Distance costs and multinationals' foreign activities ⋆

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Abstract

According to proximity-concentration models, multinational affiliates' sales increase in distance costs. Yet, this is not found in empirical gravity equations using bilateral FDI. We therefore generalize the proximity-concentration framework and derive a gravity equation from two general equilibrium models with multinational firms: a symmetric firm model where foreign affiliates' production relies on specific intermediate goods and a heterogenous firms model with country-specific fixed costs. Although the reduced form gravity equation derived from both models is the same, the structure behind it differs. In the heterogenous firm model, fewer (but larger) firms enter more distant markets which yields lower aggregate sales. In the symmetric firm intermediate input model, in contrast, lower aggregate sales result from lower sales per foreign affiliate. We use gravity equations to assess the importance of these extensive and intensive margins of affiliates' activities. Thereby, we find the extensive margin to be more important.

Keywords: Gravity equation, multinational firms, distance costs.

JEL classification: F23, F12, C21

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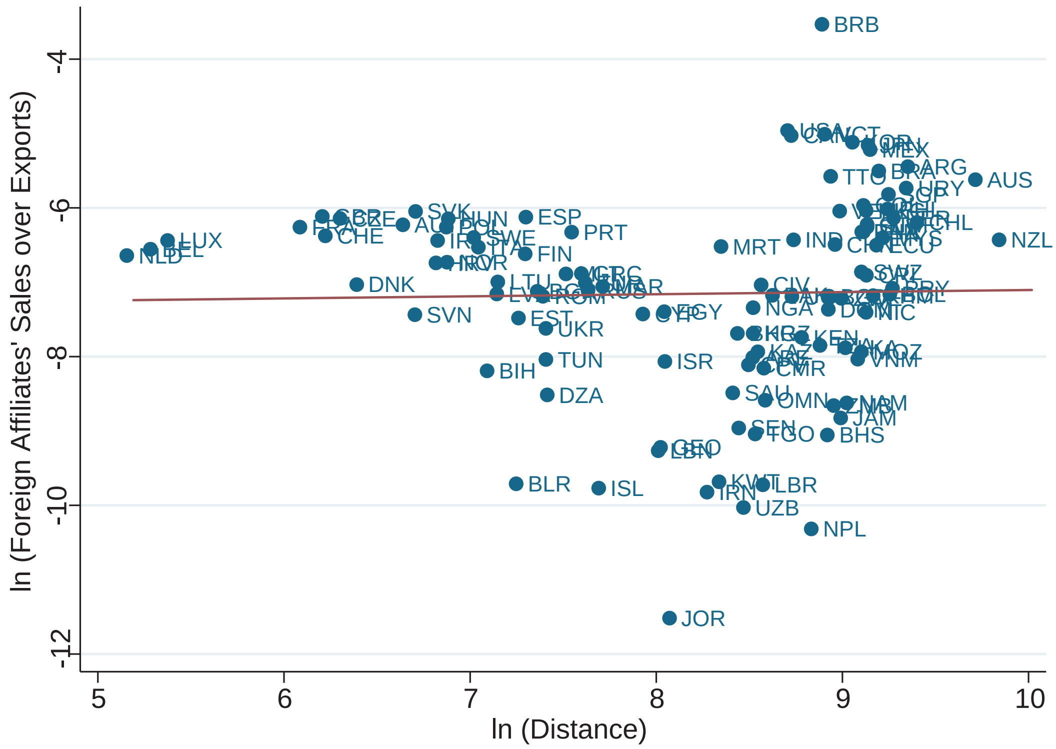
1 Introduction

Research on multinational firms' foreign activities has always pointed out the importance of distance costs for cross-border investment. A growing empirical literature uses gravity-type equations to investigate the determinants of various type of cross-border activities. This literature finds a negative impact of geographical distance on foreign direct investment (De Sousa and Lochard, 2006, Eichengreen and Tong, 2005; Eaton and Tamura, 1994; Wei, 2000) or on foreign affiliates' sales (Buch *et al.*, 2005; Carr *et al.*, 2001; Ekholm, 1998).

The theoretical literature has traditionally focussed on the proximity-concentration model to explain the bulk of cross border investment. It suggests that firms face a trade-off between concentrating their production at home to save on plant set-up costs and producing abroad to save on distance costs. Thus, the model that distance costs favor affiliate sales over exports. While that not necessarily implies increasing affiliate sale in distance, it implies at least that foreign affiliates' sales increase relatively more than exports when distance costs increases. Yet, even this much milder prediction of the theory in shares is at odds with the empirical findings based on aggregate data, which show that the ratio of foreign affiliate sales over exports remains constant in distance. Figure 1 illustrates this striking point using foreign affiliates' sales and exports from Germany.

Figure 1 shows in a cross section of 114 countries that the ratio of foreign affiliate sales over total exports is unaffected by distance. Thus, there remains the question how the theory can explain the huge increases in affiliate sales that strongly outpaced exports in the last two decades. Neary (2008) offers two possible explanations to this paradox, that are outside the bilateral proximity-concentration framework. First, preferential trade liberalization leads to more

Fig. 1. Impact of distance on:



Foreign affiliates' sales have been computed from the MiDi database of the *Deutsche* Bundesbank. Total exports from Germany have been taken from the COMTRADE database. The Y-axis corresponds to the logarithm of the share of foreign affiliate sales over total exports. The X-axis measures the log of distance between the largest cities in Germany and its partner.

activities by multinational firms from third countries. Second, mergers and acquisitions (M&A) are encouraged rather than discouraged by falling distance costs. Marin and Schnitzer (2004) and Head and Ries (2008) explore the implication of distance costs for the volume of cross border M&A. They explicitly consider monitoring costs that are increasing in distance.

