from the *Directorate of Taxes' Foreign Company Report* and comprises all outward

[5] Only mainland Norway manufacturing, i.e. non-oil firms, are included in the database. Mainland manufacturing accounted for 14 per cent of total mainland GDP in 2004. Statistics Norway's Capital Database is described in detail in Raknerud, Rønningen, and Skjerpen (2004).

FDI stocks and associated affiliate sales by destination in the manufacturing sector.[6][7] Total affiliate sales amounted to over 60 billion NOK, or 13 per cent of domestic manufacturing revenue in 2004, but only about 1.3 per cent of the population of firms conducted FDI.[8] Among firms conducting FDI, the average number of FDI destinations was 4.4.[9] Foreign direct investment and trade data have been merged with the capital database using a unique firm identifier. Even though over 200 export destinations and 59 FDI destinations are present in the dataset, in this paper we choose to work only with OECD countries: first, a theory of horizontal FDI is more relevant in the OECD area; second, maximum likelihood estimation is relatively CPU intensive, and this restriction saves us a significant amount of processing time.[10] OECD export sales constitute 96.8 per cent of total exports, whereas OECD affiliate sales constitute 80.7 per cent of total affiliate sales.

2.2 The Extensive Margin of Affiliate Sales

As is well known, the gravity model performs well in explaining bilateral trade flows. The top left panel of Figure 1 shows a linear in logs relationship between total export sales and distance, adjusted for destination country absorption. The top right panel shows that total affiliate sales too are negatively related with distance, adjusting for

[6] Affiliate sales are defined as total revenue of the affiliate adjusted by the parent's ownership share. A 20 per cent ownership threshold is used to distinguish direct investment from portfolio investment. Direct investment comprises investors' share of equity in foreign companies and investors' debt to and claims on foreign companies.

[7] Foreign owned firms conducting outwards FDI from Norway are also present in the data, but their numbers are fairly small. About 10.6 per cent of the affiliate-destination pairs in 2004 had a foreign-owned parent that was located in Norway. Foreign-owned parents employed 11.0 per cent of the total outwards FDI workforce.

[8] Kleinert and Toubal (2006b) report that 0.21 percent of all German firms are multinationals and they account for 27 percent of total sales in Germany.

[9] Some firms only export to a particular destination, others only conduct FDI and others do both. Out of $22,236$ firm-destination pairs in our sample, 98.6 percent are export-only, 0.3 percent are FDI-only and 1.1 percent are export-FDI.

[10] Luxembourg is excluded since no Norwegian firm conducts FDI there.

destination country size. The bottom panels show the extensive margin (the number of exporters and firms conducting FDI) instead: both the number of exporters and of firms conducting FDI are clearly decreasing in distance, after adjusting for destination absorption.[11] As we alluded to in the introduction, the strong dampening effect of distance on MP (both overall and on the extensive margin) presents a puzzle in horizontal models of FDI. At the same time, there is mounting empirical evidence on the importance of intra-firm trade (e.g. Bernard, Jensen and Schott, 2005). Our database does not provide direct information about intra-firm trade, but it shows clear circumstantial evidence: 75 per cent of the firms conducting FDI to destination n also export to n.[12] This is also inconsistent with the basic HFDI model. As we do not know whether affiliate output is sold locally or not, from the outset we cannot reject the hypothesis that Norwegian FDI flows are mostly vertical or export-platform FDI. However, our data suggest that both simple vertical fragmentation and export-platform strategies are not widespread.[13] First, 85 per cent of the Norwegian parents show imports from destination n that are less than 30 per cent of the sales of their affiliates in destination n. Median imports relative to affiliate sales (in the same destination) are just below 3 per cent. Second, most FDI occurs in countries similar to Norway in terms of wages and relative factor endowments. Also, in the next paragraph we show that the number of entrants are increasing in the size of the

[11] Figure 1 is not intended to provide an assessment of the validity of the gravity model, but makes it clear why we introduce intra-firm trade in the Helpman, Melitz and Yeaple (2004) framework. As Anderson and van Wincoop (2003) showed, gravity theory tells us that after controlling for size, trade between two regions is decreasing in their bilateral trade barrier *relative* to the average barrier of the two regions to trade with all their partners. The model we develop in the next section and our estimation strategy take this into account.

[12] Moreover, preliminary data show that no fewer than 20 per cent of Norwegian multinationals have intra-firm sales from parent to foreign affiliates. Since the data are incomplete, we exclude them when estimating our model.

[13] In a recent paper, Chor, Manova and Watt (2008) find that over 70 per cent of US affiliate sales are intended for the destination market, 20 per cent are intended for 3rd countries, while less than 10 per cent are shipped back to the US.

destination market, suggesting that the size of the destination market itself, and not 3rd countries, determines entry. Third, among the firms exporting and conducting FDI to the same destination, the median ratio of exports to affiliate sales is 0.23, i.e. most multinationals are selling substantially less through exports than through affiliate sales (to the same destination).[14] This evidence suggests the use of a model where multinational firms are allowed to provide inputs to their foreign affiliates and where foreign direct investment is mostly horizontal.

2.3 Regularities for FDI at the Firm Level

Before laying out our model, we show that firm-level facts for MP are quite similar to those that Eaton, Kortum and Kramarz (2008) found for exports, and that these facts are consistent with what heterogeneous firms models of trade would predict.[15]

Number of MP firms and size of the market. First, the number of Norwegian multi-national enterprises (MNEs) selling to a market, relative to the Norwegian market share, increases with market size, indicating that fixed costs are important in MP. This is shown in Figure 2. The x-axis represents the size of the destination market, while the y-axis measures the number of Norwegian affiliates selling there, divided by Norwegian market share (in log scale). Norwegian market share is measured as total exports to destination n relative to country n absorption. We divide by market share to subtract other factors determining the number of entrants, such as proximity to the market. For example, Norway's market share in Sweden is the highest among Norway's trading partners. Dividing by market share will adjust Swedish entry downwards in the graph.[16]

[14] It is tempting to use exports/affiliate output as an upper bound of the share of intra-firm trade in affiliate output. However, we believe there are large measurement errors associated with intra-firm trade, due to (i) uncertainty related to transfer pricing and (ii) the fact that service exports are omitted in our export data.

[15] Firm-level facts for Norwegian exporters (which we do not report in this paper but are available upon request) are also consistent with those for French exporters shown in Eaton, Kortum and Kramarz (2008).

[16] Kleinert and Toubal (2006b) find that the same fact holds for German data: the number of

Market popularity and firm size. Second, average sales in Norway rise with selling to less popular destinations, although the relationship is a cloudy one. Figure 3 depicts average sales in Norway (in logs) on the y-axis of those firms selling to the nth most popular market, where n is reported on the x-axis. Market popularity is measured as the rank in terms of the number of Norwegian-based firms conducting FDI to the destination. All in all, the relationship suggests that selling to less popular markets requires higher firm efficiency, which translates into higher domestic sales.[17]

Destinations hierarchy. Third, the data show that FDI (and export) destinations follow in part a hierarchical structure, meaning that many firms engaging in FDI to the $k+1$st most popular destination do so for the kth most popular as well.[18] As in Eaton, Kortum and Kramarz (2008), we need a model that recognizes both a tendency for firms to export and engage in FDI according to a hierarchy while allowing them significant latitude to depart from it. Figure 4 plots the number of firms engaging in FDI in the kth most popular destination on the horizontal axis against the number of firms engaging in FDI in k or more countries. If the choice of where to direct FDI followed a strict hierarchy, the data would lie on the 45 degree line. The figure shows that there is a significant departure from the hierarchy, especially for the less popular destinations. In order to account for this departure we will introduce into the model firm- and destination-specific shocks to the fixed cost of entry into a market. This potentially allows the destination hierarchy to be firm-specific. Moreover, we will also introduce firm- and destination-specific sales shocks (as in Eaton, Kortum and Kramarz, 2008) in order to account for the widely documented heterogeneity in export intensity across firms for a given destination.

German firms' foreign affiliates, normalized by German market share, increases regularly with market size.

[17] Yeaple (2008) finds that, consistently with our results, more efficient firms are more likely to own an affiliate in any given host country.

[18] Export entry data also partially follow a destination hierarchy. This is sometimes referred to as a "pecking order" (e.g. Yeaple, 2008 and Manova, 2008).

3 Model

In this section we present a theoretical model consistent with the facts outlined above. The model is a parsimonious extension of Helpman, Melitz and Yeaple's (2004) model of horizontal FDI, but crucially adds intra-firm trade as well as sales and fixed cost shocks.

3.1 Preferences

There are N potentially asymmetric countries that produce goods using only labor. Country i is populated by L_i consumers that maximize utility derived from the consumption of goods belonging to two sectors. One sector provides a homogeneous good and the other a continuum of differentiated goods. An exogenous fraction μ of income is spent on differentiated products and the remaining fraction $1-\mu$ on the homogeneous good. Preferences across varieties of the differentiated product have the standard CES form with an elasticity of substitution $\sigma > 1$. Each variety enters the utility function with its own country-specific weight η_i. These preferences generate a demand function $A_i p_i^{1-\sigma}$ in country i for every brand of the product with price p_i. The demand level $A_i = \mu\eta_i Y_i P_i^{\sigma-1}$ is exogenous from the point of view of the individual supplier and depends on total expenditure Y_i and the consumption-based price index P_i.

3.2 Technology and Trade Barriers

The homogeneous good is freely traded and produced under constant return to scale with one unit of labor producing w_i units of the good in country i. This sector is perfectly competitive, and the price is normalized to one so that if country i produces this good, the wage in the country is w_i. We consider equilibria only where every country produces some of the homogeneous good, which is used as *numéraire*. As long as the share of the homogeneous good, $(1-\mu)$, is large enough, or trade barriers in the other sector are large enough, this condition will hold.

A firm owns a technology, associated with productivity z, that can be used in any location.[19] A firm in country i can access the domestic market by sustaining a fixed cost f_{iiE} in units of the numéraire, and then produce a variety of the differentiated good with marginal cost w_i/z. There are two alternative ways of selling a good in foreign markets: exports and horizontal FDI. A firm in country i that exports to country n must pay a fixed cost f_{inE}/ε_n where ε_n is a random shock that varies by firm and destination. Marginal costs for an exporter are,

$$c_{inE}(z) = \tau_{in} w_i / z \tag{1}$$

where $\tau_{in} > 1$ is a melting-iceberg transportation cost. A firm that instead decides to serve country n through foreign direct investment must pay a fixed cost f_{inI}/ε_n. Note that the entry shock is identical for export and FDI entry. We assume that the final good produced by the affiliate is assembled from intermediates and local labor with a Cobb-Douglas production function. Intermediates, which can be interpreted either as headquarters goods or as services, are supplied by the parent firm to the affiliate. Every firm supplies its own requirements, they are not traded at arm's length. Implicitly, we assume that the headquarters service is produced by a constant return to scale production function where one unit of labor yields z units of output. Hence, the competitive price of the intermediate is just equal to the unit cost of the intermediate $\tau_{in} w_i/z$. Marginal costs for an FDI firm are then

$$c_{inI}(z) = (w_i \tau_{in})^{1-\alpha} w_n^{\alpha} / z \tag{2}$$

where α is the fixed ratio of affiliate labor expenditure to total variable costs. Note that our model encompasses the Helpman, Melitz and Yeaple (2004) model when α is equal to 1, that is when the marginal cost of affiliate output no longer depends on

[19] Eaton, Kortum and Kramarz (2008), Helpman, Melitz and Yeaple (2004) and many others adopt the same assumption. Moreover, Yeaple (2008) finds that the logarithm of a foreign affiliate's sales is increasing in the logarithm of its parent firm's productivity, controlling for country and industry fixed effects.

variable trade barriers.[20]

Productivity z is here Hicks-neutral, i.e. affects both domestic and foreign production identically. Note that variable trade costs will affect both exports and the transfer of intermediates. Producers of the differentiated good engage in monopolistic competition so that the price of a good is a markup $\sigma/(\sigma-1)$ on marginal costs.

We assume that the total mass of potential entrants in country i is proportional to labor income w_iL_i, so that larger and wealthier countries have more entrants. This assumption, as in Chaney (2008), greatly simplifies the analysis and it is similar to Eaton and Kortum (2002), where the set of goods is exogenously given. Without a free entry condition, firms generate net profits that have to be redistributed. We assume that all consumers own w_i shares of a totally diversified global fund and that profits are redistributed to them in units of the numéraire good. The total income Y_i spent by workers in country i, is the sum of their labor income w_iL_i and of the dividends they get from their portfolio $w_iL_i\pi$, where π is the dividend per share of the global mutual fund.

Given preferences and the optimal pricing of firms, profits from exporting (E) and FDI (I) are

$$\pi_{inv}(z,\eta_n) = \frac{s_{inv}(z,\eta_n)}{\sigma} - \frac{f_{inv}}{\varepsilon_n}$$

where $v = \{E, I\}$ and $s_{inv}(z,\eta_n) = A_n p_{inv}^{1-\sigma}(z)$ are sales from location i to destination n of a firm with productivity z and sales shock η_n. Firms enter market n only if they can earn positive profits there. Some low-productive firms may not generate sufficient revenue to cover their fixed costs. We define the productivity threshold $\bar{z}_{inE}$ from $\pi_{inE}(\bar{z}_{inE}) = 0$ as the lowest possible productivity level consistent with non-negative profits in export markets

$$\bar{z}_{inE}(\varepsilon_n,\eta_n) = \delta_1 \left(\frac{f_{inE}}{\eta_n \varepsilon_n Y_n}\right)^{\frac{1}{\sigma-1}} P_n^{-1} w_i \tau_{in} \tag{3}$$

with δ_1 a constant.[21] Note that the cutoff $\bar{z}_{inE}$ is a stochastic version of the one found

[20] Yeaple (2008) finds a negative relationship between average affiliate sales and distance, suggesting that marginal MP costs are increasing in trade costs.

[21] $\delta_1 = (\sigma/\mu)^{1/(\sigma-1)} \frac{\sigma}{\sigma-1}$.

by Chaney (2008).

Similarly, we define the FDI cutoff $\bar{z}_{inI}$ from $\pi_{inE}(\bar{z}_{inI}) = \pi_{inI}(\bar{z}_{inI})$ as the lowest possible productivity level such that the firm is indifferent between FDI and exports,

$$\bar{z}_{inI}\left(\varepsilon_n, \eta_n\right) = \delta_1 \left(\frac{\Omega_{in}}{\eta_n \varepsilon_n Y_n}\right)^{\frac{1}{\sigma-1}} P_n^{-1} w_i \tau_{in} \tag{4}$$

where $\Omega_{in} = (f_{inI} - f_{inE}) / \left[(\omega_{in}\tau_{in})^{\alpha(\sigma-1)} - 1\right]$.[22] Comparing (3) with (4), it is easy to see that Ω_{in} can be interpreted as the relative cost of FDI: when plant-level returns to scale are high and variable trade costs are low, i.e. $(\omega_{in}\tau_{in})^{\alpha(\sigma-1)} < f_{inI}/f_{inE}$, the cutoffs are ordered as $\bar{z}_{inE} < \bar{z}_{inI}$, for any pair of shocks (ε_n, η_n). As in Helpman, Melitz and Yeaple (2004), this means that, *ceteris paribus*, low productive firms will serve only the domestic market, medium-productive firms will choose to export, while high-productive firms will maximize profits by choosing MP.[23] However, in our model the role of trade barriers is more complex. Differentiating $\bar{z}_{inI}$ with respect to τ_{in}, holding P_n constant, yields the elasticity χ_I of the FDI cutoff to variable trade barriers,

$$\chi_I = \frac{(\omega_{in}\tau_{in})^{\alpha(\sigma-1)}(1-\alpha) - 1}{(\omega_{in}\tau_{in})^{\alpha(\sigma-1)} - 1} \lesseqgtr 0,$$

so that the FDI cutoff is increasing with distance iff

$$(\omega_{in}\tau_{in})^{\alpha(\sigma-1)}(1-\alpha) > 1. \tag{5}$$

This means that the number of MNEs will decrease in trade costs τ_{in} under certain parameter restrictions[24]. In the appendix, we show that endogenizing the price index P_n will not alter this result. Gravity for FDI emerges when (a) variable trade costs are already high, (b) local wages are high relative to foreign wages or (c) the elasticity of substitution is high. The intuition is the following: for low initial values of the trade

[22] $\omega_{in} = w_i/w_n$ is the relative wage of country i with respect to country n. Below, we impose $(\omega_{in}\tau_{in})^{\alpha(\sigma-1)} > 1$, which will ensure that $\Omega_{in} > 0$ and some firms will choose MP.

[23] Our model does not contemplate the case of firms performing FDI but not exporting to a destination. As shown in Section 2.1, this is entirely consistent with our data.

[24] Note that if (5) holds, then total MP must also decrease in trade costs.

costs, higher trade costs will reduce export sales more than affiliate sales, making FDI relatively more attractive. When trade costs are high, FDI profits may turn negative, forcing the firm to abandon affiliate sales. A higher home wage means that the parent firm's cost share is larger, all else equal. Hence, trade barriers will have a stronger negative effect on MP if home wages are high. A high elasticity of substitution will exacerbate the negative effect on sales of an increase in τ_{in} (or ω_{in}), increasing the likelihood of negative FDI profits.