We show in this paper that the "*distance costs puzzle*" can also be explained within the bilateral proximity-concentration framework. We argue that the discrepancies between the empirical findings and the theoretical models can be solved by relaxing simplifying assumptions. We propose two channels through which distance can affect negatively foreign affiliates' sales. First, we show in a model of monopolistic competition with *symmetric* firms, that increasing distance costs affect negatively the *volume* of each affiliate's production when production requires imports of domestic intermediate inputs. The model is close to the seminal paper of Brainard (1993), but incorporates intermediate inputs. We assume that these intermediates are imported from the home country. We base this assumption on the empirical fact that one third of world trade is intra-firm trade and this trade is increasingly in intermediate goods (Andersson and Fredriksson, 2000). The US Bureau of Economic Analysis reports that the ratio of imports of goods shipped to US affiliates of foreign multinational firms over affiliate sales is about 17% in 2002. BEA statistics show also that about 80% of these imports are coming from the foreign parents. Borga and Zeile (2004) present evidence for significant affiliates' imports from the parent firms from the 1994 benchmark survey of US multinational firms' foreign affiliates. In 1994, the ratio of imported intermediate goods from the parent firm over total sales of the foreign affiliate in manufacturing stood at 10.4%.

We introduce imported intermediate inputs in a framework of symmetric firms to focus on the *intensive* margin of firms' activities. Aggregate sales of affiliates fall, because all affiliates sell less in more distant countries.

Second, we show in a model of monopolistic competition with *heterogenous* firms, that increasing distance costs affect negatively the *number* of foreign affiliates if fixed set-up costs increase in distance. This model extends Helpman *et al.* (2004), by relaxing the assumption that the fixed set-up costs are identical in all countries. We motivate the assumption that fixed costs increase with distance by the fact that distance raises upfront search costs and organization costs (Chaney, 2006; Rauch, 1999). The model allows to examine the extensive margin of firms' activities. Aggregate sales of affiliates fall, because fewer firms are active in more distant countries.

We introduce two models in order to make a clear distinction between the two possible channels through which distance costs affect negatively aggregated foreign affiliates' sales. We also show that the combination of both channels in one model clouds the effect on the average size of a foreign affiliate. We analyze a model of symmetric firms to demonstrate a possible channel through which the intensive margin of a firm is affected, and not because we belief firm heterogeneity is empirically unimportant.

The models offer three predictions on the impact of distance costs on (i) aggregate foreign affiliates' production, (ii) the number of active foreign affiliates and, (iii) the average size of the foreign affiliate. First, both models predict that aggregate affiliates' production decreases in distance costs. Second, while the number of foreign affiliate is not affected by distance costs in the symmetric firm model, it decreases with distance costs in the heterogenous firm model. Third, the average size of a foreign affiliate increases with distance costs in the heterogenous firm model but decreases with distance costs in the symmetric firm model.

We test our three predictions using the OECD *Measuring Globalization* data set. This database has the merit to contain information on 21 OECD countries but it has the drawback of being unbalanced. The number of observations for some countries is very low. We therefore use an extensive data set on German multinationals' foreign sales in order to check the robustness of our results. We find a large and significantly negative effect of distance on aggregate affiliate sales and the number of foreign affiliates in a particular host country but no significant effect of distance on the average size of the foreign affiliate. Our results suggest that distance works mainly through the extensive margin. That is also found for international trade in Eaton *et al.* (2004).

The remainder of the paper is structured as follows. In Section 2, we present the models and derive the equations to estimate. In Section 3, we provide a discussion of the data and present the empirical strategy. In section 4, we present our main results and the robustness check. In section 5, we conclude.

2 Two models of the horizontal multinational firm

We consider an economy with two sectors: agriculture, which produces a homogeneous good A and manufacturing which produces a bundle M of differentiated goods. Consumers purchase A and M and have identical preferences described by a utility function defined on A and M. Consumers preferences for single varieties of the M good are described by a sub-utility function defined on the varieties. The utility function of the representative consumer from country j has the Cobb-Douglas form described in equation (1):

$$U_j = X_{Aj}^{\mu} X_{Mj}^{(1-\mu)} \tag{1}$$

where $0 < \mu < 1$. X_{Mj} is a sub-utility function of CES-type defined in (2)

$$X_{Mj} = \left[\int_i \int_k x_{kij}^{(\sigma-1)/\sigma} dk di \right]^{\sigma/(\sigma-1)} \tag{2}$$

x_{kij} is the consumption by an individual in country j of a single variety produced by firm k from country i. The elasticity of substitution, σ, is the same for any pair of product and larger than one. We assume monopolistic competition in manufacturing so that each variety of the manufacturing good is produced by only one firm.

We start with a symmetric firm model with specific intermediate inputs and then develop a model with heterogenous firms with country-specific distance-dependent fixed costs but abstain from intermediate inputs. In Appendix A, we present the results of an unified framework where we build imported intermediates into the heterogenous firms' model and show that it delivers ambiguous results on the impact of distance costs on the average sales of foreign affiliates.

2.1 A symmetric firm model with firm specific intermediate goods

We assume in this model that all varieties are symmetric. This simplifies the integral $\int_k x_{kij}^{(\sigma-1)/\sigma} dk$ from equation (2) to the product $n_i x_{ij}^{(\sigma-1)/\sigma}$, where we suppressed the firm subscript k. The price index in the manufacturing sector, P_{Mj}, corresponds to the CES sub-utility function: $P_{Mj} = \left[\int_i n_i p_{ij}^{1-\sigma}\right]^{1/(1-\sigma)}$. Given the total demand $(1-\mu)Y_j$ for differentiated products in country j which is derived from equation (1), the demand for each variety is given by equation (3). Each firm's sales in foreign markets depend on its own price p_{ij} in country j, on the price index P_{Mj} in j and on j's market size Y_j.

$$x_{ij} = p_{ij}^{-\sigma}(1-\mu)Y_j P_{Mj}^{\sigma-1} \tag{3}$$

Firms can serve foreign market j either by export or by producing abroad. They choose to produce abroad if production abroad is more profitable than exports, i.e if inequality (4) holds

$$\pi_i^{MNE} - \pi_i^{Ex} > 0 \Leftrightarrow \frac{1}{\sigma}[p_{ij}^{MNE} x_{ij}^{MNE} - p_{ij}^{Ex} x_{ij}^{Ex}] > f_j, \tag{4}$$

where f_j denotes the fixed costs for an additional plant in country j. Thus entry of multinational firms is determined by the level of the additional fixed costs and by the difference in sales in the foreign market. As seen in (4), the latter depends on the prices of the exported good p_{ij}^{Ex} relative to the prices of the good produced abroad p_{ij}^{MNE}. Note, that the endogenous number of firms producing in the foreign country does not depend on distance costs, τ. All firms from country i produce in country j or none of them, because firms are symmetric.