The marginal role of intermediates is more complicated, because α affects the first term in (5) positively and the second term negatively. However, we prove in the appendix that high intermediate trade (low α) will always strengthen gravity.

Intra-firm trade is simply proportional to affiliate sales. We know that $(1-\alpha)$ is the expenditure share for the headquarters good, so intra-firm trade s_{inIF} is a fraction $(1-\alpha)$ of total variable costs (i.e. excluding fixed costs). Since gross profits are a fraction $1/\sigma$ of sales, intra-firm trade can be written as

$$s_{inIF} = (1-\alpha)\,\frac{\sigma-1}{\sigma} s_{inI} \tag{6}$$

3.3 General Equilibrium

So far we have not taken into account changes in the price index. The price index is

$$P_n^{1-\sigma} = E_{\varepsilon_n,\eta_n} \sum_i w_i L_i \left[\int_{\bar{z}_{inE}(\varepsilon_n,\eta_n)}^{\bar{z}_{inI}(\varepsilon_n,\eta_n)} \eta_n p_{inE}(z)^{1-\sigma} dG(z) + \int_{\bar{z}_{inI}(\varepsilon_n,\eta_n)}^{\infty} \eta_n p_{inI}(z)^{1-\sigma} dG(z) \right].$$

Note that $\bar{z}_{iiE}$ is the domestic exit cutoff in country i and $\bar{z}_{iiI} = \infty$ (no firm conducts FDI at home).[25] As in Helpman, Melitz and Yeaple (2004), Chaney (2008) and others, we assume that productivity is distributed as a Pareto, along $[1, +\infty)$, that is $dG(z) = \gamma z^{-\gamma-1} dz$ where γ is an inverse measure of heterogeneity. The Pareto assumption greatly simplifies the analysis in that all general equilibrium expressions can be solved in closed form. Also, recent evidence (e.g. Luttmer, 2007), suggests that it approximates the distribution of firm sizes in the U.S. fairly well. Given that

[25] Because $w_{ii}\tau_{ii} = 1$, $\Omega_{ii} = \infty$, so $\bar{z}_{iiI} = \infty$ in (4).

$\gamma > \sigma - 1$,[26] the equilibrium price index is

$$P_n = \delta_2 Y_n^{1/\gamma - 1/(\sigma-1)} \theta_n \left(\frac{1+\pi}{Y} \right)^{1/\gamma} \tag{7}$$

where $\theta_n^{-\gamma} = \sum_i (Y_i/Y)(w_i \tau_{in})^{-\gamma} \left\{ \Omega_{in}^{1-\gamma/(\sigma-1)} \left[(\omega_{in}\tau_{in})^{\alpha(\sigma-1)} - 1 \right] + f_{inE}^{1-\gamma/(\sigma-1)} \right\}$, δ_2 is a constant and Y is world income.[27] Note that θ_n can be interpreted as a multilateral resistance variable as in Anderson and van Wincoop (2003). It is a weighted average of i) country n trade barriers, ii) wages in the source countries and iii) the fixed costs of selling to n, where the weights are the economic sizes of the trading partners. It remains to determine total income Y_i, which will depend on the dividends received from the global fund. It turns out that dividends per share is a constant in equilibrium.[28] After solving for the price index we can write latent export sales of a firm with productivity z and sales shock η_n as

$$s_{inE}(z, \eta_n) = \delta_3 (1+\pi)^{(\sigma-1)/\gamma} \left(\frac{Y_n}{Y} \right)^{(\sigma-1)/\gamma} \left(\frac{\theta_n}{w_i \tau_{in}} \right)^{\sigma-1} z^{\sigma-1} \eta_n. \tag{8}$$

where δ_3 is a constant.[29]

Similarly, we obtain latent affiliate sales of a firm with productivity z and sales shock η_n as

$$s_{inI}(z, \eta_n) = \delta_3 (1+\pi)^{(\sigma-1)/\gamma} \left(\frac{Y_n}{Y} \right)^{(\sigma-1)/\gamma} \left[\frac{\theta_n}{(w_i \tau_{in})^{1-\alpha} w_n^{\alpha}} \right]^{\sigma-1} z^{\sigma-1} \eta_n. \tag{9}$$

Note that export and affiliate sales in a market increase less than proportionally to the size of the market Y_n. As in Eaton, Kortum and Kramarz (2008), the intuition is that a larger market attracts more entry, so that the price index is lower.

The following proposition states expressions for the extensive margin for both exports and affiliate sales.

[26] The assumption that $\gamma > \sigma - 1$ ensures that, in equilibrium, the size distribution of firms has a finite mean.

[27] $\delta_2^{-\gamma} = \delta_1^{\sigma-\gamma-1} \left(\frac{\sigma}{\sigma-1} \right)^{1-\sigma} \frac{\gamma}{\gamma-(\sigma-1)} E_{\eta_n, \varepsilon_n} \left[(\eta_n \varepsilon_n)^{\gamma/(\sigma-1)-1} \eta_n \right]$.

[28] Specifically, $\pi = [\sigma\gamma/\mu(\sigma-1)+1]^{-1}$. See the appendix for a proof.

[29] $\delta_3 = \sigma (\delta_2/\delta_1)^{\sigma-1}$.

Proposition 1 (Extensive Margin) *The equilibrium number of country i firms exporting to country n is*

$$n_{inE} = \delta_4^{-\gamma}\delta_5 \frac{Y_i Y_n}{Y}\left(\frac{\theta_n}{w_i \tau_{in}}\right)^{\gamma}\left(f_{inE}^{-\gamma/(\sigma-1)} - \Omega_{in}^{-\gamma/(\sigma-1)}\right) \tag{10}$$

while the number of country i firms conducting FDI in country n is

$$n_{inI} = \delta_4^{-\gamma}\delta_5 \frac{Y_i Y_n}{Y}\left(\frac{\theta_n}{w_i \tau_{in}}\right)^{\gamma}\Omega_{in}^{-\gamma/(\sigma-1)}. \tag{11}$$

where δ_4 and δ_5 are constants.[30]

Proof. See appendix. ■

The extensive margin of foreign market access, represented by both the number of exporters and the number of FDI firms, depends on the extent of intra-firm trade. In the appendix we show that in a partial equilibrium framework, that is when $\partial P_n/\partial\tau_{in} = 0$, both the number of exporters and the number of FDI firms are a decreasing function of τ_{in}, as long as (5) holds. In general equilibrium instead, the number of FDI firms declines with τ_{in} as long as destination n has a sufficient number of trading partners, meaning that source i must not be important enough to affect the price index P_n. Without intra-firm trade the number of FDI firms is instead increasing in variable trade barriers, in clear contrast with the pattern showed in Figure 1.

Using firm-level sales equations (8) and (9), we can aggregate over the set of firms which exports and conducts FDI to obtain aggregate sales equations. These expressions are shown in the following proposition.

Proposition 2 (Aggregate Sales) *Aggregate export from country i to country n can be written as*

$$S_{inE} = \mu \frac{Y_i Y_n}{Y}\left(\frac{\theta_n}{w_i \tau_{in}}\right)^{\gamma}\left(f_{inE}^{1-\gamma/(\sigma-1)} - \Omega_{in}^{1-\gamma/(\sigma-1)}\right)$$

[30] $\delta_4 = \delta_1/\delta_2$ and $\delta_5 = E_{\eta_n,\varepsilon_n}\left[(\eta_n\varepsilon_n)^{\gamma/(\sigma-1)}\right]$

whereas affiliate sales is given by

$$S_{inI} = \mu \frac{Y_i Y_n}{Y} \left(\frac{\theta_n}{w_i \tau_{in}} \right)^{\gamma} (\omega_{in}\tau_{in})^{\alpha(\sigma-1)} \Omega_{in}^{1-\gamma/(\sigma-1)}.$$

Both exports and affiliate sales are a function of country sizes (Y_i and Y_n), workers' productivity (w_i and w_n), variable trade costs (τ_{in}), fixed trade costs (f_{inE} and f_{inI}), and the measure of n's remoteness from the rest of the world (θ_n).[31]

Proof. See appendix. ■

The gravity equation for exports is similar to the one found by Chaney (2008) except for the presence of an extra term, the relative FDI cost Ω_{in}.[32] As shown by Chaney, a reduction in variable trade barriers not only increases the sales of current exporters (with an elasticity equal to $\sigma - 1$), but also has an extensive margin effect.

The gravity equation for FDI is even more interesting. The overall effect of an increase in variable trade barriers on total affiliate sales can be decomposed into intensive and extensive margin,

$$\frac{d \ln S_{inI}}{d \ln \tau_{in}} = - \underbrace{(1-\alpha)(\sigma-1)}_{\text{intensive margin}} - \underbrace{(\gamma - \sigma + 1)\chi_I}_{\text{extensive margin}}.$$

As long as there is intra-firm trade, affiliate sales of any firm are negatively affected by an increase in variable trade barriers through an increase in the cost of transferring intermediate goods from the parent to the affiliate (intensive margin effect).[33] The higher the degree of intrafirm trade and the higher the elasticity of substitution the stronger the intensive margin effect. Aggregate affiliate sales depend also on the location of the FDI cutoff and therefore on the number of affiliates. The extensive

[31] Aggregate export here does not include intra-firm trade which, as we have shown above, is proportional to affiliate sales. Moreover, this facilitates the comparison with the results in Chaney (2008).

[32] When the fixed cost of export is the same as the fixed cost of FDI $\Omega_{in} = 0$ and the gravity equation for exports becomes the same as Chaney's.

[33] In general equilibrium, an increase in variable trade barriers also implies a rise in the price index in the destination country. This indirect effect dampens the negative direct effect but is relatively unimportant as long as the source country holds a small market share in the destination country.

margin term in the decomposition captures this effect. As long as condition (5) holds, the elasticity χ_I is positive so that when variable trade barriers increase, the FDI cutoff increases as well, while the number of firms engaged in FDI decreases.[34] The reduction in the number of FDI firms is stronger the lower is the degree of firm heterogeneity (the higher is γ), while the impact of this reduction on total affiliate sales is stronger the lower is the elasticity of substitution. When there is no intra-firm trade ($\alpha = 1$), the intensive margin effect is null, while the extensive margin effect is positive.[35] In this case, total affiliate sales (and the number of firms conducting FDI) are increasing in variable trade barriers.

Finally, the ratio of total exports relative to affiliate sales is decreasing in distance[36]

$$\frac{S_{inE}}{S_{inI}} = (\omega_{in}\tau_{in})^{\alpha(1-\sigma)} \left[\left(\frac{\Omega_{in}}{f_{inE}} \right)^{\frac{\gamma}{\sigma-1}-1} - 1 \right].$$

It is interesting that the main prediction of Helpman, Melitz and Yeaple (2004) still holds. Whereas in their paper export declines and FDI increases when τ_{in} increases, our model predicts decreasing exports and decreasing FDI (for some parameter values), with the decrease in FDI being smaller than the decrease in exports. Total affiliate sales fall less rapidly than exports with τ_{in}.

4 Empirical Implementation

In this section we estimate the structural parameters of the model described in Section 3. We proceed in two steps. In the first stage, we estimate the country-specific parameters and the variance of the sales and fixed cost shocks. In this stage the structural parameters from the model can be estimated with maximum likelihood techniques using firm-level data on export and FDI entry and on export and affiliate sales. The

[34] We have shown above that, even in general equilibrium, the number of FDI firms declines with variable trade barriers as long as the destination country has a sufficient number of trading partners.

[35] When $\alpha = 1$ condition (5) never holds and the elasticity of the FDI cutoff with respect to variable trade barriers is always negative.

[36] The ratio between the number of exporters and MNEs is also decreasing in τ_{in}.

econometric model can be thought of as micro-gravity equations, i.e. we estimate theory consistent gravity-like equations at the firm level. There are two main advantages of firm-level estimation: first, it allows us to properly model selection, which may affect parameter estimates. Second, it is more general, as the econometric model does not rely on any assumptions about the productivity distribution. We emphasize that the estimation procedure will identify an index of fixed costs of exporting and FDI. The intuition is that while the extensive margin will depend on both fixed and variable costs, the intensive margin (sales per firm) will depend only on variable costs. Hence, we can subtract the latter from the former to obtain an estimate of fixed costs alone.

In the second stage, under some assumptions about trade costs and assuming that the productivity distribution is Pareto, we estimate the shape parameter of the productivity distribution and the parameter of the labor share of affiliate expenditure α that is consistent with the general equilibrium of the model. In this stage, the estimation relies on the fact that our model implies that the intensive margin for MP should respond less to trade costs than the margin for exports. The intensive margin for MP can thus be represented as the intensive margin for exports plus an MP-specific term.

4.1 First Stage

In the first stage of the estimation we use data on export and FDI entry, export and affiliate sales for all J Norwegian manufacturing firms in 2004. Let $y_{nE}(j)$ be a dummy variable equal to one if firm j exports to country n and $y_{nI}(j)$ be equal to one if firm j invests into country n. Let $\{s_H(j), s_{nE}(j), s_{nI}(j)\}$ denote home, export and affiliate sales respectively of firm j to country n.[37] We follow other authors (e.g. Anderson & van Wincoop, 2003) in hypothesizing that iceberg trade costs τ_{in} are a loglinear function of observables. Specifically, we use $\tau_{in} = d_{in}^{\rho_1}$ where d_{in} denotes distance (in kilometers) between country i and country n. Moreover, we assume that the wage

[37] We drop the subscript i for all these variables since the source country is always Norway.

in country n is a loglinear function, with coefficient ρ_2, of a wage index published by the Bureau of Labor Statistics.[38] As in the theory section, we consider two types of firm- and destination-specific shocks: one for entry $\varepsilon_n(j)$ and one for sales $\eta_n(j)$. We assume that they are *iid* lognormally distributed over firms j and destinations n, but we allow for correlation between $\varepsilon_n(j)$ and $\eta_n(j)$ within the same firm-destination pair. These distributional assumptions allow us to write the likelihood function in closed form.[39]

4.1.1 Re-Expressing Entry and Sales Equations

Since our estimation is conditional on the sales of firms at home, and productivity is not readily observable, it is useful to rewrite the equation for entry and sales in terms of home sales.

FDI and Export entry. First we derive an expression for FDI entry in terms of home sales. We know that firm j invests in country n if its productivity is higher than the FDI cutoff $\bar{z}_{nI}(j)$. Recalling that home sales are

$$s_H(j) = \mu\eta_H(j)Y_H\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} w_H^{1-\sigma}z(j)^{\sigma-1}P_H^{\sigma-1}, \tag{12}$$

and using the FDI cutoff (4), we can re-express the entry condition in terms of home sales

$$\ln s_H(j) + \upsilon_n(j) > \ln\sigma - \kappa_n + \ln\Omega_n \equiv M_{nI},$$

where $\eta_n^* = \eta_n(j)/\eta_H(j)$, $\upsilon_n(j)$ is the sum of the entry and sales shocks and κ_n is a country fixed effect.[40] As we show further below, κ_n can be interpreted as export sales' potential in market n. Hence, firm j establishes an affiliate in country n if

[38] BLS's index of hourly compensation costs for production workers, United States=100.

[39] Estimating the dataset with an acceptable number of destination countries is quite CPU-intensive, even with a closed-form likelihood. With the OECD set of destination countries, the MLE converges after approx. 20 minutes on an Intel server with 8 Xeon cores. More flexible distributional assumptions would require simulating the likelihood, which would increase the computational burden, probably to a point where estimation would become infeasible.

[40] Specifically $\upsilon_n(j) \equiv \ln\varepsilon_n(j) + \ln\eta_n^*(j)$ and $\kappa_n = \ln(Y_n/Y_H) + (\sigma-1)\ln(P_n/P_H) - \rho_1(\sigma-1)\ln d_n$.

home sales, adjusted for the sum of the entry and sales shocks, are higher than the entry hurdle M_{nI}. The entry hurdle is increasing in the FDI cost variable Ω_n and decreasing in sales potential κ_n.

The shocks have homoskedastic variance $\sigma^2_{\eta^*}$ and σ^2_{ε} and the covariance is $\sigma_{\varepsilon\eta^*}$. Then, the probability that firm j invests in country n, conditional on home sales, can be written as $1 - \Phi\left\{\left[M_{nI} - \ln s_H(j)\right]/\sigma_\upsilon\right\}$ where $\Phi(.)$ denotes the standard normal CDF and $\sigma^2_\upsilon = \sigma^2_\varepsilon + \sigma^2_{\eta^*} + 2\sigma_{\varepsilon,\eta^*}$.

The probability of exporting can be derived in a similar fashion. Using the cutoff condition for exports (3), the export entry condition in terms of home sales can be expressed as

$$M_{nE} < \ln s_H(j) + \upsilon_n(j) < M_{nI},$$

where the export entry hurdle (in terms of home sales) is $M_{nE} \equiv \ln\sigma - \kappa_n + \ln f_{nE}$.[41] The probability of exporting is then $\Phi\left\{\left[M_{nI} - \ln s_H(j)\right]/\sigma_\upsilon\right\} - \Phi\left\{\left[M_{nE} - \ln s_H(j)\right]/\sigma_\upsilon\right\}$. Finally, the probability of not exporting or selling through an affiliate is likewise $\Phi\left\{\left[M_{nE} - \ln s_H(j)\right]/\sigma_\upsilon\right\}$. This is essentially an ordered probit, where the problem is well-behaved only if $M_{nE} < M_{nI}$.