Following the proximity-concentration literature, we assume that exports incur distance costs of iceberg-type. We denote distance costs between country i and j by τ_{ij}. Hence, $p_{ij}^{Ex} = p_{ii}\tau_{ij}$. We assume that the production of multinationals' affiliates relies on intermediate inputs which are imported from the home country. [1] The production technology of a firm from country i producing in country j is described by the cost function $C_j = \left(\frac{w_j}{\epsilon}\right)^{\epsilon}\left(\frac{q_{ij}}{1-\epsilon}\right)^{1-\epsilon}$. This cost function stems from a Cobb-Douglas production function with cost share ϵ for labor and $1-\epsilon$ for the intermediate input. q_{ij} is the price for the intermediate input used in the foreign affiliate located in country j of a firm locate in country i. w_j denotes the wage in country j. Like final manufacturing goods, intermediate inputs are subject to distance costs of iceberg-type. Hence, $q_{ij} = q_{ii}\tau_{ij}$. Given that the optimal price of a monopolistic competitive firm is always a fixed markup over marginal costs, and that marginal costs increase in distance costs, prices of goods produced in foreign affiliates also increase in distance costs. Consequently, quantities sold abroad decrease in distance costs. Nevertheless, profits from producing abroad might be higher than from exporting. Aggregate sales of country i firms' affiliates in country j are given by equation (5).

$$n_i p_{ij} x_{ij} = n_i p_{ii}^{1-\sigma} \tau_{ij}^{(1-\sigma)(1-\epsilon)} (1-\mu) Y_j P_j^{\sigma-1} \tag{5}$$

This equation of bilateral affiliates' sales can be transformed into a gravity equation for affiliate sales. It contains home country's supply characteristics and demand characteristics of the host country. As Redding and Venables (2004), we refer to $(1-\mu)Y_j P_j^{\sigma-1}$ aas host country j's *market capacity* and to $n_i p_{ii}^{1-\sigma}$ as home country's *supply capacity.* We follow Redding and Venables' terminology and denote market capacity as m_j and supply capacity as s_i. We

[1] Multinational firms could additionally also draw some intermediate inputs locally. However, assuming the use of non-specific local intermediate inputs by the foreign affiliates has no effect on the firm's decision between exporting and producing abroad. For sake of simplicity, we do not include local intermediate inputs in the model.

denote bilateral foreign affiliates' production by AS_{ij}. We assume that distance costs, τ_{ij}, are an increasing function of geographical distance between country i and j, $\tau_{ij} = \lambda_1 D_{ij}^{\eta_1}$ with λ_1 being unit distance costs and $\eta_1 > 0$. Then, equation (5) can be written in log-linearized form as

$$ln(AS_{ij}) = \alpha_1 + \zeta_1 ln(s_i) - \beta_1 ln(D_{ij}) + \xi_1 ln(m_j) \qquad (6)$$

where $\alpha_1 = (1-\sigma)(1-\epsilon)ln(\lambda_1)$, $\beta_1 = \eta_1(\sigma-1)(1-\epsilon)$. The structural gravity equation implies a constraint on the estimates of parameter ζ_1 and ξ_1. They equal one. It is straightforward to test whether these constraints hold in the empirical analysis.

2.2 A heterogenous firm model with distance dependent fixed costs

The symmetric firms assumption yields an equilibrium where all firms are active in the foreign country, independently of the distance between the two countries. According to Buch *et al.* (2005), the number of firms falls with distance between two countries. Symmetric firms models cannot explain this stylized fact. We, therefore, depart from this assumption and incorporate heterogenous firms as in Helpman *et al.* (2004). Firms have different levels of productivity that they draw from a common distribution. Differences in productivity translate into different marginal costs, different prices and different quantities for each firm k. We denote the marginal costs of a firm k by a_k and define the productivity level as $\omega_k = 1/a_k$. Profit maximization yields a fixed markup over the marginal costs a_k of $\rho = (\sigma-1)/\sigma$. Thus, the price of firm k located in country i and selling in country j, $p_{kij} = a_{kij}/\rho$ leads to firm specific quantities sold in j. Equation (3), which described the optimal quantity sold in country j by a firm located in country i in our symmetric firm model case changes slightly to equation (7) when we consider firm-specific productivity levels.

$$x_{kij} = p_{kij}^{-\sigma}(1-\mu)Y_j P_{Mj}^{\sigma-1} \tag{7}$$

Although denoted by the same variable, the price index, P_{Mj}, in country j differs from the one in the symmetric firm model. First, it is affected by the difference in productivity between firms and thus their different prices and quantities. Second, it depends on the choice between serving the foreign market j or not. Firms that choose to serve the foreign market decide to export or to produce abroad. Their choice depends on their productivity level ω_k. The price index of country j changes therefore to $P_{Mj} = \left[\int_k \left(p_{kij}^h\right)^{1-\sigma} dk\right]^{1/(1-\sigma)}$. We normalize the mass of firms from country i to one. p_{kij}^h is the price of firm k from country i selling in market j and having chosen the mode of entry h. The subscript h, $h = Ex, MNE$, indicates respectively whether a firm is an exporter or produces abroad.