Affiliate and Export Sales. To estimate affiliate and export sales we need to control for the selection of more productive firms into export and FDI status. First we need to express affiliate sales in terms of home sales. Recalling that affiliate sales for firm j in market n are

$$s_{nI}(j) = \mu\eta_n(j)Y_n\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}\left(w_H d_n^{\rho_1}\right)^{(1-\alpha)(1-\sigma)} w_n^{\alpha(1-\sigma)} z(j)^{\sigma-1} P_n^{\sigma-1},$$

and using (12) we have

$$\ln s_{nI}(j) = \kappa_n + \rho_1\alpha\left(\sigma-1\right)\ln d_n + \rho_2\alpha\left(\sigma-1\right)\ln\omega_n + \ln s_H(j) + \ln\eta^*_n(j).$$

Notice that in the absence of intra-firm trade ($\alpha = 1$) firm-level affiliate sales are independent of distance d_n.[42] This expression states that multinational production

[41] Note that wages are not embedded in M_{nE} (except for wages' effect on income Y_n through κ_n). The reason is that higher labor costs affect both home sales and foreign sales. Since we are already controlling for home sales, wages cancel out in the equation.

[42] $\rho_1\left(\sigma-1\right)$ also appears in the κ_n, so α cancels out.

in market n equals the export sales potential κ_n adjusted for the fact that trade costs are less for multinational production than for exports (the $\rho_1\alpha(\sigma-1)\ln d_n$ term). Less intra-firm trade (high α) will tend to cancel out the negative effect of trade barriers embedded in κ_n. Also, lower unit costs abroad (high ω_n) translates into higher sales because firm j can charge a lower price. Note that it is the relative wage that matters: a proportional reduction in both home and foreign wage would boost both home sales and MP, so that the change in $s_H(j)$ would fully explain the change in $s_{nI}(j)$. Expected affiliate sales conditional on home sales and entry $\nu_{nI}(j) \equiv E[\ln s_{nI}(j)|s_H(j), y_{nI}(j)=1]$ are similar to the above equation but with $\ln\eta_n^*(j)$ replaced by $E[\ln\eta_n^*(j)|y_{inI}(j)=1]$. The expectation of this error term is

$$\begin{aligned}
E[\ln\eta_n^*(j)|y_{nI}(j)=1] &= E[\ln\eta_n^*(j)|\ln s_H(j)+\upsilon_n(j)>M_{nI}] \\
&= \frac{\sigma_{\eta^*}^2+\sigma_{\varepsilon\eta^*}}{\sigma_\upsilon^2}E[\upsilon_n(j)|\ln s_H(j)+\upsilon_n(j)>M_{nI}] \\
&= \frac{\sigma_{\eta^*}^2+\sigma_{\varepsilon\eta^*}}{\sigma_\upsilon^2}\sigma_\upsilon\lambda\left[\frac{\ln s_H(j)-M_{nI}}{\sigma_\upsilon}\right]
\end{aligned}$$

where $\lambda(.)$ is the inverse Mills ratio. The variance of the truncated error $\widetilde{\sigma}_{\eta^*I}^2$ along with further derivations are shown in the appendix.

Following similar steps we can derive an expression for export sales as a function of home sales and find the conditional expectation. Knowing that export sales of firm j in market n are

$$s_{nE}(j) = \mu\eta_n(j)Y_n\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} w_H^{1-\sigma}d_n^{\rho_1(1-\sigma)}z(j)^{\sigma-1}P_n^{\sigma-1},$$

and using (12) we have,

$$\ln s_{nE}(j) = \kappa_n + \ln s_H(j) + \ln\eta_n^*(j).$$

Export sales are equal to potential export sales κ_n adjusted for home sales and sales shocks. Expected sales, conditional on home sales and entry $\nu_{nE}(j) \equiv E[\ln s_{nE}(j)|s_H(j), y_{nE}(j)=1]$ are similar to the above equation, but with $\ln\eta_n^*(j)$ replaced by $E[\ln\eta_n^*(j)|y_{nE}(j)=1]$.

The mean of the truncated error term is

$$
\begin{aligned}
E\left[\ln \eta_n^*(j) | y_{nE}(j)=1\right] &= E\left[\ln \eta_n^*(j) | M_{nE} < \upsilon_n(j) + \ln s_H(j) < M_{nI}\right] \\
&= \frac{\sigma_{\eta^*}^2 + \sigma_{\varepsilon\eta^*}}{\sigma_\upsilon^2}\sigma_\upsilon \frac{\phi\left[\frac{M_{nE}-\ln s_H(j)}{\sigma_\upsilon}\right] - \phi\left[\frac{M_{nI}-\ln s_H(j)}{\sigma_\upsilon}\right]}{\Phi\left[\frac{M_{nI}-\ln s_H(j)}{\sigma_\upsilon}\right] - \Phi\left[\frac{M_{nE}-\ln s_H(j)}{\sigma_\upsilon}\right]}
\end{aligned}
$$

where $\phi(.)$ is the standard normal density. The variance of the truncated error $\widetilde{\sigma}_{\eta^* E}^2$ along with derivations are shown in the appendix.

4.1.2 The Likelihood Function

We estimate the closed-form likelihood function with respect to the parameter vector $\vartheta = \left\{\kappa_n, M_{nE}, M_{nI}, \alpha\rho_1(\sigma-1), \alpha\rho_2(\sigma-1), \sigma_{\eta^*}^2, \sigma_\upsilon^2, \sigma_{\varepsilon\eta^*}\right\}$. The likelihood function can be decomposed into two parts: one representing entry and the other representing sales conditional on entry. The entry component can be written as

$$
\begin{aligned}
l_{entry}(\vartheta_1) = \sum_{n=1}^{N}\sum_{j=1}^{J} &\left[1 - y_{nE}(j)\right]\left[1 - y_{nI}(j)\right] \ln \Phi\left[\frac{M_{nE} - \ln s_H(j)}{\sigma_\upsilon}\right] \\
+ y_{nE}(j)\left[1 - y_{nI}(j)\right] \ln &\left\{\Phi\left[\frac{M_{nI} - \ln s_H(j)}{\sigma_\upsilon}\right] - \Phi\left[\frac{M_{nE} - \ln s_H(j)}{\sigma_\upsilon}\right]\right\} \\
&+ y_{nI}(j)\left\{\ln\left[1 - \Phi\left(\frac{M_{nI} - \ln s_H(j)}{\sigma_\upsilon}\right)\right]\right\}
\end{aligned}
$$

where $\vartheta_1 = \{M_{nE}, M_{nI}, \sigma_\upsilon^2\}$. The first term represents the likelihood of observing firms neither exporting nor conducting FDI, the second term the likelihood of observing exporters and the last term the likelihood of observing firms conducting FDI. We maximize the likelihood subject to $M_{nI} > M_{nE}$ (N constraints).

The sales component of the likelihood function is

$$
\begin{aligned}
l_{sales}(\vartheta_2) = \sum_{n=1}^{N}\sum_{j\in J_e} & y_{nE}(j)\left(1 - y_{nI}(j)\right) \ln \phi\left[\left(s_{nE}(j) - \nu_{nE}(j)\right)/\widetilde{\sigma}_{\eta^* E}\right] \\
&+ y_{nI}(j) \ln \phi\left[\left(s_{nI}(j) - \nu_{nI}(j)\right)/\widetilde{\sigma}_{\eta^* I}\right]
\end{aligned}
$$

where $\vartheta_2 = \{\kappa_n, \alpha\rho_1(\sigma-1), \alpha\rho_2(\sigma-1), \sigma_{\eta^*}^2, \sigma_{\varepsilon\eta^*}\}$ and J_e is the set of firms that either export or choose to conduct FDI. The first term represents the likelihood of sales for exporters and the second the likelihood of sales for affiliates.

The export flows of a firm conducting FDI to the same destination do not enter the likelihood. In other words, $(y_{nE}(j), y_{nI}(j)) = (1,1)$ is interpreted as $(0,1)$.[43] There are two reasons for this. First, our theory is incompatible with firms selling final goods both through exports and FDI. Second, our data do not identify to what extent these export flows are intra-firm or final goods exports (which would enter the likelihood differently).

4.1.3 Identification

To facilitate the exposition of our identification strategy we summarize the equations for entry and sales,

$$\begin{aligned}
y_{nI}(j) &= 1\left[\ln s_H(j) + \upsilon_n(j) > M_{nI}\right], &(13)\\
y_{nE}(j) &= 1\left[M_{nE} < \ln s_H(j) + \upsilon_n(j) < M_{nI}\right], &(14)\\
\ln s_{nI}(j) &= \kappa_n + \alpha\rho_1(\sigma-1)\ln d_n + \alpha\rho_2(\sigma-1)\ln\omega_n + \ln s_H(j) + \ln\eta_n^*(j), &(15)\\
\ln s_{nE}(j) &= \kappa_n + \ln s_H(j) + \ln\eta_n^*(j), &(16)
\end{aligned}$$

where 1[.] is an indicator function.

The κ_n term is identified as a fixed effect in the sales equation (16). The entry hurdles M_{nI} and M_{nE} are identified directly as fixed effects in the ordered probit equations (13) and (14). The structural interpretation of the fixed effects are

$$\begin{aligned}
\kappa_n &= \ln(Y_n/Y_H) + (\sigma-1)\ln(P_n/P_H) - \rho_1(\sigma-1)\ln d_n, &(17)\\
M_{nE} &= \ln\sigma - \kappa_n + \ln f_{nE}, &(18)\\
M_{nI} &= \ln\sigma - \kappa_n + \ln\Omega_n. &(19)
\end{aligned}$$

Given an estimate of κ_n, it is clear that the clusters of parameters $\alpha\rho_1(\sigma-1)$ and $\alpha\rho_2(\sigma-1)$ are identified from (15).

In the next subsection we discuss our procedure to estimate α. However, equations (13) to (16) already show that identification of the degree of intrafirm trade

[43] Below, we evaluate the implications of this procedure. If a firm owns more than one affiliate in the same destination (a rare event in the data) we add up sales across all affiliated plants.

occurs mainly through comparisons of sales patterns. Variations in sales across destinations of affiliates that belong to the same firm and differences between export sales and affiliate sales of different firms in the same destination also contribute to the identification of α.

As is usual in classical regression models, the variance of the sales shocks $\sigma^2_{\eta^*}$ is identified. In standard (ordered) probit models the variance of the composite shock σ^2_{υ} is not usually identified. In this paper, however, σ^2_{υ} is identified by imposing the theoretical structure of the model. Specifically, the restriction that there is no coefficient in front of $\ln s_H$ in (13) and (14) facilitates the identification of σ^2_{υ}. Given estimates of σ^2_{υ}, $\sigma^2_{\eta^*}$ and $\sigma_{\varepsilon\eta^*}$, $\sigma^2_{\varepsilon} = \sigma^2_{\upsilon} - \sigma^2_{\eta^*} - 2\sigma_{\varepsilon\eta^*}$ is also identified.

It is important to note that the equations for entry and sales are not mutually dependent.[44] Hence, we can estimate the model using a two-step procedure, where the first step estimates the entry equations (13) and (14), while the second step estimates the sales equations (15) and (16). The econometric setup incorporates therefore an ordered probit for the entry decision, while the sales decision resembles a Heckman (1979) selection model. This approach takes into account that entrants in general have unobserved positive shocks that also influence the amount of sales.

Our structural estimation is related to the work of Helpman, Melitz and Rubinstein (2008). They consider a model similar to ours that is able to explain bilateral flows at the aggregate level. They control for endogeneity in the extensive margin and for the selection of country-pairs trading partners. In contrast, we do not need to control for the selection at the aggregate level since we use information at the firm level. However, we correct for the selection due to the incidental truncation implied by our model when we estimate the sales equations. The shocks in Helpman, Melitz and Rubinstein (2008) are aggregate whereas our shocks are firm-specific.

Another related paper is that of Eaton, Kortum and Kramarz (2008), who struc-

[44] The entry equations do not depend on the sales equations. Given the estimates from the ordered probit, we have sufficient information to calculate the expected sales shocks (the Mills ratios) in the sales equations.

turally estimate a general equilibrium model with exports. Their model is similar to ours, but it considers only export decisions. It is more general in the sense that they estimate the full general equilibrium through simulated method of moments. In contrast, we condition our estimation on home sales, without considering the change in the mass of firms operating in the domestic market. Our structural shocks are similar to those considered by Eaton, Kortum and Kramarz (2008). However, our maximum likelihood estimation strategy uses all of the information at the firm level, whereas Eaton, Kortum and Kramarz (2008) use aggregate moments to identify their parameters.

4.2 Second Stage

In the second stage we simultaneously calculate the intra-firm parameter α and the price index in every country. The general equilibrium effects in the model can be large, so an estimate of the price index will be important for policy experiments. However, the price index is a complex function of all multilateral variables and fixed costs, as well as σ and α, which are unknowns. Therefore, i) we need to make further assumptions about the matrix of fixed costs, ii) we need a specific functional form for the productivity distribution and iii) we need to use the structure of the model. In this stage of the estimation, besides first-stage estimates, we use OECD data on absorption to compute Y_n for each country n and we set μ, the expenditure share on the monopolistic good, equal to 0.52, which is the consumption share of goods relative to total consumption in Norway in 2004.[45]

Fixed costs of exporting and FDI from Norway to other destinations are identified from (18) and (19), given a choice of σ. It remains to populate the full matrix of fixed costs, i.e. f_{inI} and f_{inE} when $i \neq NO$. Here we assume (a) symmetry, so that $f_{iNOv} = f_{NOiv}$ for all $i \neq NO$ and $v = \{E, I\}$ and (b) $f_{inv} = f_{NOnv}$ for all $i \neq n$, $n \neq NO,\ v = \{E, I\}$. The second assumption means that fixed costs to country n are

[45] Computed from Table 23 "Household final consumption expenditure by function. Current prices. Million kroner" of the "Annual National Accounts 1970-2007" published by Statistics Norway.

equal to the fixed costs from Norway to country n, for all possible source countries. We also need an estimate of fixed costs at home, $f_{iiE.}$ Here we simply posit that home fixed costs are half of the lowest exporting fixed costs, $f_{ii} = \min(f_{NOn})/2$ for all i.

4.2.1 Finding γ

According to our model, the sales distribution captures the joint effect of the dispersion of productivity, the sales shocks and the elasticity of substitution, which tends to magnify productivity differences across firms. Since the first stage is entirely conditional on firm-level home sales, the dispersion of productivity is not identified in the first stage. Here we use the simulated method of moments in order to quantify γ. Specifically we estimate the vector of parameters $\left\{a, \gamma, \sigma^2_{\eta_H}\right\}$, where a is a constant term that represents the sum of country-wide variables affecting home sales (home wage, price index and country income), $\sigma^2_{\eta_H}$ is the variance of the home sales shock,[46] and γ is the Pareto shape parameter. The estimating procedure is as follows: i) we guess an initial value for the vector of parameters to be estimated; ii) we draw productivities and shocks $z(j)$, $\varepsilon_n(j)$, $\eta_n(j)$, given our guess from i) and using our 1^{st} stage estimates of $\sigma^2_{\eta^*}$, σ^2_{ε} and $\sigma_{\eta^*\varepsilon}$;[47] the simulated number of firms is $50,000$. iii) We calculate entry and sales patterns for the home country. Latent home sales are $\ln s_H(j) = a + \ln \eta_H(j) + (\sigma - 1)\ln z(j)$. Our econometric model does not directly identify the domestic entry hurdle M_H. However, given our assumption about f_{ii} above, the home hurdle is simply $M_H = \ln(\sigma f_H)$. iv) Given the value of $\ln s_H(j)$, we determine entry and sales for all destinations, given the first stage estimates of κ_n, M_{nE} and M_{nI}. v) We construct the simulated moments $E[\ln s_{nE}|entry]$ and

[46] Recall that $\sigma^2_{\eta_H} = \sigma^2_{\eta^*} - \sigma^2_{\eta_n}$.We allow $var(\eta_H) \neq var(\eta_n)$, $n \neq H$. This is compatible with cases where demand uncertainty is higher in foreign relative to local markets.

[47] Note that $cov(\eta^*_n, \varepsilon_n) = cov(\eta_n, \varepsilon_n) - cov(\eta_H, \varepsilon_n) = cov(\eta_n, \varepsilon_n)$ for $n \neq H$, given that there is no correlation between destinations. $cov(\eta_H, \varepsilon_H)$ is not identified from the 1. stage, so here we assume that the correlation between shocks are identical at home and abroad. Formally, $\rho = cov(\eta_n, \varepsilon_n)/(\sigma_\eta \sigma_\varepsilon)$, $n \neq H$, so $cov(\eta_H, \varepsilon_H) = \rho \sigma_{\eta_H} \sigma_\varepsilon$. Draws from the multivariate normal are performed using Cholesky decomposition.

$var\left[\ln s_{nE}|entry\right]$ for each $n = 1, ..N + 1$, where $N + 1$ is the number of destinations including the home country. Dispersion in home sales will provide information about the variance of home sales shocks (and hence foreign sales shocks because $\sigma^2_{\eta^*}$ is known from the first stage), while export sales dispersion[48] will provide information about the variance of productivity, given $\sigma^2_{\eta_n}$. The mean of sales enables us to identify a as well as modeling the extent of selection into each market. vi) Finally, we minimize the objective function[49]

$$O\left(a, \gamma, \sigma^2_{\eta_H}\right) = \left(\mathbf{M} - \widetilde{\mathbf{M}}\right)' \left(\mathbf{M} - \widetilde{\mathbf{M}}\right)$$

where M is a $2\left(N+1\right)$ vector of empirical moments while $\widetilde{M}$ is the simulated counterpart. $\gamma/\left(\sigma - 1\right)$ is estimated between 0.96 and 1.02, depending on the chosen value of $\sigma \in [2, 15]$.[50] In the following numerical experiments, we choose a value in between, $\gamma/\left(\sigma - 1\right) = 1.01$, which will also ensure that closed form solutions exist (for $\gamma/\left(\sigma - 1\right) < 1$ the price index is undefined).

4.2.2 Finding α

We are particularly interested in the volume of intra-firm trade that is consistent with the observed geography of multinational production. The share produced by the affiliate α is not directly identified by the ML routine. Here we propose a method that will tease out the value of α. The general idea is to find the elasticity of export sales with respect to distance $\rho_1\left(\sigma - 1\right)$ based on the definition of the fixed effect (17). Given this information, α is simply $\widehat{\alpha\rho_1\left(\sigma - 1\right)}/\rho_1\left(\sigma - 1\right)$. Solving (17) with respect to $\left[\rho_1\left(\sigma - 1\right)\right]^{-1}$ and multiplying with $\alpha\rho_1\left(\sigma - 1\right)$ yields

$$\alpha_n = f\left(P_n; \sigma, \vartheta\right) = \alpha\rho_1\left(\sigma - 1\right)\ln d_n\left[\ln\left(Y_n/Y_H\right) + \left(\sigma - 1\right)\ln\left(P_n/P_H\right) - \kappa_n\right]^{-1}$$

[48] Moments for affiliate sales are not included because of the low number of MP entrants in some destinations, contributing to increased volatility in the empirical moments.

[49] Minimization is performed under the restriction that $0 < \sigma^2_{\eta_H} < \sigma^2_{\upsilon} - \sigma^2_{\varepsilon} - 2cov\left(\eta^*_n, \varepsilon_n\right)$ since, by definition, $\sigma^2_{\upsilon} = \sigma^2_{\eta^*} + \sigma^2_{\varepsilon} + 2cov\left(\eta^*_n, \varepsilon_n\right)$.

[50] The estimates of γ are significant, with a standard error of 0.6, averaged across the choice of σ.

The price index, however, is a function of α, $P_n = g(\alpha; \sigma, \vartheta)$, so we cannot find an analytical solution for α. We can, however, solve for α with numerical methods. Specifically, we iterate over $\alpha_n^{i+1} = f\left[g\left(\overline{\alpha}^i; \sigma\right)\right]$ for i iterations until convergence is reached.[51] We must also deal with the fact that α_n^{i+1} is an $(Nx1)$ vector whereas our model only allows for a scalar α in the construction of the price index. Here, we simply take the mean of the α_n's for each iteration (indicated by $\overline{\alpha}^i$ above). Given the estimate of α, the price index P_n can be recovered using equation (7). The above solution method is conditional on a guess of σ. However, under the special case of identical price indices, $P_i = P_n$, σ will cancel out of the equation and α can be solved analytically, and simplifies to $\alpha_n = \alpha\rho_1(\sigma-1)\ln d_n\left[\ln(Y_n/Y_H) - \kappa_n\right]^{-1}$.

5 Results

In this section, we present the results of the two-stage estimation. We first show that the estimates are in line with the theory outlined in Section 3. Then, we show how the model is able to predict export and FDI entry and sales patterns. Finally, we test the relative importance of the information we did not use in the estimation by evaluating how the model is able to predict out-of-sample intra-firm trade.

5.1 Parameters Estimates

5.1.1 First Stage

Our sample comprises 7,949 firms and 28 destinations. The number of active firm-destination pairs is 14,246, 2.3 per cent of which are affiliate sales, 97.7 per cent of which are exports. The first stage delivers estimates of $\alpha\rho_1(\sigma-1)$, $\alpha\rho_2(\sigma-1)$, the variance of the shocks to sales $\sigma^2_{\eta^*}$, the ratio of shocks σ^2_{υ}, the covariance $\sigma_{\varepsilon\eta^*}$, the sales potential κ_n and the entry hurdles M_{nE} and M_{nI} by destination. Table 1 shows that the parameter $\alpha\rho_1(\sigma-1)$ is positive and significant. Furthermore, the

[51] We find the fixed point α where $f(\alpha) = \alpha$. Tests show that the same fixed point is reached regardless of the initial value α^0.

coefficient of distance $\alpha\rho_2(\sigma-1)$ is negative but not significant.

Entry and sales shocks. The variance of the shocks to sales $\sigma^2_{\eta^*}$, the ratio of shocks σ^2_{υ} and the covariance $\sigma_{\eta\upsilon}$ are all significant. The standard deviation for the sales shock is 3.01 which represents approximately 33 percent of the mean of log of home sales. Similarly, with the value for σ_υ and $\sigma_{\eta\upsilon}$ we can compute a value for $\sigma_\varepsilon = 2.37$, which is about 26 percent of the mean of log of home sales. The correlation between the shocks is -0.40.

Entry hurdles. Figure 5 (as well as Table 3) shows the estimated cutoffs M_{nE} and M_{nI} (normalized by absorption). The graph indicates that firms in the data must in general be larger and more efficient at home in order to expand into more remote markets. Note that this result is entirely data-driven, because the reduced form equations put no particular structure on the fixed effects M_{nE} and M_{nI}. This result is consistent with the patterns described in Eaton, Kortum and Kramarz (2008) for French exporters.

Furthermore, the threshold for conducting FDI is much higher than for exports, indicating that FDI firms are substantially more productive than exporters and non-exporters. The FDI threshold is 140 times higher than the export cutoff, in terms of domestic sales (the median across destinations, not logs)[52]. The entry hurdles M_{nv}, however, confound the variable and fixed costs of trade.

Export and FDI fixed costs. To clarify the importance of fixed cost we use equations (18) and (19) to recover f_{nI} and f_{nE}, measured relative to the fixed cost of exporting to Sweden.[53] Figure 6 (and Table 3) shows a number of interesting patterns. First, fixed costs of exporting are increasing in distance, while MP costs are

[52] Tomiura (2007) shows that firm productivity varies with the choice of globalization modes and concludes that FDI firms are distinctly more productive than foreign outsourcers and exporters, which in turn are more productive than domestic firms.

[53] Note that this measure is independent of the elasticity of substitution σ. If, instead, we set a value for σ we obtain an estimate of the absolute level of the fixed costs. For example, if $\sigma = 8$ then the fixed cost of exporting to Sweden is \$2136. To find f_{inI} recall that $f_{inI} = \Omega_n\left(d_n^{\psi_1} - 1\right) + f_{inE}$. Here and below, ψ_2 (and hence ρ_2), the coefficient for relative wages w_{in}, is dropped because it is not significantly different from zero.

fairly constant across destinations.[54] This suggests that fixed costs of FDI are indeed not related to distance. Hence, other explanations for gravity for MP are needed. Second, median FDI fixed costs are about 700 times higher than export costs to Sweden. Third, by comparing Figure 6 with Figure 5 we can now better understand why is it difficult to enter a foreign market. From Figure 6 we observe, for example, that even though Mexico has the highest M_E, fixed costs there are fairly average. This suggests that entry is difficult in Mexico because it is a remote and small market (as proxied by export sales potential κ_n), not because fixed costs are particularly high. Conversely, Sweden has the lowest M_E, which we find is due to both low fixed costs as well as a high export sales potential κ_n (because of the proximity to the market). However, the fixed costs of MP to Sweden are not particularly low.[55]

Are fixed costs increasing with trade barriers? We also conduct a formal test of the null hypothesis that fixed costs are increasing with trade barriers. Specifically, we estimate a restricted model where $f_{inI} = Ad_{in}^{\rho_{3I}}$ and $f_{inE} = d_{in}^{\rho_{3E}}$ and perform a likelihood ratio test between the restricted and unrestricted models. Since fixed costs only affect the extensive margin of trade, the equations for the intensive margin (firm-level sales) remain unchanged. On the extensive margin, M_{nE} and M_{nI} become

$$\begin{aligned} M_{nE} &= \ln\sigma - \kappa_n + \rho_{3E}\ln d_n \\ M_{nI} &= \ln\sigma - \kappa_n + \ln\left(Ad_n^{\rho_{3I}} - d_n^{\rho_{3E}}\right) - \ln\left(d_n^{\rho_1\alpha(\sigma-1)} - 1\right) \end{aligned}$$

Hence, we have $2N$ restrictions on the entry hurdles M_{nE} and M_{nI}. Clearly, they cannot be estimated as fixed effects anymore. Also, since the hurdles are functions of

[54] The correlations between variable costs, as proxied by the log of distance, and the export and MP fixed cost index are 0.61 and -0.08 respectively. The correlations between destination absorption and fixed costs are 0.20 and 0.03, for exports and MP.

[55] Das, Roberts and Tybout (2007) is the only other paper (to the best of our knowledge) that estimates sunk costs of entry into foreign markets. They propose a dynamic structural model of export supply to study the decision to enter export markets and the decision of how much to sell there. They focus only on exports and not on FDI and estimate sunk cost of entry for three sectors of the Colombian economy (leather products, knitted fabrics, and basic chemicals). Their finding is that sunk costs of export for Colombian firms are substantial.

κ_n, which are identified in the sales stage of the maximum likelihood, the entry and sales stage system of equations must be estimated simultaneously.

The resulting restricted log likelihood is $75,345$.[56] The likelihood ratio test statistic is $LR = -2\left[l_{restricted}(\widetilde{\vartheta}) - l_{entry}(\vartheta_1^*) - l_{sales}(\vartheta_2^*)\right] = 279.8$, which is asymptotically chi-square distributed with $2N$ degrees of freedom under the null hypothesis (the restricted model). The null is rejected at any conventional significance levels.

Potential export and FDI sales. Figure 7 (and Table 3) shows the estimates of export sales potential κ_n and MP sales potential $\kappa_n + \alpha\rho_1 (\sigma - 1) \ln d_n$, normalized by destination absorption. As explained, these are measures of expected firm export/MP sales, for a given efficiency level (we simply set home sales to zero for convenience). The left graph shows a clear downward sloping relationship for exports. Interestingly, the graph for FDI (right) is very similar, implying that the estimated parameter $\alpha\rho_1 (\sigma - 1)$ is not large enough to counteract the gravity relationship. This indicates that intra-firm trade is very high and that trade costs are incurred on a large share of affiliate output, or in other words, that the unit cost of MP is increasing in trade barriers.

5.1.2 Second Stage

The second stage delivers an estimate of α, given a guess of σ. In Table 1 we show that the average α over $\sigma \in [2, 15]$ is 0.11. The value of α was more or less unchanged for any choice of σ, as well as under the special case where $P_i = P_j$. Taken at face value, it means that an affiliate adds only 11 per cent of value to the goods it sells. The result is robust to geographical differences in fixed costs. For example, if fixed costs of FDI were increasing in distance but α were equal to one, FDI entry would decrease in distance, while firm level affiliate sales would not vary across destinations (for a given firm and conditional on destination size).[57] Given our use of firm-level

[56] The estimates for the slope coefficients are $\rho_{3E} = -0.07$ (0.05) $\rho_{3I} = 0.43$ (0.03) (standard errors in parentheses).

[57] We provide some additional intuition about this scenario below, where we ask how the geography of multinational production would look if entry patterns were unchanged but $\alpha = 1$.

data, this pattern would be identified by our estimation routine. As a result, the interpretation for the low α is that variable trade costs are highly present between parent and affiliate. In fact, variable costs are so high that the model has problems distinguishing between the geography of exports and affiliate sales. Obviously, we do not believe that intra-firm trade is the sole explanation for the low α. Hence, our estimate can be interpreted as a lower bound on the true α. To offer other explanations is outside the scope of this paper, but our exercise shows that assumptions about fixed costs, for example increasing fixed costs in distance, is insufficient for explaining the data points in this study.

We saw above that gravity for MP emerged if $(\omega_{in}\tau_{in})^{\alpha(\sigma-1)}(1-\alpha) > 1$. The estimate of α together with the results from the MLE indicate that gravity for MP is present for all countries in our sample.

5.1.3 How Important is the Selection Bias?

We evaluate the importance of the selection bias through the following procedure. First we choose a set of structural parameters ϑ. Then, we generate a set of errors $\ln \varepsilon_n(j)$ and $\ln \eta_n^*(j)$ for all firm-destination pairs in our dataset and create entry and sales patterns based on i) ϑ, ii) the random draws and iii) the data for domestic sales s_H as well as absorption Y_n and distance d_n. Finally, we estimate the model based on the artificial dataset and compare the estimated parameters with and without the selection equation.

Table 2 shows an example of our guess of ϑ along with the recovered parameters $\widehat{\vartheta}$. The recovered parameters are estimated under (a) our main model and (b) a model that does not control for unobserved selection. The coefficients under (a) are in general very close to the true values, showing that identification is successful and that the parameter values are recovered with high accuracy. Under model (b) however, the sales potentials κ_n's, $\alpha\rho_1(\sigma-1)$ and the extent of intra-firm trade α are severely biased[58]. The κ_n's are too high, meaning that we would overpredict trade flows and

[58] Note that selection bias will occur as long as shocks in the entry and sales equations (υ and η^*)

erroneously conclude that trade barriers are low. The bias of $\alpha\rho_1(\sigma-1)$ shows that intra-firm trade would be underestimated (the share of local inputs in affiliate total costs would be overestimated).

5.2 Model Evaluation

We compute traditional ML measures to evaluate goodness of fit. We calculate the likelihood ratio index $1 - l_{entry}(\vartheta_1^*)/l_{entry}(\widetilde{\vartheta}_1)$, where $l_{entry}(\vartheta_1^*)$ is the log likelihood at the estimated parameters and $l_{entry}(\widetilde{\vartheta}_1)$ is its value if domestic sales $s_H(j)$ had no explanatory power. We perform the same calculation for $l_{sales}()$. The likelihood ratio index turns out to be 0.77 and 0.41 in the entry and sales models, respectively, indicating that home sales are in fact affecting both intensive and extensive margins. We also calculate $1 - l_{entry}(\vartheta_1^*)/l_{entry}(0)$, where $l_{entry}(0)$ means that all parameters, including the fixed effects, are set to zero as well. Then the index becomes 0.93 and 0.84. All in all, these tests show that our econometric model is able to capture a substantial share of the variation in the data.

We also evaluate how well the model can predict important moments in the data. We compare predicted with actual entry and sales patterns for both exports and FDI. We use equations (13) and (14) to compute the number of firms that, according to our model, belong to nonexporters, exporters or multinationals categories, by destination. Entry is determined based on the actual value of home sales $s_H(j)$ and R random draws of the shocks $\varepsilon_n(j)$ and $\eta_n^*(j)$ per firm and destination. Then, conditional on entry, we compute firm-level sales in each market using equations (15) and (16).

Predicting entry and sales. Figure 8 plots the actual number of firms entering in different markets versus the values predicted by the model. The model captures very well entry for both exports and FDI. Likewise, Figure 9 depicts simulated and actual total sales for exporters and FDI firms across markets. The fit is somewhat less tight compared to entry graph. In particuar, total MP is overpredicted for many destinations. Overall, the model picks up quite well the decline of total affiliate sales

are correlated. Our structural model implies that $cov(\upsilon_n, \eta_n^*) = cov(\eta_n^* + \varepsilon_n, \eta_n^*) = \sigma_{\eta^*}^2 + \sigma_{\varepsilon\eta^*}$.

with distance that we showed in Section 2 and the positive relationship between aggregate affiliate sales and the size of the destination country.

Out-of-sample prediction of intra-firm trade. Recall that in our estimation we disregard export data of companies that undertake both export and FDI to the same destination. If the exports of an FDI firm are truly intra-firm trade, we discard important information in the ML estimation. However, we believe that there are large measurement errors associated with intra-firm trade, due to i) uncertainty related to transfer pricing[59] and ii) the fact that service exports are omitted in our export data. In many cases the export flows are probably not intra-firm trade, but different products.[60] Our model is silent on the possibility that a firm exports and establishes a plant in the same country. To test how important this potential omission is, we compare predicted intra-firm sales with reported export sales for those firms that both export and undertake FDI in the same country. First, we select the subset of firms that exports and conducts FDI to the same destination. Then we simulate export and FDI entry for the selected firms and count as a success the event that a firm enters to the destination that is actually reported in the data. Then we compute affiliate sales and intra-firm sales for these firms using equation (6).