Each firm compares the profit related to each mode of entry in market j. The firms that have a higher productivity level than ω_j^{Ex} are active in this market and earn positive profit. Firms that have a productivity level equal to ω_j^{MNE} are indifferent between exporting and producing abroad because both strategies yield the same profit. Firms with a productivity level higher than ω_j^{MNE} produce in country j and have higher profits than firms with a lower productivity level that export to j. We use the zero-profit conditions to derive the critical productivity levels (a) for a firm that produces only for the home market j (b) for an exporting firm from i selling in j and (c) for a firm from i that also produces in j. These are given in equations (8).

$$\left(\omega^{Dom}\right)^{\sigma-1} \frac{(1-\mu)Y_j(1-\rho)}{P_{Mj}^{1-\sigma}\rho^{1-\sigma}} = f_j^{Dom} \tag{8a}$$

$$\left(\frac{\omega_{ij}^{Ex}}{\tau_{ij}}\right)^{\sigma-1} \frac{(1-\mu)Y_j(1-\rho)}{P_{Mj}^{1-\sigma}\rho^{1-\sigma}} = f_{ij}^{Ex} \tag{8b}$$

$$\left(\omega_{ij}^{MNE}\right)^{\sigma-1}\left(1-\tau_{ij}^{1-\sigma}\right)\frac{(1-\mu)Y_j(1-\rho)}{P_{Mj}^{1-\sigma}\rho^{1-\sigma}}=f_{ij}^{MNE}-f_{ij}^{Ex} \tag{8c}$$

We assume that fixed costs of exporting f^{Ex} is a fixed share ϕ of the fixed costs, f^{MNE}, associated with the production abroad with $0<\phi<1$.

Following Helpman *et al.* (2004), we use a Pareto distribution to parameterize the distribution of firms with respect to their productivity $\omega_k = 1/a_k$. We denote the shape parameter by κ. Aggregated affiliates' sales of all firms from country i in the foreign market j, AS_{ij}, are thus given by equation (9) which is derived in the Appendix B.

$$\begin{aligned} AS_{ij} &= \int_{\omega_{ij}^{MNE}}^{\infty}(\omega_k\rho)^{\sigma-1}g(\omega)\frac{(1-\mu)Y_j}{P_j^{1-\sigma}}d\omega_k \\ &= \left(\frac{\omega_i^{Dom}}{\omega_{ij}^{MNE}}\right)^{\kappa}\left(\frac{\kappa}{\kappa-\sigma+1}\right)\left(\omega_{ij}^{MNE}\right)^{(\sigma-1)}\frac{\rho^{\sigma-1}(1-\mu)Y_j}{P_j^{1-\sigma}} \end{aligned} \tag{9}$$

Where ω_i^{Dom} is the productivity level of the least productive (domestic) firm from country i that is active in the market. The first term gives the cumulative probability of firms from country i having an affiliate in country j. Multiplied by the total mass of firms from i, which is one by normalization, this gives the number of affiliates in country j that we denote by n_{ij}.[2] The second term gives the sales of the average foreign affiliate of firms from country i in country j.

The threshold productivity level, ω_{ij}^{MNE}, determines the minimal size and the number of affiliates from country i in country j. It is easy to see in (9) that the threshold productivity level ω_{ij}^{MNE} is inversely related to aggregate affiliate sales. From the first term of equation (9), we see that the threshold productivity level is negatively related to the number of firms producing in country j. From the second term, we see that the threshold productivity is

[2] The normalization does not change the results because the minimum productivity threshold, ω_{ij}^{MNE} determines the fraction of all firms from country i having an affiliate in the foreign country j.

positively related to the average size of the affiliate.

The effect of the minimum productivity threshold on aggregate affiliate sales is given by

$$\frac{\partial AS_{ij}}{\partial \omega_{ij}^{MNE}} = (-\kappa + (\sigma - 1)) \left(\omega_{ij}^{MNE}\right)^{(-\kappa+\sigma-2)} \Lambda_j < 0$$

where $\Lambda_j = (\omega_i^{Dom})^{\kappa} \left(\frac{\kappa}{\kappa-\sigma+1}\right) \frac{\rho^{\sigma-1}(1-\mu)Y_j}{P_{Mj}^{1-\sigma}}$.

The total effect is negative, since κ is larger than $\sigma - 1$.[3]

Moreover, we show in the Appendix C that distance has a positive impact on the threshold productivity level if distance between countries is not too small. Since aggregate sales are negatively related to the threshold productivity level and distance affects the threshold productivity level positively, aggregate sales are a decreasing function of distance.

$$\frac{\partial AS_{ij}}{\partial \omega_{ij}^{MNE}} \frac{\partial \omega_{ij}^{MNE}}{\partial D_{ij}} < 0, \quad if \quad \frac{\partial \omega_{ij}^{MNE}}{\partial D_{ij}} > 0$$

Sales of active firms in country i are proportional to the sales of country i's affiliates in country j. In order to derive the gravity equation we re-write equation (9) as

$$AS_{ij} = \underbrace{\left[\left(\frac{\kappa}{\kappa - \sigma + 1}\right) \left(\omega_i^{Dom} \rho\right)^{\sigma-1}\right]}_{s_i} \underbrace{\left(\frac{\omega_i^{Dom}}{\omega_{ij}^{MNE}}\right)^{\kappa-(\sigma-1)}}_{\Phi} \underbrace{\frac{(1-\mu)Y_j}{P_{Mj}^{1-\sigma}}}_{m_j}.$$

The first term gives the *supply capacity*, s_i, of country i. It represents the sales of the average firm from country i multiplied with the number of firms which is normalized to one.

The second term, which we denote by Φ, is the weighted ratio of the smallest productivity level of a domestic firm and the threshold productivity level for

[3] κ must be larger than $\sigma - 1$ for the integral in equation (9) to be finite.

production in country j. As shown in Appendix C, the distance effect on the minimum productivity of a multinational firm ω_{ij}^{MNE} is positive. Thus, distance affects the second term Φ negatively. For simplicity, we assume that $\Phi = (\lambda_2 D_{ij})^{-\eta_2}$. This form is very flexible and exhibits the negative impact of distance on aggregate sales.

The third term gives the *market capacity* of country j, m_j. Thus, aggregate affiliate sales of firms from country i in country j are then given by:

$$AS_{ij} = s_i(\lambda_2 D_{ij})^{-\eta_2} m_j \tag{10}$$

Log-linearizing equation (10) yields the second gravity equation.

$$ln(AS_{ij}) = \alpha_2 + \zeta_2 ln(s_i) - \beta_2 ln(D_{ij}) + \xi_2 ln(m_j) \tag{11}$$

where $\alpha_2 = -\eta_2 ln(\lambda_2)$ and $\beta_2 = \eta_2$. As in the preceding model, the structural gravity equation implies a constraint on the estimates of parameter ζ_2 and ξ_2.