Figure 10 shows actual exports versus predicted intra-firm sales. For most observations the model predicts intra-firm sales that are greater than actual exports, suggesting the presence of "invisible" intra-firm exports, such as services, which are not included in the manufacturing trade data. For a smaller number of firms the model predicts intra-firm sales that are lower than reported exports (below ther 45 degree line). This suggests that a minority of firms service a market through both exports and FDI, requiring a more complex model.

[59] See Bernard, Jensen and Schott (2006).

[60] See recent evidence on multiproduct firms such as Bernard, Jensen, Redding and Schott (2007).

6 Implications of the Model

We have shown that our estimated model is consistent with entry patterns and captures fairly well the relationships between export and affiliate sales, distance and destination market size. In this section we perform some counterfactual analysis. First we study how the geography of multinational production would look if parent firms were not transferring any input to foreign affiliates. Then we study how welfare, export flows and domestic labor demand respond to the introduction of severe restrictions on FDI activity, modeled as a complete shutdown of FDI.

6.1 The Importance of Intra-firm Trade

In our first counterfactual we study the behaviour of the firms' exports and MP if intra-firm trade is zero ($\alpha = 1$). Our model is then identical to Helpman, Melitz and Yeaple (2004). Specifically, we want to examine how aggregate MP responds to trade barriers when we simulate MP (under $\alpha = 1$) *conditional on* actual entry. Firm-level latent affiliate sales then become, using equation (15)

$$\ln s_{nI}(j) = \kappa_n + \left(\alpha \widehat{\rho_1 (\sigma - 1)} / \widehat{\alpha}\right) \ln d_n + \ln s_H(j) + \ln \eta_n^*(j)$$

where $\widehat{\alpha}$ is the estimate of α found in the previous section. Firm-level sales are now invariant with distance because $\rho_1 (\sigma - 1) \ln d_n$ embedded in κ_n cancels out. In other words, we take the observed entry patterns for MP and check what our model would predict for total affiliate sales if variable trade costs did not affect firms' affiliate sales. Figure 11 shows actual and predicted affiliate sales given $\alpha = 1$. Predicted affiliate sales are much higher than actual ones and they are not negatively related with distance. This clearly shows that even if there is gravity on the extensive margin (entry), this is *insufficient* to generate gravity for total affiliate sales. Hence, we need variable trade costs in FDI in order to explain this feature of the data.

6.2 Prohibitive Barriers to FDI

Next, we use our model to explore the implications of severe restrictions on FDI activity, modeled as a complete shutdown of FDI. We explore the effects on welfare, trade and labor demand.

Welfare. The change in the price index P_n, and therefore the change in welfare, can be found by imposing an FDI entry hurdle so high that no firm will enter, $M_{nI} \rightarrow \infty$ for all n. Results are presented in Table 4. The decline in welfare, averaged across destination markets, is between 2.5 and 0.3 per cent, and the effect is stronger for low values of $\sigma \in [2, 15]$. The relatively small adverse impact is clearly related to the large amounts of intrafirm trade associated with FDI: firms switching from FDI to exports will not increase their prices by much because trade costs were already incurred on a large share of their output. There correlation between welfare loss and market size is negative - larger markets are generally less affected by limiting FDI.

Trade. We simulate the model by i) using estimated parameter values and actual data for domestic sales, ii) drawing 100 random shocks per firm per destination, iii) determining export and FDI entry and sales for two cases: the baseline case and the FDI shutdown case. Entry hurdles and firm sales change according to $dM_{nI} = \infty$, $dM_{nE} = -d\kappa_n$ and $d \ln s_{nE}(j) = d\kappa_n + ds_H(j) = dP_n$, where $d\kappa_n = (\sigma - 1) d \ln (P_n/P_H)$. Note that we account for endogenous changes in home sales. Restricting FDI has large effects on trade flows. Letting firms switch from FDI to exports yields a 95 per cent increase in final goods exports, averaged across markets.[61] Although the number of FDI firms is small, they are located in the right tail of the productivity distribution, which translates into large export volumes. Due to higher price indices in every market, incumbent exporters also increase their sales. But this effect is significantly smaller, contributing to approximately 3 percent more exports, averaged across markets.

Labor demand. What is the impact of prohibitive FDI barriers on multinationals'

[61] The increase in total exports, i.e. including the reduction in intrafirm trade, is between 30 and 36 percent, depending on the choice of $\sigma \in [2, 15]$.

domestic labor demand? Prohibitive costs of multinational production force firms to reallocate labor to the home country. On the other hand, costs will increase, depressing sales. A priori, therefore, the effect could go both ways. Knowing that variable domestic exporting and MP costs are $s_{nE}(j)(\sigma-1)/\sigma$ and $s_{nI}(j)(1-\alpha)(\sigma-1)/\sigma$ per firm per destination, we can compare aggregate labor costs for FDI firms forced to relocate at home. The resulting change in domestic labor expenditure is then

$$\frac{\sum_n \sum_j s_{nE}(j)}{(1-\alpha)\sum_n \sum_j s_{nI}(j)}$$

where the summation is performed over the firm-destination pairs that conducted FDI in the baseline case. Our simulation shows that domestic labor expenditure for the firms that switch from FDI to export falls by as much as 54 percent. Why do the switching firms reduce their domestic labor demand? First, domestic labor use will *decrease* because switching to exports entails higher marginal costs and prices, and therefore reduced sales. Second, home labor demand will *increase* because some labor is reallocated from subsidiaries to the headquarter. However, the large amount of intrafirm trade means that the second effect is not strong enough to counteract the first effect. Hence, we conclude that there are indeed negative labor market effects of impeding FDI because the largest firms in the economy significantly scale back their operations.

7 Conclusions

Despite numerous studies on the location of multinational production and its economic significance, there is little evidence on the interaction between exporting and MP at the firm level. We study this issue by structurally estimating a new trade model where heterogenous firms make exports and investment decisions, parents transfer inputs to their affiliates, and entry and sales in a foreign market are dependent on firms' characteristics, as well as on firm- and destination-specific shocks.

We make three main contributions to the literature. First, using a comprehensive dataset for Norwegian manufacturing firms, we describe key regularities about the entry and sales patterns of multinationals across markets. The data show a strong dampening effect of total affiliate sales with distance, overall and at the extensive margin. We uncover MP entry patterns across markets that show a striking similarity to the export facts reported in Eaton, Kortum and Kramarz (2008) and emphasize the importance of size heterogeneity, fixed costs of export and MP, and show a tendency toward a "pecking order" of multinational production.

Second, motivated by these stylized facts, we construct a parsimonious model of exports and multinational production, building on Helpman, Melitz and Yeaple's (2004) model. We modify their framework in two ways: we allow for intra-firm trade between headquarters and affiliates, which changes the HFDI model in a non-trivial and non-linear way, and we introduce firm- and destination-specific shocks to sales and fixed trade cost. Under standard assumptions about the stochastic structure of the model we simultaneously derive a micro-funded gravity equation for export and for FDI. We structurally estimate the model using maximum likelihood and show that without accounting for selection, coefficient estimates would be severely biased. In particular, trade flows would be overpredicted and estimated variable trade barriers would be too low.

Third, strong results emerge from the analysis. Our estimates show that fixed costs of exporting are increasing in distance between the source and the destination country, whereas fixed costs of conducting FDI are fairly constant. This suggests that fixed costs in multinational operations do not play a strong role in the dampening of MP with distance. Intra-firm trade instead appears to play a crucial role in shaping the geography of MP. We reject the standard proximity-concentration model where intra-firm trade is zero. This conclusion is robust to any geographical distribution of fixed costs of MP. However, our structural model seems to put too much weight on intra-firm trade in generating the spatial pattern of FDI. Specifically, the point estimate of the affiliate cost share related to purchases from the headquarters is about 9/10. This leads us to conclude that there must be additional forces contributing to dampening MP on the intensive margin. This is the subject of ongoing research.

Our counterfactual experiments indicate that impeding FDI has strong effects on trade flows but the decline is welfare is not particularly large: shutting down FDI completely leads to welfare losses in the range of 0.3 to 1.5 per cent, depending on the elasticity of substitution. However, we do find that the multinationals affected by these barriers cut their home employment by as much as 50 per cent. Hence, reducing barriers to FDI may have positive effects on the domestic labor market because outward FDI entails a substantial amount of economic activity at home.

References

[1] Alfaro, Laura, and Andrew Charlton. 2007. "Intra-Industry Foreign Direct Investment." Working Paper no. 13447 (September), NBER, Cambridge, MA.

[2] Anderson, James E., and Eric van Wincoop. 2004. "Trade Costs." *Journal of Economic Literature*, 42 (September): 691-751.

[3] Anderson, James E., and Eric van Wincoop. 2003. "Gravity with Gravitas: A Solution to the Border Puzzle" *The American Economic Review*, 93 (March): 170-192.

[4] Antràs, Pol. 2003. "Firms, Contracts, and Trade Structure." *QJE* , 118 (November): 1375-1418.

[5] Antràs, Pol, and Elhanan Helpman. 2004. "Global Sourcing." *Journal of Political Economy*, 112 (June): 552-580.

[6] Axtell, Robert L. 2001. "Zipf Distribution of U.S. Firm Sizes." *Science*, 7 (September): 1818-1820.

[7] Barba Navaretti, Giorgio, and Anthony J. Venables. 2004. "Multinational Firms in the World Economy." Princeton NJ: Princeton University Press.

[8] Bernard, Andrew, J. Bradford Jensen, Stephen J. Redding and Peter K. Schott. 2007. "Firms in International Trade" CEPR Discussion Paper No. DP6277.

[9] Bernard, Andrew, J. Bradford Jensen and Peter K. Schott. 2006. "Transfer Pricing by U.S.-Based Multinational Firms" Working Paper no. 12493 (August), NBER, Cambridge, MA.

[10] Bernard, Andrew, J. Bradford Jensen and Peter K. Schott. 2005. "Importers, Exporters, and Multinationals: A Portrait of Firms in the U.S. that Trade Goods." Working Paper no. 11404 (September), NBER, Cambridge, MA.

[11] Blonigen, Bruce A., Ronald B. Davies, and Keith Head. 2003. "Estimating the Knowledge-Capital Model of the Multinational Enterprise: Comment." *The American Economic Review*, 93 (June): 980-994.

[12] Bombarda, Pamela. 2008. "Trade and FDI: Complementarity and Substitutability (A non-monotonic relationship between distance and FDI.)" Manuscript, Graduate Institute of International and Development Studies.

[13] Brainard, S. Lael. 1997. "An Empirical Assessment of the Proximity-Concentration Trade-off Between Multinational Sales and Trade." *The American Economic Review*, 87 (September): 520-544.

[14] Caves, Richard E. 1996. "Multinational Enterprise and Economic Analysis." Cambridge, UK: Cambridge University Press.

[15] Chaney, Thomas. 2008. "Distorted Gravity: The Intensive and Extensive Margins of International Trade." *The American Economic Review*, 98 (September): 1707–1721.

[16] Chor, Davin, Manova, Kalina and Watt, Stanley B. 2008. "Host Country Financial Development and MNC Activity". Manuscript, Dept. Econ., Stanford University.

[17] Das, Sanghamitra, Mark J. Roberts, and James R. Tybout. 2007. "Market Entry Costs, Producer Heterogeneity, and Export Dynamics." *Econometrica,* 75 (May): 837-873.

[18] Eaton, Jonathan and Samuel Kortum. 2002. "Technology, Geography, and Trade." *Econometrica*, 70 (September): 1741-1779.

[19] Eaton, Jonathan, Samuel Kortum, and Francis Kramarz. 2008. “An Anatomy of International Trade: Evidence from French Firms.” Manuscript, Dept. Econ. New York University.

[20] Feinberg, Susan E. and Michael P. Keane. 2006. "Accounting for the Growth of MNC-Based Trade Using a Structural Model of U.S. MNCs." The American Economic Review, 96 (December): 1515-1558.

[21] Hanson, Gordon H., Raymond J. Mataloni, and Matthew J. Slaughter. 2003. "Vertical Production Networks in Multinational Firms." Working Paper no. 9723 (May), NBER, Cambridge, MA.

[22] Head, Keith, and John Ries. 2008. "FDI as an Outcome of the Market for Corporate Control: Theory and Evidence." *Journal of International Economics*, 74 (January): 2-20.

[23] Heckman, James J. 1979. "Sample Selection Bias as a Specification Error." *Econometrica*, 47 (January): 153-161.

[24] Helpman, Elhanan. 1984. "A Simple Theory of International Trade with Multinational Corporations." *Journal of Political Economy*, 92 (June): 451-471.

[25] Helpman, Elhanan, Marc J. Melitz, and Yona Rubinstein. 2008. “Estimating Trade Flows: Trading Partners and Trading Volumes.” *Q.J.E.*, 123 (May): 441-487.

[26] Helpman, Elhanan, Marc J. Melitz, and Stephen R. Yeaple. 2004. "Export versus FDI with Heterogeneous Firms." *The American Economic Review*, 94 (March): 300-316.

[27] Kleinert Jörn, and Farid Toubal. 2006a. "Distance Costs and Multinationals' Foreign Activities." Center for Economic Institutions, Working Paper no. 2006-6, Hitotsubashi University.

[28] Kleinert Jörn, and Farid Toubal. 2006b. "Dissecting FDI." Center for Economic Institutions, Working Paper no. 2006-7, Hitotsubashi University.

[29] Manova, Kalina B. 2008. "Credit Constraints, Heterogeneous Firms and International Trade." Manuscript, Dept. Econ., Stanford University.

[30] Markusen, James R., and Keith E. Maskus. 2002. "Discriminating Among Alternative Theories of the Multinational Enterprise." *Review of International Economics*, 10 (November): 694-707.

[31] Markusen, James R., and Keith E. Maskus. 1999. "Multinational Firms: Reconciling Theory and Evidence." Working Paper no. 7163 (June), NBER, Cambridge, MA.

[32] Mayer, Thierry, Rodrigo Paillacar and Soledad Zignago. 2008. "TradeProd. The CEPII Trade, Production and Bilateral Protection Database: Explanatory Notes." CEPII.

[33] Melitz, Mark J. 2003. "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity." *Econometrica,* 71 (November): 1695-1725.

[34] "OECD's Economic Outlook : Annual and quarterly data Vol. 2008 Release 01", SourceOECD, Volume 115 (June).

[35] Raknerud, Arvid, Dag Rønningen, and Terje Skjerpen. 2004. "Documentation of the Capital Database." Manuscript, Statistics Norway.

[36] Ramondo, Natalia, and Andres Rodriguez-Clare. 2008. "The Gains from Openness: Trade, Multinational Production and Diffusion." Manuscript. Austin TX: University of Texas-Austin, Dept. Econ.

[37] Tomiura, Eiichi. 2007. "Foreign Outsourcing, Exporting, and FDI: A Productivity Comparison at the Firm Level." *Journal of International Economics*, 72 (May): 113–127.

[38] Yeaple, Stephen R. 2008. "Firm Heterogeneity and the Structure of U.S. Multinational Activity: An Empirical Analysis." Working Paper no. 14072 (June), NBER, Cambridge, MA.

[39] UNCTAD. 2007. "World Investment Report: Transnational Corporations, Extractive Industries and Development." October.

8 Appendix

8.1 The Gravity Condition

We saw that gravity for MP prevails if

$$h(\tau_{in}, \alpha) = (\omega_{in}\tau_{in})^{\alpha(\sigma-1)}(1-\alpha) > 1.$$

The function $h(\tau_{in}, \alpha)$ is always increasing in τ_{in}. We find the τ_{in} where the cutoff is neither increasing nor decreasing,

$$\ln \tau_{in}^* = -\frac{\ln(1-\alpha)}{\alpha(\sigma-1)}$$

Differentiating this expression with respect to α,

$$\frac{d\ln\tau_{in}^*}{d\alpha} = \frac{\frac{\alpha}{1-\alpha} + \ln(1-\alpha)}{\alpha^2(\sigma-1)} \equiv q(\alpha)$$

$q(\alpha) \geq 0$ for $\alpha \in [0,1]$ because i) $q(0) = 0$ and ii) $q'(\alpha)$ is positive. Hence, increasing α (decreasing intra-firm trade) yields a higher cutoff value τ_{in}^*. This means that more impediments to trade are needed to ensure gravity if intra-firm trade goes down, or in other words, that gravity is more likely if intra-firm trade is high.