3 Empirical Methodology

3.1 Estimation Strategy

The theoretical analysis leads to the same reduced-form gravity equation for both models. We can however discriminate between the two models because the underlying structures of the reduced form differ. In particular, distance costs affect differently the number of foreign affiliates, n_{ij}, and the average size of an affiliate, $as_{ij} = \bar{p}_{ij}\bar{x}_{ij}$, in the two models, although the effect on aggregate sales $AS_{ij} = n_{ij} as_{ij}$ is qualitatively the same.

One outcome of the first model, which assumes symmetric firms and incorporates specific intermediate inputs, is that distance costs have a negative impact on the (average) size of an affiliate but have no impact on the number of affiliates in the foreign country. Using equation (5), and assuming $\tau_{ij} = \lambda_1 D_{ij}^{\eta_1}$ it is easy to show that distance affects aggregate affiliates' sales only through the average affiliate sales.

$$\frac{\partial n_{ij}}{\partial D_{ij}} = 0$$
$$\frac{\partial as_{ij}}{\partial D_{ij}} = p_{ii}^{1-\sigma} \lambda_1^{(1-\sigma)(1-\epsilon)} \left(\eta_1 (1-\sigma)(1-\epsilon) D_{ij}^{\eta_1(1-\sigma)(1-\epsilon)-1} \right) (1-\mu) Y_j P_j^{\sigma-1} < 0$$

According to the second model, which assumes heterogenous firms, distance has a positive impact on the threshold productivity level ω_{ij}^{MNE}. This impact depends on the fixed costs, f, the variable distance costs λ_1 and the elasticity of substitution σ (See Appendix C for derivation). If distance has a positive impact on the productivity threshold, then the aggregate sales of foreign affiliates decrease in distance (equation 9). Considering the sales of the foreign affiliate with average productivity, $as_{ij} = \left(\frac{\kappa}{\kappa-\sigma+1}\right)\left(\omega_{ij}^{MNE}\right)^{(\sigma-1)}$, it follows that distance has a positive effect on average size of a foreign affiliate if the distance effect on the productivity threshold is positive. Thus, in the second model, distance has a negative effect on *aggregate sales* but a positive effect on *average sales* of foreign affiliates. Hence, the effect on the number of foreign affiliates, n_{ij}, must go in the same direction as the effect on aggregate sales. Moreover, if aggregate sales fall with distance, the number of foreign affiliates has to fall even stronger to compensate the increase of average size of the foreign affiliate. Hence, we have

$$\frac{\partial n_{ij}}{\partial \omega_{ij}^{MNE}} \frac{\partial \omega_{ij}^{MNE}}{\partial D_{ij}} = -\kappa (\omega_i^{Dom})^{\kappa} (\omega_{ij}^{MNE})^{\kappa-1} \frac{\partial \omega_{ij}^{MNE}}{\partial D_{ij}} < 0, \quad if \quad \frac{\partial \omega_{ij}^{MNE}}{\partial D_{ij}} > 0$$
$$\frac{\partial as_{ij}}{\partial \omega_{ij}^{MNE}} \frac{\partial \omega_{ij}^{MNE}}{\partial D_{ij}} = \frac{\kappa(\sigma-1)}{\kappa-\sigma+1} \left(\omega_{ij}^{MNE}\right)^{(\sigma-2)} \frac{\partial \omega_{ij}^{MNE}}{\partial D_{ij}} > 0, \quad if \quad \frac{\partial \omega_{ij}^{MNE}}{\partial D_{ij}} > 0$$

The empirical strategy allows a clear discrimination between both models and thereby an assessment of the importance of the intensive and the extensive margins of activities. We present in Appendix A the results of a unified model that builds imported intermediate inputs into the model with heterogenous firms. We show that the distance effect on the average size of the affiliate is ambiguous. The unified framework does not allow this clear discrimination we intended to make. The reason is that the selection effect and the intermediate input effect on average size go in opposite directions. This is also why we do not present the unified framework in the main text.

We estimate gravity equations, that explain the impact of distance costs on (i) aggregate foreign affiliates sales, (ii) average affiliate sales, and (iii) the number of foreign affiliates active abroad. We decompose *market capacity* $m_j = Y_j P_{Mj}^{1-\sigma}$ into its income and its weighted price level components, Y and P. While we argue that the coefficient of the *market capacity* variable is one, that does only apply to the income variable, when we also control for the price level component. We proxy the income variable by host country's GDP.

The *supply capacity* is proportional to home country's income in both models. We proxy the supply capacity by home country's GDP. As argued above, the coefficient of home country's GDP is constrained to one.

Finally, the distance between countries is proxied by the great arc distance between the largest city of any two countries.

3.2 Data

Data on bilateral activities of multinational firms are rare. For our purpose, we use the OECD *Measuring Globalization* database. It contains information on sales of foreign affiliates and their number for 21 OECD countries and about 50 partner countries from 1983 to 2001. Unfortunately, the database does not have all information for all combinations of country and year. We work with aggregated data for manufacturing to achieve the widest possible country coverage. Moreover, we restrict our analysis to the period from 1991 to 2001, because the number of observations for the eighties is very low. The sales data are converted into US dollar.

The resulting sample is very unbalanced. Overall, there are 1885 observations on affiliate sales and 1052 observations on the number of affiliates in the sample. There are 755 combinations of year, home and host country, for which we find observation on both the number of affiliates and their sales. For the activities of six host countries (Australia, Canada, Czech Republic, Hungary, Ireland, United States) there is no year-home country combination for which both information is available. This reduces the number of OECD countries in our sample to 15. The observations are not evenly distributed over time. Their number reaches from 106 observations in 1999 to 355 observations in 1994. They are also not evenly distributed regarding their cross-section dimension. They reach from 3 observations for Denmark to 86 observations for Germany.

Since a large share of the observations in the OECD sample is German data, we use the MiDi database (Microdatabase Direct Investment) of the *Deutsche Bundesbank* to assess the robustness of our results.[4] This database comprises firm level information on foreign affiliate sales of German multinational firms. The MiDi database covers a very large share of German multinational firms, because the reporting limits are fairly low. Up to 2002, the activities of foreign affiliates with annual sales of more than 1 million DM (500.000 Euro in 2001) must compulsory be reported to the German Bundesbank. In 2002, the reporting thresholds were raised to annual sales of 3 million Euro. We aggre-

[4] For a description of the database see Lipponer 2006.

gate foreign affiliates' sales and the number of foreign affiliates from each of the 16 German states in 116 countries for each year between 1989 and 2004. We restrict however our analysis to the period from 1991 to 2001 to consider the same time period as for the OECD database. These sales data are also converted into US dollar.

Regarding the explanatory variables, we retrieve the GDP data in US dollar from the WDI database of the World Bank. The price level is taken from the OECD *Comparative Price Level* database. We convert the bilateral price level indexes into an index of countries' price level relative to the OECD average. Using OECD price level data further strongly reduces the sample by restricting it to 21 OECD partner countries.[5] That excludes developing countries from the analysis but makes the results more closely comparable to the sample based on the OECD database. Distance is taken from the CEPII distance database[6] which contains the distance between the largest city of any two countries. We use the great arc distance between the largest cities of German states and their partner in the German sample.

Table 1 provides the summary statistics of our data.

Before we interpret the results, we briefly mention two econometric issues of the specified model. First, since the number of affiliates is a count variable, we use Poisson regression techniques for the equation explaining the number of foreign affiliates. Second, we use the Huber-White method to correct for serially correlated country pairs (Wooldridge 2002).

[5] Australia, Canada, Czech Republic, Denmark, Finland, France, Hungary, Ireland, Italy, Japan, Luxembourg, Mexico, Netherlands, Norway, Poland, Portugal, Spain, Sweden, Turkey, United Kingdom, United States

[6] www.cepii.fr

Table 1
Summary Statistics

Variable	Obs.	Mean	Std. Dev.
	OECD Sample		
ln Foreign Affiliates Sales	713	7.625	1.903
ln Average Sales	713	3.868	0.982
Number of Affiliates	713	3.757	1.390
ln GDP Home	713	27.768	1.271
ln GDP Host	713	27.000	1.228
ln Distance	713	7.861	1.199
Price Index	713	92.888	30.801
Border	713	0.123	0.329
Former Colony	713	0.052	0.222
	German Sample		
ln Foreign Affiliates Sales	6782	10.998	2.206
ln Average Sales	6782	9.727	1.371
Number of Affiliates	6782	8.832	16.405
ln GDP Home	6782	11.887	0.846
ln GDP Host	6567	11.832	1.649
ln Distance	6782	8.072	1.140
Price Index	3168	87.719	26.638

4 Results

We present results from 4 regressions for both samples. Specification (S1) is the gravity equation (6) and (11) explaining foreign affiliate sales. Thereby, (S1) explicitly accounts for the parameter restriction on the coefficients of the GDP of the home country ζ and the GDP of the host country ξ discussed above. Both coefficients are constrained to one. Specification (S2) is the gravity equation (6) and (11) explaining foreign affiliate sale but estimates ζ and ξ. Specification (S3) and (S4) are gravity equations explaining average affiliate sales and the number of foreign affiliates, respectively.

4.1 The OECD Sample

The effect of the gravity variables on foreign affiliates sales, average sales of a foreign affiliate and, the number of foreign affiliates in the OECD countries is

Table 2
Gravity Equation explaining Total foreign sales, Average foreign sales and the Number of Affiliates: OECD Sample

	Constrained Model	Unconstrained Model		
	(S1)	(S2)	(S3)	(S4)
	A_{ij}	A_{ij}	a_{ij}	$n_{ij}^{\dagger}$
GDP_{home}	1.00	0.534***	0.173***	0.456***
		(0.105)	(0.050)	(0.143)
GDP_{host}	1.00	0.779***	0.336***	0.510***
		(0.113)	(0.048)	(0.080)
Distance	-0.506***	-0.378***	0.016	-0.320***
	(0.049)	(0.103)	(0.050)	(0.106)
Price Level	-0.001	0.005	0.004	-0.011**
	(0.002)	(0.005)	(0.004)	(0.004)
Constant	-43.096***	-25.778***	-10.476***	-18.606***
	(0.426)	(4.381)	(1.928)	(3.999)
Observations	713	713	713	713
R^2		0.43	0.29	
LR-statistics	112.457***			
p-value	0.000			

Robust standard errors in parentheses.
Standard errors have been adjusted for clustering around country pairs.
$n_{ij}^{\dagger}$: Poisson regression
*** denotes statistical significance at one percent level of significance.
** denotes statistical significance at five percent level of significance.
* denotes statistical significance at ten percent level of significance.

shown in Table (2). Specification (S1) presents the results of the constrained model and the LR-statistics on the validity of the constraints. The results of the unconstrained models are presented in specifications (S2) to (S4).

The results in (S2) confirm earlier results from gravity equations. While home and host country GDP affect foreign affiliate sales positively, distance between the two countries affects sales negatively. All three coefficients are significant at one percent. In particular the coefficient on home country GDP is smaller than one. The restriction on both coefficients in (S1) is therefore rejected at the one percent level of significance. Although the gravity equation suggests that the coefficients on both GDP variables are one, this restriction is not consistent with the data.

The gravity equation related to the number of foreign affiliates (S4) shows basically the same effects as the one presented in specification (S2). The effect of distance on foreign affiliates' sales is larger (in absolute terms) than on the number of foreign affiliates. Yet, the difference between both coefficients is not statistically significant ($F(1, 168) = 0.32, p{-}value = 0.574$). This insignificant difference can also be read from (S3). The effect of distance on average sales of foreign affiliates is positive but insignificant. Thus, distance affects total affiliate sales negatively through reducing the number of affiliates in a foreign country but not by changing the average size of the foreign affiliate.