8.2 General Equilibrium

Derivation of the Price Index. The price index is

$$P_n^{1-\sigma} = E_{\varepsilon_n,\eta_n}\sum_i w_i L_i \left[\int_{\bar{z}_{inE}(\varepsilon_n,\eta_n)}^{\bar{z}_{inI}(\varepsilon_n,\eta_n)} \eta_n p_{inE}(z)^{1-\sigma} dG(z) + \int_{\bar{z}_{inI}(\varepsilon_n,\eta_n)}^{\infty} \eta_n p_{inI}(z)^{1-\sigma} dG(z)\right]$$

where $dG(z) = \gamma z^{-\gamma-1}dz$ along $[1,+\infty)$ with $\gamma > \sigma - 1$. Inserting the equilibrium prices and solving the integrals we get,

$$P_n^{1-\sigma} = \frac{\gamma\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}}{\gamma-(\sigma-1)}\sum_i w_i L_i E_{\varepsilon_n,\eta_n}\left\{\eta_n (w_i\tau_{in})^{1-\sigma}\left[\begin{array}{c}\bar{z}_{inI}(\varepsilon_n,\eta_n)^{\sigma-\gamma-1}\left[(\omega_{in}\tau_{in})^{\alpha(\sigma-1)}-1\right] \\ +\bar{z}_{inE}(\varepsilon_n,\eta_n)^{\sigma-\gamma-1}\end{array}\right]\right\}.$$

Inserting the equilibrium cutoffs (3) and (4), which are functions of P_n, yields

$$\begin{aligned} P_n^{1-\sigma} &= \delta_1^{\sigma-\gamma-1}\frac{\gamma\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}}{\gamma-(\sigma-1)}E\left[(\eta_n\varepsilon_n)^{\gamma/(\sigma-1)-1}\eta_n\right]P_n^{1-\sigma+\gamma}Y_n^{-1+\gamma/(\sigma-1)} \\ &\quad \sum_i w_i L_i (w_i\tau_{in})^{-\gamma}\left[\Omega_{in}^{1-\gamma/(\sigma-1)}\left((\omega_{in}\tau_{in})^{\alpha(\sigma-1)}-1\right)+f_{inE}^{1-\gamma/(\sigma-1)}\right], \end{aligned}$$

which can be solved for P_n,

$$P_n^{-\gamma} = \delta_2^{-\gamma} Y_n^{-1+\gamma/(\sigma-1)} \frac{Y}{1+\pi} \sum_i \frac{Y_i}{Y} \left(w_i \tau_{in}\right)^{-\gamma} \left[\Omega_{in}^{1-\gamma/(\sigma-1)} \left(\left(\omega_{in}\tau_{in}\right)^{\alpha(\sigma-1)} - 1\right) + f_{inE}^{1-\gamma/(\sigma-1)}\right]$$

where $\delta_2^{-\gamma} = \delta_1^{\sigma-\gamma-1} \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} \frac{\gamma}{\gamma-(\sigma-1)} E\left[\left(\eta_n\varepsilon_n\right)^{\gamma/(\sigma-1)-1} \eta_n\right]$ and $Y_i = w_i L_i (1+\pi)$. Hence, using the multilateral resistance variable θ_n defined in the text we obtain

$$P_n = \delta_2 Y_n^{1/\gamma - 1/(\sigma-1)} \theta_n \left(\frac{1+\pi}{Y}\right)^{1/\gamma}$$

which is equivalent to expression (7). ■

Proof of Proposition 1 and 2. Aggregate exports (affiliate sales) from i to n is defined as the sum of exports (affiliate sales) of each individual firm with productivity $\bar{z}_{inE}\left(\varepsilon_n, \eta_n\right) \leq z \leq \bar{z}_{inI}\left(\varepsilon_n, \eta_n\right)$ $\left(z \geq \bar{z}_{inI}\left(\varepsilon_n, \eta_n\right)\right)$,

$$\begin{aligned} S_{inE} &= w_i L_i E_{\varepsilon_n, \eta_n} \int_{\bar{z}_{inE}(\varepsilon_n,\eta_n)}^{\bar{z}_{inI}(\varepsilon_n,\eta_n)} s_{inE}\left(z, \eta_n\right) dG\left(z\right), \\ S_{inI} &= w_i L_i E_{\varepsilon_n, \eta_n} \int_{\bar{z}_{inI}(\varepsilon_n,\eta_n)}^{\infty} s_{inI}\left(z, \eta_n\right) dG\left(z\right). \end{aligned}$$

From Eqs. (8) and (9) we know the reduced form size of firm level exports and affiliate sales. Using the reduced form expression for the price index we can derive the general equilibrium cutoffs,

$$\begin{aligned} \bar{z}_{inE}\left(\varepsilon_n, \eta_n\right) &= \delta_4 \left(1+\pi\right)^{-1/\gamma} \left(\frac{Y}{Y_n}\right)^{1/\gamma} \frac{w_i \tau_{in}}{\theta_n} f_{inE}^{1/(\sigma-1)} \left(\eta_n \varepsilon_n\right)^{-1/(\sigma-1)} \text{ and} \\ \bar{z}_{inI}\left(\varepsilon_n, \eta_n\right) &= \delta_4 \left(1+\pi\right)^{-1/\gamma} \left(\frac{Y}{Y_n}\right)^{1/\gamma} \frac{w_i \tau_{in}}{\theta_n} \Omega_{in}^{1/(\sigma-1)} \left(\eta_n \varepsilon_n\right)^{-1/(\sigma-1)} \end{aligned}$$

where $\delta_4 = \delta_1/\delta_2$. Using our assumption about the distribution $G(z)$ of productivity shocks, we can rewrite aggregate exports as[62]

$$\begin{aligned} S_{inE} &= \frac{\gamma}{\gamma-(\sigma-1)} \delta_3 \delta_4^{\sigma-\gamma-1} \left(1+\pi\right) w_i L_i \frac{Y_n}{Y} \left(\frac{\theta_n}{w_i \tau_{in}}\right)^{\gamma} \\ &\quad \left(f_{inE}^{1-\gamma/(\sigma-1)} - \Omega^{1-\gamma/(\sigma-1)}\right) E\left[\left(\eta_n \varepsilon_n\right)^{\gamma/(\sigma-1)-1} \eta_n\right] \\ &= \mu \frac{Y_i Y_n}{Y} \left(\frac{\theta_n}{w_i \tau_{in}}\right)^{\gamma} \left(f_{inE}^{1-\gamma/(\sigma-1)} - \Omega_{in}^{1-\gamma/(\sigma-1)}\right). \end{aligned}$$

[62] Recall that $\delta_3 = \sigma \left(\delta_2/\delta_1\right)^{\sigma-1}$.

Similarly, total affiliate sales are

$$\begin{aligned} S_{inI} &= \frac{\gamma}{\gamma-(\sigma-1)} w_i L_i \delta_3 (1+\pi)^{(\sigma-1)/\gamma} \left(\frac{Y_n}{Y}\right)^{(\sigma-1)/\gamma} \left(\frac{\theta_n}{(w_i\tau_{in})^{1-\alpha} w_n^{\alpha}}\right)^{\sigma-1} \\ & \quad E_{\varepsilon_n,\eta_n} \left\{\eta_n \bar{z}_{inI}(\varepsilon_n,\eta_n)^{\sigma-\gamma-1}\right\} \\ &= \mu \frac{Y_i Y_n}{Y} \left(\frac{\theta_n}{w_i \tau_{in}}\right)^{\gamma} (\omega_{in}\tau_{in})^{\alpha(\sigma-1)} \Omega_{in}^{1-\gamma/(\sigma-1)}. \end{aligned}$$

The number of exporters (FDI firms) from i to n is defined as the measure of firms with productivity $\bar{z}_{inE}(\varepsilon_n,\eta_n) \leq z \leq \bar{z}_{inI}(\varepsilon_n,\eta_n)$ $(z \geq \bar{z}_{inI}(\varepsilon_n,\eta_n))$,

$$\begin{aligned} n_{inE} &= w_i L_i E_{\varepsilon_n,\eta_n} \int_{\bar{z}_{inE}(\varepsilon_n,\eta_n)}^{\bar{z}_{inI}(\varepsilon_n,\eta_n)} dG(z), \\ n_{inI} &= w_i L_i E_{\varepsilon_n,\eta_n} \int_{\bar{z}_{inI}(\varepsilon_n,\eta_n)}^{\infty} dG(z). \end{aligned}$$

Using the reduced form expressions for the cutoffs and the Pareto distribution for $G(z)$, the number of exporters and the number of FDI firms are

$$\begin{aligned} n_{inE} &= -w_i L_i E_{\varepsilon_n,\eta_n} \left[\bar{z}_{inI}(\varepsilon_n,\eta_n)^{-\gamma} - \bar{z}_{inE}(\varepsilon_n,\eta_n)^{-\gamma}\right] \\ &= \delta_4^{-\gamma} \frac{Y_i Y_n}{Y} \left(\frac{\theta_n}{w_i\tau_{in}}\right)^{\gamma} \left(f_{inE}^{-\gamma/(\sigma-1)} - \Omega_{in}^{-\gamma/(\sigma-1)}\right) E\left[(\eta_n\varepsilon_n)^{\gamma/(\sigma-1)}\right] \end{aligned}$$

and

$$\begin{aligned} n_{inI} &= w_i L_i E_{\varepsilon_n,\eta_n} \bar{z}_{inI}(\varepsilon_n,\eta_n)^{-\gamma} \\ &= \delta_4^{-\gamma} \frac{Y_i Y_n}{Y} \left(\frac{\theta_n}{w_i\tau_{in}}\right)^{\gamma} \Omega_{in}^{-\gamma/(\sigma-1)} E\left[(\eta_n\varepsilon_n)^{\gamma/(\sigma-1)}\right]. \end{aligned}$$

■

Derivation of the Dividend per Share . Dividend per share in the economy is defined as $\pi = \Pi/\sum w_i L_i$. Total profits Π include profits from exporting and from affiliate sales,

$$\Pi = \sum_i \sum_n (\pi_{inE} + \pi_{inI}).$$

Profits for country i firms exporting to n are

$$\begin{aligned} \pi_{inE} &= w_i L_i E_{\eta_n,\varepsilon_n} \int_{\bar{z}_{inE}(\varepsilon_n,\eta_n)}^{\bar{z}_{inI}(\varepsilon_n,\eta_n)} \left[\frac{s_{inE}(z,\eta_n)}{\sigma} - \frac{f_{inE}}{\varepsilon_n}\right] dG(z) \\ &= \frac{S_{inE}}{\sigma} - n_{inE} f_{inE} \frac{E\varepsilon_n^{\gamma/(\sigma-1)-1}}{E\varepsilon_n^{\gamma/(\sigma-1)}} \end{aligned}$$

and, similarly, profits for country i firms conducting FDI in country n are

$$\pi_{inI} = \frac{S_{inI}}{\sigma} - n_{inI} f_{inI} \frac{E\varepsilon_n^{\gamma/(\sigma-1)-1}}{E\varepsilon_n^{\gamma/(\sigma-1)}}.$$

Total profits are then,

$$\Pi = \sum_i \sum_n \left[\frac{S_{inE} + S_{inI}}{\sigma} - \frac{E\varepsilon_n^{\gamma/(\sigma-1)-1}}{E\varepsilon_n^{\gamma/(\sigma-1)}} \left(n_{inE} f_{inE} + n_{ini} f_{inI} \right) \right].$$

Note that the first term $\sum_i (S_{inE} + S_{inI})$ is simply μY_n. The second term, using the expressions found for the number of entrants and summing over i, is

$$\frac{E\varepsilon_n^{\gamma/(\sigma-1)-1}}{E\varepsilon_n^{\gamma/(\sigma-1)}} \sum_i \left(n_{inE} f_{inE} + n_{inI} f_{inI} \right) =$$

$$= \frac{\mu}{\sigma} \frac{\gamma - (\sigma - 1)}{\gamma} Y_n \theta_n^{\gamma} \sum_i \frac{Y_i}{Y} \left(w_i \tau_{in} \right)^{-\gamma} \left[\Omega_{in}^{1-\gamma/(\sigma-1)} \left(\left(\omega_{in} \tau_{in} \right)^{\alpha(\sigma-1)} - 1 \right) + f_{inE}^{1-\gamma/(\sigma-1)} \right]$$

$$= \frac{\mu}{\sigma} \frac{\gamma - (\sigma - 1)}{\gamma} Y_n$$

where we used the definition of θ_n in the second line. So worldwide profits are

$$\Pi = \sum_n \left[\frac{\mu Y_n}{\sigma} - \frac{\mu}{\sigma} \frac{\gamma - (\sigma - 1)}{\gamma} Y_n \right] = \frac{\mu}{\sigma} \frac{\sigma - 1}{\gamma} Y.$$

Hence, dividends per share are

$$\pi = \Pi / \sum w_i L_i = \frac{\mu}{\sigma} \frac{\sigma - 1}{\gamma} (1 + \pi)$$

where we used $Y = \sum w_i L_i (1 + \pi)$. Finally,

$$\pi = \frac{\frac{\mu}{\sigma} \frac{\sigma-1}{\gamma}}{1 + \frac{\mu}{\sigma} \frac{\sigma-1}{\gamma}}.$$

■

8.3 Truncated Normal Distributions

We briefly review results for truncated normals. It can be shown that

$$E \left[v | M_{nE} - s_H < v_n < M_{nI} - s_H \right] = \sigma_v \frac{\phi(\zeta_n^L) - \phi(\zeta_n^U)}{\Phi(\zeta_n^U) - \Phi(\zeta_n^L)}$$

where $\zeta_n^U(j) \equiv [M_{nI} - \ln s_H(j)]/\sigma_\upsilon$ and $\zeta_n^L(j) \equiv [M_{nE} - \ln s_H(j)]/\sigma_\upsilon$. Similarly, it can be shown that

$$var(\upsilon|M_{nE} - s_H < \upsilon < M_{nI} - s_H) = \sigma_\upsilon^2 \left\{ \begin{array}{c} 1 + \frac{\zeta_n^L \phi(\zeta_n^L) - \zeta_n^U \phi(\zeta_n^U)}{\Phi(\zeta_n^U) - \Phi(\zeta_n^L)} \\ - \left[\frac{\phi(\zeta_n^L) - \phi(\zeta_n^U)}{\Phi(\zeta_n^U) - \Phi(\zeta_n^L)}\right]^2 \end{array} \right\}.$$

Note that one-sided truncation is just a special case with $M_{nI} = Inf$,

$$E(\omega|M_{nE} - s_H < \upsilon < Inf) = \sigma_\upsilon \lambda(-\zeta_n^L)$$
$$var(\upsilon|M_{nE} - s_H < \upsilon < Inf) = \sigma_\upsilon^2 \left[1 + \zeta_n^L \lambda(-\zeta_n^L) - \lambda(-\zeta_n^L)^2\right]$$

where $\lambda()$ is the inverse Mills ratio, $\lambda(z) \equiv \phi(z)/\Phi(z)$.

We are interested in $E(\ln \eta_n^*|y_{nE} = 1) = E(\ln \eta_n^*|M_{nE} - s_H < \upsilon_n < M_{nI} - s_H)$. υ_n is the sum of two normal random variables and is therefore also normal. The conditional normal distribution is

$$\ln \eta^*|\upsilon \backsim N(\Sigma_{\eta^*\upsilon}\Sigma_{\upsilon\upsilon}^{-1}\upsilon, \Sigma_{\eta^*\eta^*} - \Sigma_{\eta^*\upsilon}\Sigma_{\upsilon\upsilon}^{-1}\Sigma_{\upsilon\eta^*})$$

where Σ_{in} is an element of the covariance matrix. Hence, $\ln \eta^* = \Sigma_{\eta^*\upsilon}\Sigma_{\upsilon\upsilon}^{-1}\upsilon + \xi$, were $\xi \backsim N(0, \Sigma_{\eta^*\eta^*} - \Sigma_{\eta^*\upsilon}\Sigma_{\upsilon\upsilon}^{-1}\Sigma_{\upsilon\eta^*})$. Then we can write

$$\begin{aligned} & E[\ln \eta^*|M_{nE} - s_H < \upsilon < M_{nI} - s_H] \\ = \; & E\left[\Sigma_{\eta^*\upsilon}\Sigma_{\upsilon\upsilon}^{-1}\upsilon + \xi|M_{nE} - s_H < \upsilon < M_{nI} - s_H\right] \\ = \; & \frac{\sigma_{\eta^*}^2 + \sigma_{\varepsilon\eta^*}}{\sigma_\upsilon^2} E[\upsilon|M_{nE} - s_H < \upsilon < M_{nI} - s_H] \end{aligned}$$

and

$$\begin{aligned} & var[\ln \eta^*|M_{nE} - s_H < \upsilon < M_{nI} - s_H] \\ = \; & \Sigma_{\eta^*\upsilon}^2 \Sigma_{\upsilon\upsilon}^{-2} var[\upsilon|M_{nE} - s_H < \upsilon < M_{nI} - s_H] + \Sigma_{\eta^*\eta^*} - \Sigma_{\eta^*\upsilon}\Sigma_{\upsilon\upsilon}^{-1}\Sigma_{\upsilon\eta^*} \\ = \; & \left(\frac{\sigma_{\eta^*}^2 + \sigma_{\varepsilon\eta^*}}{\sigma_\upsilon^2}\right)^2 var[\upsilon|M_{nE} - s_H < \upsilon < M_{nI} - s_H] + \sigma_{\eta^*}^2 - \frac{\left(\sigma_{\eta^*}^2 + \sigma_{\varepsilon\eta^*}\right)^2}{\sigma_\upsilon^2} \end{aligned}$$

where we have used that $\Sigma_{\upsilon\eta^*} = cov(\upsilon, \ln \eta^*) = cov(\ln \varepsilon + \ln \eta^*, \ln \eta^*) = \sigma_{\eta^*}^2 + \sigma_{\varepsilon\eta^*}$, $\Sigma_{\upsilon\upsilon} = \sigma_\upsilon^2$ and $\Sigma_{\eta^*\eta^*} = \sigma_{\eta^*}^2$. This expression equals $\widetilde{\sigma}_{\eta^*E}^2$ in the main text, while $\widetilde{\sigma}_{\eta^*I}^2$ is similar, but with $var[\upsilon|M_{nE} - s_H < \upsilon < M_{nI} - s_H]$ replaced with $var(\upsilon|M_{nE} - s_H < \upsilon < Inf)$.