Concerning the channel through which distance costs affects aggregate affiliates' sales, our results give support only to the extensive margin. We find two main results. First, distance affects both, affiliates sales and the number of foreign affiliates negatively. In more distant markets, fewer firms are active. The symmetric firm model with specific intermediate goods, does not feature this selection process by assumption. Second, average sales of a foreign affiliate are unaffected by distance. The heterogenous firm model predicts increasing average sales with increasing distance whereas the specific intermediate goods model predicts decreasing average sales with increasing distance. We show in the unified model in Appendix A that when both channels are at work we cannot disentangle the effect in the data. That might explain the insignificant coefficient.

While distance does not have a significant effect on average sales of a foreign affiliate, the size of the home market has a positive effect on the average sales. This gives support to the selection effect in the heterogenous firm model. In this model, sales of foreign affiliates are proportional to the sales of their parent firm. Parent firms, however, are larger in larger countries if productivity, and therefore firm size, is log-normal or Pareto distributed. [7] Thus, home country's size affects the average size of a foreign affiliate positively in the heterogenous firm model. In the symmetric firm model larger countries host more but not larger affiliates.

In Table (3), we conduct a number of robustness tests by including three dummy variables. First, we construct a border dummy that takes the value of one if two countries share the same border and zero otherwise. Second, we include a dummy variable that takes the value of one for a pair of countries which used to be in a colonizer-colony relationship and the value of zero otherwise. Third, we include a common language dummy variable that takes the value of one if a language is spoken by at least 9% [8] of the population in both countries and zero otherwise.

The results regarding the dummy variable indicating a neighboring country (Border) are also in line with earlier finding (Barba-Navaretti and Venables 2004). Activities in neighboring countries are significantly higher than predicted by their size and distance alone. The border effect for the number of firms is not statistically distinguishable from that for foreign affiliates sales ($F(1, 168) = 0.04, p - value = 0.848$). The border coefficient is negative but has no significant impact on average sales of foreign affiliates. Note that the distance coefficient becomes smaller when we include the border dummy variable. This is in line with the previous results since there are more foreign affiliates in countries that are closer. We find a positive coefficient for the colonial relationship variable on foreign affiliate sales and the number of affiliates abroad. The effect on average sales, in contrast, is insignificant. There is no significant effect of common language on foreign activities of multinational firms.

[7] See Sutton (1997) and Axtell (2001) for empirical analyses of firm distributions.
[8] The variable is taken from the CEPII Database.

Table 3
Robustness Tests: OECD Sample

	A_{ij}	a_{ij}	$n_{ij}^{\dagger}$
GDP_{home}	0.544***	0.170***	0.415***
	(0.100)	(0.050)	(0.094)
GDP_{host}	0.714***	0.358***	0.398***
	(0.112)	(0.049)	(0.077)
Distance	-0.309***	-0.008	-0.194
	(0.112)	(0.049)	(0.138)
Price Level	0.006	0.003	-0.006*
	(0.005)	(0.003)	(0.003)
Border	0.815**	-0.229	0.888**
	(0.379)	(0.148)	(0.372)
Colonial relationship	1.270***	0.016	1.195***
	(0.431)	(0.250)	(0.346)
Common language	-0.496	-0.261	0.225
	(0.565)	(0.326)	(0.533)
Constant	-25.055***	-10.745***	-16.070***
	(4.362)	(1.912)	(2.951)
Observations	713	713	713
R-squared	0.46	0.30	

Robust standard errors in parentheses.
Standard errors have been adjusted for clustering around country pairs.
$n_{ij}^{\dagger}$: Poisson regression
*** denotes statistical significance at one percent level of significance.
** denotes statistical significance at five percent level of significance.
* denotes statistical significance at ten percent level of significance.

4.2 The German Sample

We conduct the same analysis using the German *MiDi* database because the results from the OECD sample might be affected by its unbalanced structure. The German data, in contrast, are balanced. We construct the aggregated data from a firm-level database which entails information on *all* foreign affiliates of German multinational firms if they exceed the reporting limit. We aggregate the micro data for each combination of German State, host country and year. [9] We adjust the distance variable to the distance between the largest

[9] We are not aware of any bias we could incur by treating German states as home countries.

Table 4
Gravity Equation explaining Total foreign sales, Average foreign sales and the Number of Affiliates: German Sample

	Constrained Model	Unconstrained Model		
	(S1)	(S2)	(S3)	(S4)
	A_{ij}	A_{ij}	a_{ij}	$n^{\dagger}_{ij}$
GDP_{home}	1.00	1.481***	0.407***	1.129***
		(0.088)	(0.060)	(0.055)
GDP_{host}	1.00	0.884***	0.330***	0.620***
		(0.075)	(0.049)	(0.045)
Distance	-0.531***	-0.506***	-0.044	-0.486***
	(0.026)	(0.079)	(0.056)	(0.043)
Price Level	-0.014***	-0.012***	0.003*	-0.016***
	(0.001)	(0.003)	(0.002)	(0.002)
Constant	-7.315***	-11.815***	1.284	-14.050***
	(0.226)	(1.293)	(0.842)	(0.845)
Observations	2964	2964	2964	2987
R-squared		0.50	0.21	
LR-statistics	69.072***			
p-value	0.000			

Robust standard errors in parentheses.
Standard errors have been adjusted for clustering around country pairs.
$n^{\dagger}_{ij}$: Poisson regression
*** denotes statistical significance at one percent level of significance.
** denotes statistical significance at five percent level of significance.
* denotes statistical significance at ten percent level of significance.

city in the partner country and the capital of the German state. The sample shrinks strongly, because price level data is only available for OECD countries. Our samples comprises of 2987 observations. 23 state-country combinations, although existent, report affiliate sales of zero. We estimate OLS regressions comparable to those for the OECD sample.

Table (4) presents the coefficient of the OLS gravity equations. The results are qualitatively very similar to the results for the OECD sample presented in Table (2).