8.4 Re-Expressing Entry and Sales Equations

Firm j chooses to do FDI in country n if its productivity $z(j)$ is higher than the corresponding firm- and destination-specific FDI cutoff, i.e.

$$z(j) \geq \bar{z}_{nI}(j) = \delta_1 \left[P_n^{\sigma-1} Y_n \varepsilon_n(j) \eta_n(j)\right]^{-1/(\sigma-1)} w_H d_n^{\rho_1} \Omega_n^{1/(\sigma-1)}. \tag{20}$$

This condition can be re-expressed in terms of home sales. From (12) if firm j sells $s_H(j)$ at home, then its productivity level is

$$z(j) = s_H(j)^{1/(\sigma-1)} w_H P_H^{-1} \frac{\sigma}{\sigma-1} \left(Y_H \mu \eta_H(j)\right)^{-1/(\sigma-1)}. \tag{21}$$

Inserting (21) in (20) yields

$$\begin{aligned}
\left[s_H(j)\varepsilon_n(j)\frac{\eta_n(j)}{\eta_H(j)}\right]^{1/(\sigma-1)} &> \mu^{1/(\sigma-1)} \frac{\sigma-1}{\sigma} \delta_1 \frac{P_H}{P_n} d_n^{\rho_1} \Omega_n^{1/(\sigma-1)} \\
s_H(j)\varepsilon_n(j)\eta_n^*(j) &> \sigma \left(\frac{P_H}{P_n}\right)^{\sigma-1} \frac{Y_H}{Y_n} d_n^{\rho_1(\sigma-1)} \Omega_n \\
\ln s_H(j) + \ln \varepsilon_n(j) + \ln \eta_n^*(j) &> \ln \sigma - \kappa_n + \ln \Omega_n \equiv M_{nI}
\end{aligned}$$

where we have used $\delta_1 = (\sigma/\mu)^{1/\sigma-1} \sigma/(\sigma-1)$ and $\eta_n^*(j) = \eta_n(j)/\eta_H(j)$ from the second to the third line. Note that the domestic wage w_H cancels out. κ_n is a country fixed effect,

$$\kappa_n = \ln \frac{Y_n}{Y_H} + (\sigma-1) \ln \frac{P_n}{P_H} - \rho_1 (\sigma-1) \ln d_n.$$

The export entry condition in terms of home sales is derived in a similar way.

8.5 Analytical Derivatives

8.5.1 Price Index and Distance

Here we show the relationship between the price index (P_n) and variable trade barriers (τ_{in}). As a preliminary step note that Ω_{in}, which measures the cost of FDI relative to exports, is decreasing in τ_{in}:

$$\frac{\partial \ln \Omega_{in}}{\partial \ln \tau_{in}} = -\frac{\alpha(\sigma-1)(\omega_{in}\tau_{in})^{\alpha(\sigma-1)}}{(\omega_{in}\tau_{in})^{\alpha(\sigma-1)} - 1} < 0 .$$

When a bilateral barrier τ_{in} changes, the price index in the destination country n changes through changes in θ_n. The elasticity of θ_n with respect to τ_{in},

$$\frac{\partial \ln \theta_n}{\partial \ln \tau_{in}} = \theta_n^{\gamma} \frac{Y_i}{Y} (w_i \tau_{in})^{-\gamma} \left\{ \Omega_{in}^{-\gamma/(\sigma-1)} (f_{inI} - f_{inE}) \frac{(\omega_{in}\tau_{in})^{\alpha(\sigma-1)} (1-\alpha) - 1}{(\omega_{in}\tau_{in})^{\alpha(\sigma-1)} - 1} + f_{inE}^{1-\frac{\gamma}{\sigma-1}} \right\}$$

is positive if

$$\Omega_{in}^{1-\gamma/(\sigma-1)} (\omega_{in}\tau_{in})^{\alpha(\sigma-1)} (1-\alpha) + f_{inE}^{1-\frac{\gamma}{\sigma-1}} - \Omega_{in}^{1-\gamma/(\sigma-1)} > 0 \ .$$

Note that: i) $\Omega_{in}^{1-\gamma/(\sigma-1)} (\omega_{in}\tau_{in})^{\alpha(\sigma-1)} (1-\alpha) > 0$ since we assume $(\omega_{in}\tau_{in})^{\alpha(\sigma-1)} - 1 > 0$ and ii) $f_{inE}^{1-\gamma/(\sigma-1)} - \Omega_{in}^{1-\gamma/(\sigma-1)} > 0$ requires $f_{inI} > (\omega_{in}\tau_{in})^{\alpha(\sigma-1)} f_{inE}$, which is also assumed and necessary for the export cutoff to be lower than the FDI cutoff. Therefore, the price index P_n is always increasing in τ_{in}.

8.5.2 Entry into Export and MP

Here we show how the number of exporters (n_{inE}) and the number of multinational firms (n_{inI}) depend on variable trade barriers (τ_{in}). Using (11) and our earlier derivation of $\partial \ln \Omega_{in} / \partial \ln \tau_{in}$ we have,

$$\frac{\partial \ln n_{inI}}{\partial \ln \tau_{in}} = \gamma \left[-\frac{(\omega_{in}\tau_{in})^{\alpha(\sigma-1)} (1-\alpha) - 1}{(\omega_{in}\tau_{in})^{\alpha(\sigma-1)} - 1} + \frac{\partial \ln \theta_n}{\partial \ln \tau_{in}} \right] . \tag{22}$$

If the gravity condition (5) holds, with no changes via the price index (and θ_n), the number of firms declines with trade barriers. Accounting for the price index as well,

$$\frac{\partial \ln n_{inI}}{\partial \ln \tau_{in}} < 0 \Longleftrightarrow \theta_n^{-\gamma} > (Y_i/Y) (w_i \tau_{in})^{-\gamma} \left[\Omega_{in}^{-\gamma/(\sigma-1)} (f_{inI} - f_{inE}) + \chi_I^{-1} f_{inE}^{1-\frac{\gamma}{\sigma-1}} \right] \tag{23}$$

where χ_I^{-1}, as shown above, is the inverse of the elasticity of the FDI cutoff with respect to variable trade barriers. Note that $\chi_I^{-1} > 1$ when condition (5) holds. Comparing (23) with the definition of $\theta_n^{-\gamma}$, we see that the number of entrants declines as long as destination n has a sufficient number of trading partners J, meaning that source i must not be important enough to affect P_n. If J is small and χ_I small, the condition may not hold. Numerical simulations show that this is unlikely, however.

Intuitively, the number of entrants declines with trade barriers as long as the increase in the price index (which is favorable from the firm's point of view) is not larger than the increase in barriers (which is unfavorable from the firm's point of view). When there is no parent-affiliate trade ($\alpha = 1$), both terms of condition (22) are positive, so that the number of multinational firms is clearly increasing in variable trade barriers.

Using (10), the relationship between the number of exporters and variable trade barriers is

$$\frac{\partial \ln n_{inE}}{\partial \ln \tau_{in}} = \gamma \left(\frac{\partial \ln \theta_n}{\partial \ln \tau_{in}} - 1 \right) - \frac{1}{f_{inE}^{-\gamma/(\sigma-1)} - \Omega_{in}^{-\gamma/(\sigma-1)}} \frac{\partial \Omega_{in}^{-\gamma/(\sigma-1)}}{\partial \ln \tau_{in}} .$$

Note that i) the last element of the product term is positive since we showed that $\partial \ln \Omega_{in} / \partial \ln \tau_{in} < 0$ and since $\sigma > 1$, ii) $f_{inE}^{-\gamma/(\sigma-1)} - \Omega_{in}^{-\gamma/(\sigma-1)} > 0$ because we assume $f_{inI} > (\omega_{in}\tau_{in})^{(\sigma-1)} f_{inE}$ (necessary for the export cutoff to be lower than the FDI cutoff.). Therefore, in partial equilibrium, the number of exporters is decreasing in variable trade barriers.

8.6 Additional Data Sources

Wage index data are from the Bureau of Labor Statistics' *International Comparisons of Hourly Compensation Costs in Manufacturing* database.[63] The wage index measures nominal compensation costs for production workers in 2004. Absorption is calculated as total production minus exports plus imports in 2004. Data are gathered from OECD's Economic Outlook: Annual and quarterly data Vol. 2008 release 01.[64] Distance data (simple distance between most populated cities, measured in kilometers) are taken from CEPII's *Trade, Production and Bilateral Protection* database (Mayer, Paillacar and Zignago, 2008).

[63] http://www.bls.gov/news.release/ichcc.toc.htm

[64] http://oberon.sourceoecd.org/vl=5146063/cl=12/nw=1/rpsv/ij/oecdstats/16081153/v115n1/s1/p1

Table 1: Estimates

Parameter	Estimate	Std. Error
$\alpha\rho_1\,(\sigma-1)$	0.12	(0.03)
$\alpha\rho_2\,(\sigma-1)$	0.01	(0.25)
σ_{η^*}	3.01	(0.01)
σ_{υ}	2.99	(0.01)
$\sigma_{\varepsilon\eta^*}$	-2.86	(0.01)
α	0.11	(0.0054)
$l_{entry}(\vartheta_1)$	$-42,830$	
$l_{sales}(\vartheta_2)$	$-32,375$	
N	28	
J	$7,949$	

Notes: The reported estimate of α is an average of the estimates over a range of values for σ. The standard deviation of α is computed using boostrapping with random resampling of 90 percent of the data and estimating the model 100 times.

Table 2: Selection Bias

Parameter	True value	Main model (a)	No selection (b)
κ_n	-5.43	-5.40	-2.89
M_{nE}	11.61	11.60	11.60
M_{nI}	15.85	15.89	15.89
$\alpha\rho_1\,(\sigma-1)$	0.35	0.36	0.61
α	0.50	0.51	1.48
σ_{η^*}	3.00	3.00	2.44
σ_{ε}	2.00	2.03	4.13
$\sigma_{\varepsilon\eta^*}$	-3.00	-3.00	–

Notes: reported estimates for sales potential κ_n, entry hurdles M_{nE} and M_{nI} are averages across destinations. The initial parameters for this example are $N=6$, ρ_1= .1, ρ_2= 0, $\sigma=8$, $\gamma/\,(\sigma-1)=1.1$, f_{nE}= \$0.01 million and f_{nI}= \$10 million.

Table 3: First-Stage Country-Specific Estimates

	κ_n		M_{nE}		M_{nI}		$ln\,(\sigma f_{nE})$	$ln\,(\sigma f_{nI})$
AT	-9.39	(0.16)	15.21	(0.11)	20.14	(0.48)	5.83	11.12
AU	-9.40	(0.16)	15.31	(0.11)	19.30	(0.33)	5.91	10.74
BE	-8.83	(0.13)	14.49	(0.09)	20.18	(0.46)	5.67	11.67
CA	-9.04	(0.15)	14.91	(0.10)	19.20	(0.33)	5.86	10.81
CH	-9.22	(0.14)	14.77	(0.10)	20.12	(0.46)	5.55	11.28
CZ	-9.77	(0.18)	15.73	(0.12)	19.89	(0.41)	5.96	10.45
DE	-7.54	(0.09)	12.80	(0.07)	18.74	(0.26)	5.26	11.49
DK	-7.35	(0.08)	11.94	(0.06)	18.73	(0.26)	4.60	11.52
ES	-8.53	(0.13)	14.19	(0.09)	19.88	(0.41)	5.66	11.83
FI	-8.07	(0.11)	13.45	(0.08)	19.21	(0.30)	5.37	11.38
FR	-8.18	(0.12)	14.00	(0.09)	19.00	(0.30)	5.82	11.19
GB	-7.39	(0.10)	12.93	(0.07)	18.29	(0.22)	5.54	11.22
GR	-9.63	(0.18)	15.58	(0.11)	21.86	(1.04)	5.95	12.73
HU	-10.41	(0.22)	16.37	(0.14)	21.14	(0.85)	5.96	11.12
IE	-9.62	(0.17)	15.46	(0.11)	19.78	(0.40)	5.84	10.52
IS	-9.38	(0.13)	14.39	(0.09)	21.07	(0.92)	5.01	12.10
IT	-8.35	(0.13)	14.27	(0.09)	19.49	(0.36)	5.91	11.58
JP	-8.63	(0.16)	15.03	(0.10)	19.53	(0.37)	6.40	11.62
KR	-8.85	(0.17)	15.52	(0.11)	20.20	(0.47)	6.67	12.05
MX	-10.82	(0.28)	17.08	(0.18)	20.75	(0.61)	6.26	10.67
NL	-7.98	(0.10)	13.39	(0.08)	19.39	(0.33)	5.41	11.69
NZ	-10.69	(0.23)	16.51	(0.15)	20.68	(0.60)	5.82	10.85
PL	-8.42	(0.13)	14.34	(0.09)	19.04	(0.30)	5.92	10.94
PT	-9.67	(0.18)	15.68	(0.12)	20.61	(0.60)	6.01	11.45
SE	-6.56	(0.07)	11.30	(0.05)	17.86	(0.20)	4.75	11.40
SK	-10.64	(0.26)	16.83	(0.15)	21.25	(0.93)	6.20	10.98
TR	-9.15	(0.20)	15.95	(0.12)	21.85	(1.01)	6.81	13.19
US	-7.77	(0.12)	13.82	(0.09)	18.35	(0.24)	6.05	11.24

Notes: standard errors in parentheses.

Table 4: Counterfactuals: Prohibitive barriers to FDI

	Welfare	Change in exports* due to	
		entrants	incumbents
AT	−0.40	138.26	2.41
AU	−0.03	157.36	0.16
BE	−0.66	102.16	4.04
CA	−0.17	85.10	1.01
CH	−0.42	154.35	2.57
CZ	−1.07	99.17	6.67
DE	−0.05	103.53	0.33
DK	−0.48	86.95	2.91
ES	−0.07	61.67	0.45
FI	−0.41	114.16	2.52
FR	−0.07	75.30	0.43
GB	−0.06	112.02	0.37
GR	−0.26	11.45	1.56
HU	−0.91	60.60	5.66
IE	−0.71	74.32	4.39
IS	−3.56	49.48	24.27
IT	−0.05	256.18	0.28
JP	−0.01	80.83	0.03
KR	−0.07	63.36	0.42
MX	−0.06	159.61	0.35
NL	−0.38	121.51	2.29
NZ	−0.18	43.66	1.07
PL	−0.35	102.81	2.14
PT	−0.40	19.74	2.46
SE	−0.26	149.61	1.56
SK	−2.38	18.25	15.57
TR	−0.16	40.50	0.94
US	0.00	109.23	0.02
NO	−0.41		
avg	−0.48	94.68	3.10

∗ Exports from Norway. Per cent change.
Welfare is calculated under $\sigma = 8$.
Other results are independent of σ.

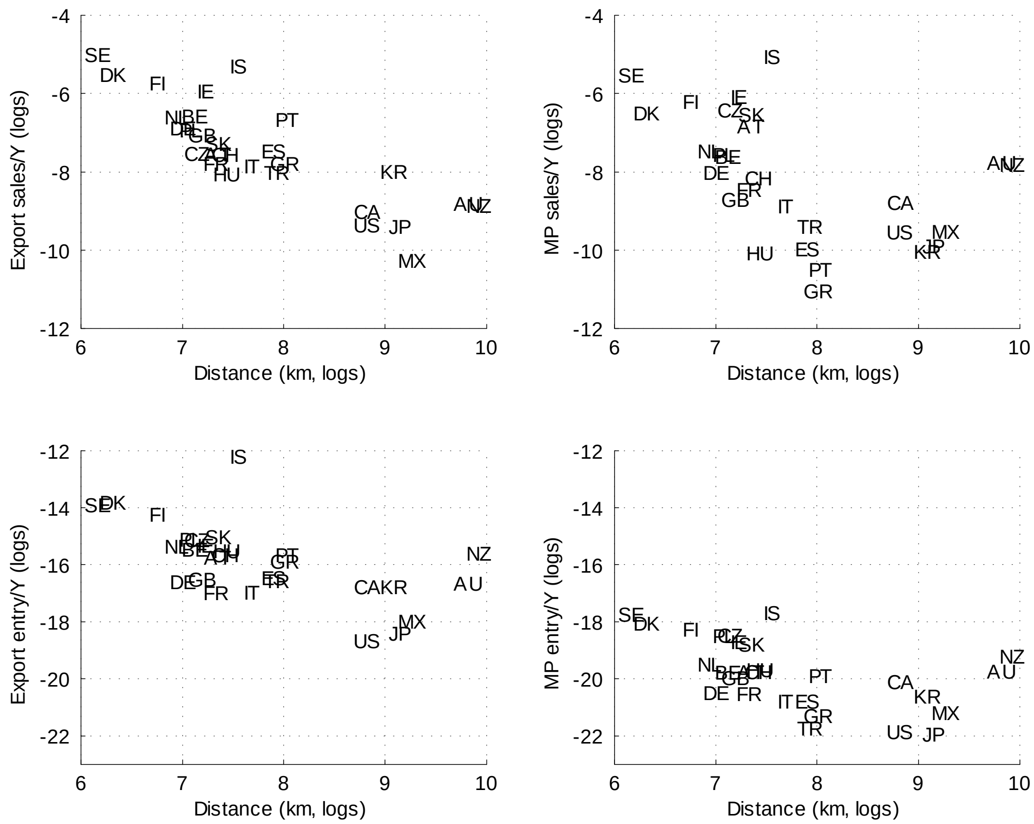

Figure 1: Gravity for Export and FDI, Overall and Extensive Margin

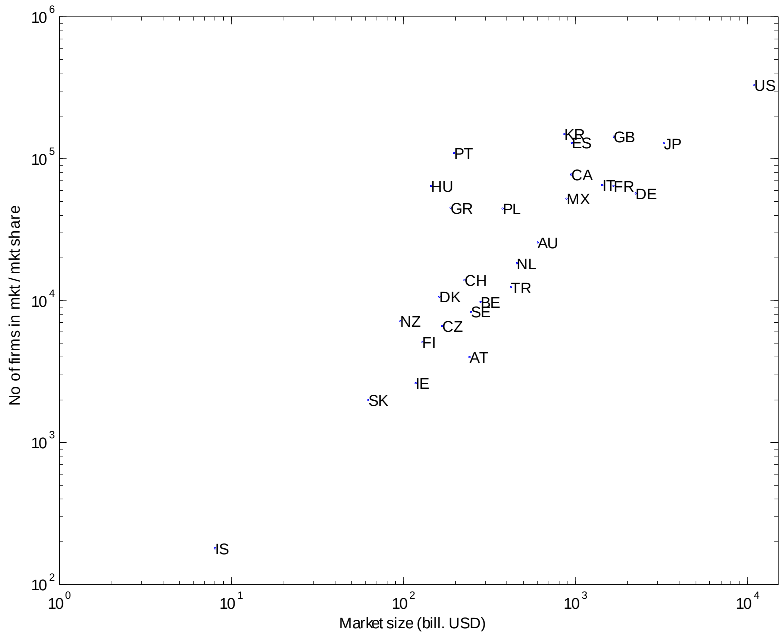

Figure 2: Entry and Market Size

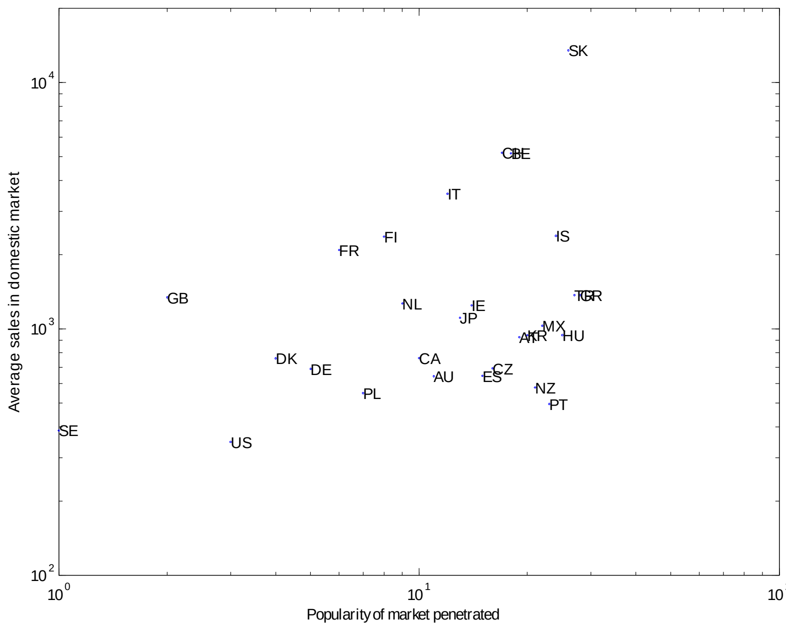

Figure 3: Average Sales in Norway and Destination Market Popularity

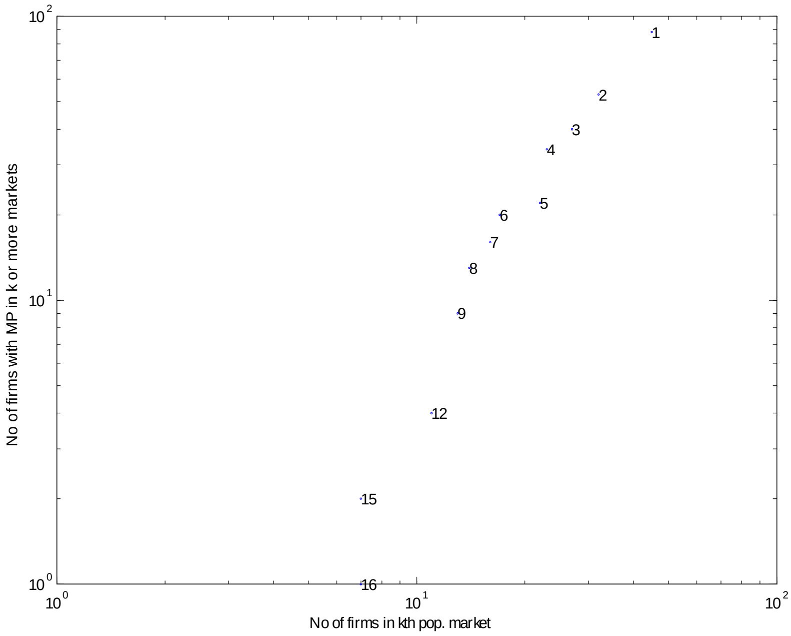

Figure 4: Entry market hierarchy for MP

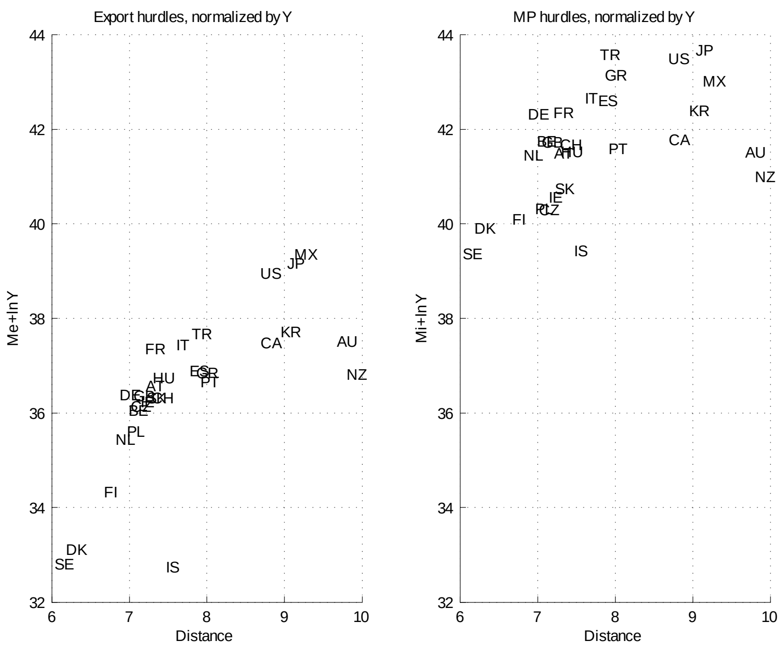

Figure 5: Entry Hurdles

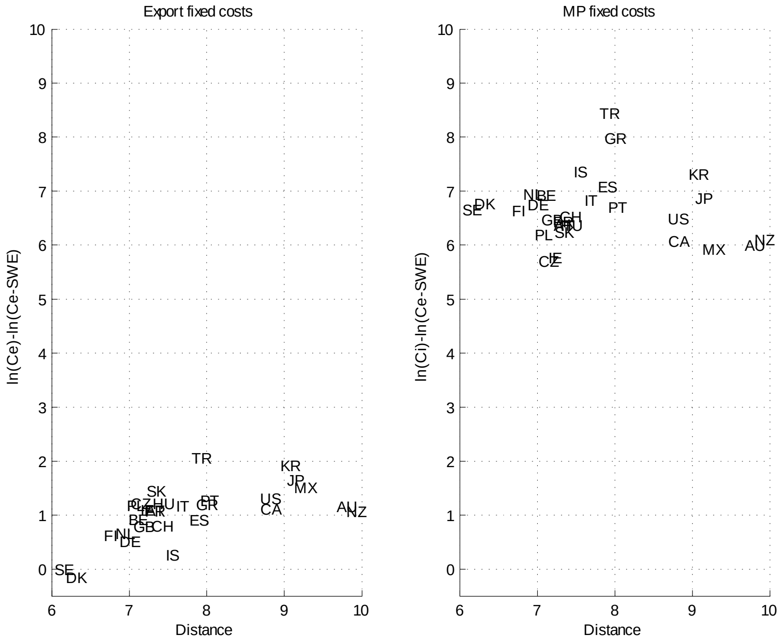

Figure 6: Entry Fixed Costs

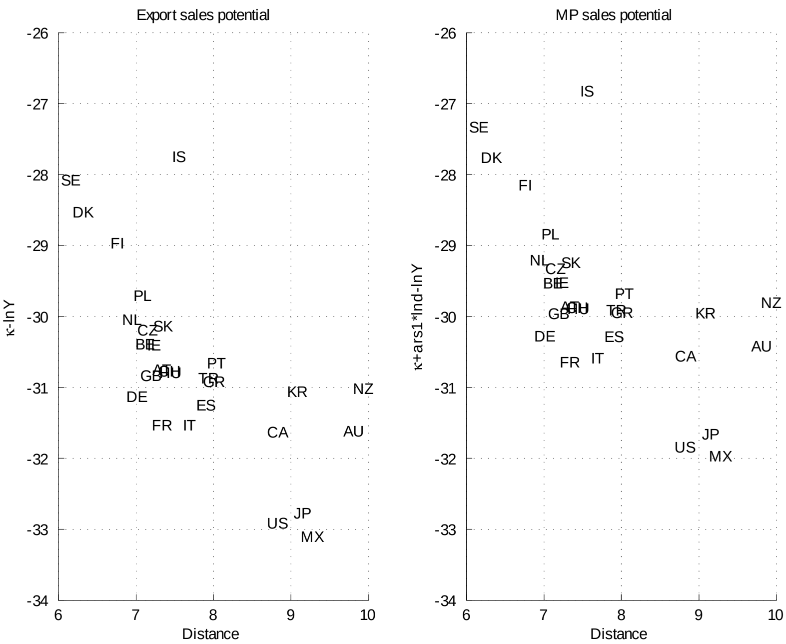

Figure 7: Sales Potential

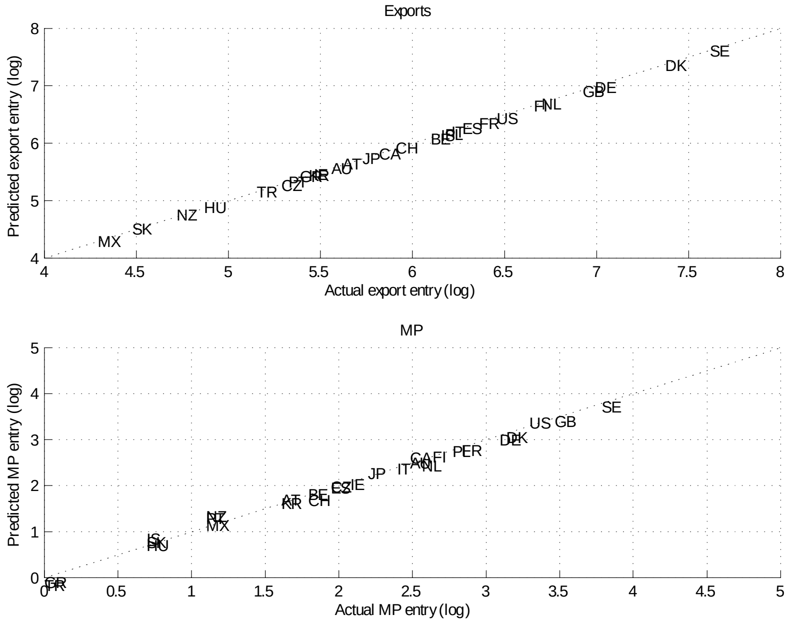

Figure 8: Actual vs Predicted Entry

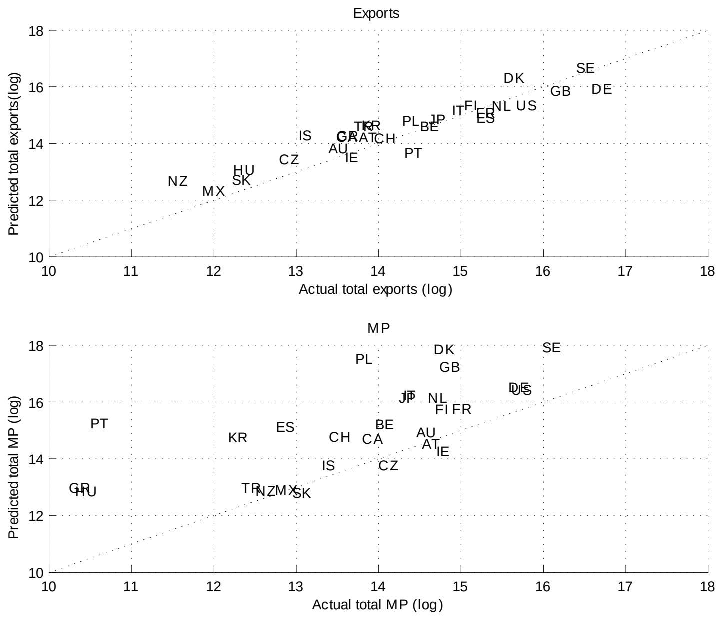

Figure 9: Actual vs Predicted Sales

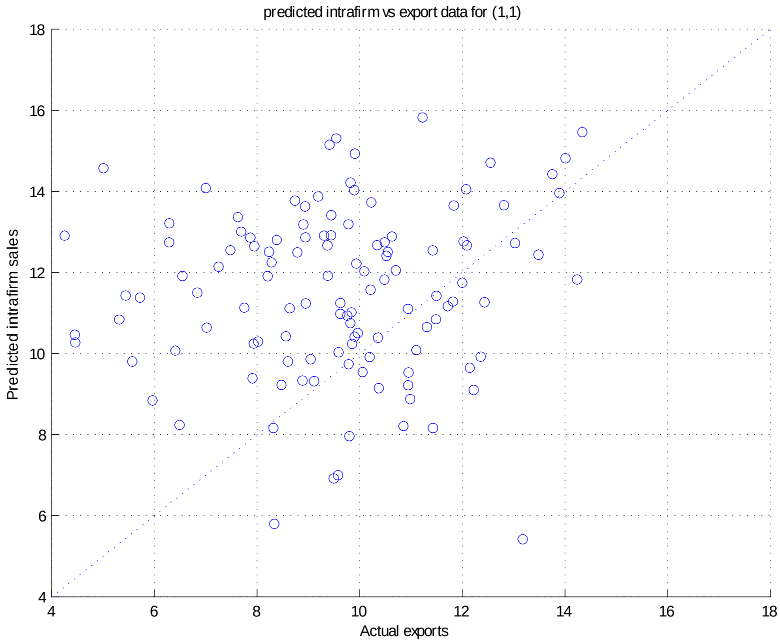

Figure 10: Out-of-Sample Prediction of Intra-Firm Trade

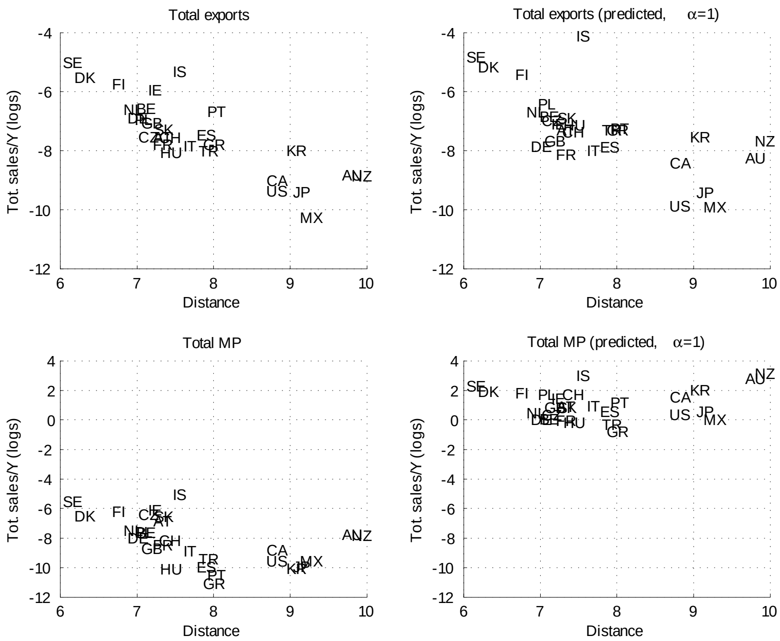

Figure 11: Actual vs Predicted Sales without Intra-firm Trade