As for the OECD sample, the likelihood ratio test rejects the validity of the constraints at the one percent level of significance. This results from the coef-

Table 5
Robustness Tests: German Sample

	A_{ij}	a_{ij}	$n^{\dagger}_{ij}$
GDP_{home}	1.331***	0.351***	1.037***
	(0.088)	(0.064)	(0.055)
GDP_{host}	0.929***	0.352***	0.620***
	(0.071)	(0.065)	(0.043)
Distance	-0.515***	-0.065	-0.434***
	(0.077)	(0.058)	(0.039)
Price Level	-0.015***	0.002	-0.017***
	(0.003)	(0.002)	(0.002)
State-Border	0.676*	0.028	0.492**
	(0.360)	(0.238)	(0.221)
East German States	-1.849***	-0.707***	-1.391***
	(0.244)	(0.202)	(0.131)
Constant	-10.215***	1.977**	-13.247***
	(1.201)	(0.848)	(0.837)
Observations	2964	2964	2987
R-squared	0.55	0.23	

Robust standard errors in parentheses.
Standard errors have been adjusted for clustering around country pairs.
$n^{\dagger}_{ij}$: Poisson regression
*** denotes statistical significance at one percent level of significance.
** denotes statistical significance at five percent level of significance.
* denotes statistical significance at ten percent level of significance.

ficient of German state GDP, which is well above unity. The large coefficient of the GDP_{home} variable might result from the low internationalization level of firms in the low GDP states in East Germany. Firms in East Germany have started to internationalize their activities only in 1991. In order to control for this effect, we include a dummy variable which is takes the value of one for East German State and zero otherwise. Additionally, we include a State-border dummy which takes the value one if a German state and a partner country share a common border and zero otherwise. Our empirical results are robust to the introduction of the dummy variables. The results are shown in Table (5).

The state-border dummy variable has a significant and positive effect on foreign affiliate sales and the number of affiliates in a particular partner country.

The coefficient in the regression explaining average sales, in contrast, is not significant. The distance coefficient is not affected by the inclusion of the state-border dummy variable. The East German dummy variable is significantly negative at one percent level of significance in all three regressions. East German firms have less and smaller foreign affiliates than firms from West Germany. That stems from the late start of their internationalization process.

In sum, the results from the German sample confirm that aggregated sales of foreign affiliates fall in distance and that this fall is mainly due to the smaller number of affiliates that are active in more distant countries.

5 Conclusion

In this paper, we present two models of multinational firms that predict that aggregated affiliates' sales fall in distance. Moreover, we derive a gravity equation explaining aggregate foreign affiliate sales as reduced form from both models. Yet, although the reduced form is the same the structure behind it differs. That allows us to discriminate between the two models we proposed and to assess their relative importance. In particular, distance affects the number of affiliates negatively, i.e. the extensive margin, only in the heterogenous firm model. The models differ also with respect to the distance effect on the average size of a foreign affiliate, i.e. the intensive margin. While distance affects the size of the average affiliate positively in the heterogenous firm model, it affects size negatively in the specific intermediate goods model.

For the empirical assessment of the relative importance of the extensive and the intensive margin of activities, we use a panel of 16 host countries reporting activities of multinational firms from about 50 home countries in the time period from 1991 to 2001. The data set comes from the OECD *Measuring Globalization* database. We used aggregate sales of foreign affiliates and their number in every host country broken down by the home country of the parent firms. Unfortunately, the data is very unbalanced. We therefore verified the robustness of our results using a German data set at the level of German states.

Our results demonstrate the importance of the extensive margin of activities. The number of foreign affiliates of firms from a particular home country in a particular host country decreases in the distance between the two countries. Additionally, neighboring countries receive an over-proportional share of foreign affiliates. The fall in the number of affiliates in more distant foreign countries explains a very large fraction of the fall in total affiliate sales in these countries. Yet, there might also be adjustment along the intensive margin. Distance does not significantly affect the average size of foreign affiliates, neither positively nor negatively as predicted by our models. Since the distance induced effect of intermediate goods and selection of heterogenous firms operate in opposite directions, the insignificant effect of distance on average affiliate sales might result from their combined effect.

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Appendices

A Including Imported Intermediates into the Heterogenous firms' Model: Results from an Unified Model

We present the results of an unified model that integrates the costs structure of the intermediate good model into the heterogeneous firm framework. The marginal cost of firm k is thus given by $c_k = \frac{1}{\omega_k}(\frac{w_j}{\epsilon})^{\epsilon}(\frac{q_i \tau_{ij}}{1-\epsilon})^{1-\epsilon} = \frac{1}{\omega_k} c_i$.

The productivity threshold defined in equation (8c) becomes

$$\left(\omega_{ij}^{MNE}\right)^{\sigma-1}\left(\tau^{(1-\epsilon)(1-\sigma)} - \tau^{1-\sigma}\right) c_i \frac{(1-\mu)Y_j(1-\rho)}{P_{Mj}^{1-\sigma}\rho^{1-\sigma}} = f_{ij}^{MNE} - f_{ij}^{Ex} \qquad (8c')$$

So that the aggregate sales in equation (9) becomes

$$\begin{aligned} AS_{ij} &= \int_{\omega_{ij}^{MNE}}^{\infty} c_i^{(1-\sigma)} \tau_{ij}^{(1-\sigma)(1-\epsilon)} (\omega_k \rho)^{\sigma-1} g(\omega) \frac{(1-\mu)Y_j}{P_j^{1-\sigma}} d\omega_k \\ &= \left(\frac{\omega_i^{Dom}}{\omega_{ij}^{MNE}}\right)^{\kappa} c_i^{(1-\sigma)} \tau_{ij}^{(1-\sigma)(1-\epsilon)} \left(\frac{\kappa}{\kappa-\sigma+1}\right) \left(\omega_{ij}^{MNE}\right)^{(\sigma-1)} \frac{\rho^{\sigma-1}(1-\mu)Y_j}{P_j^{1-\sigma}} \end{aligned} \qquad (9')$$

Assuming as before that the distance costs are function of distance, $\tau_{ij} = \lambda_1 D_{ij}^{\eta_1}$, it follows from equation (9') that the effects of distance on average size, $as_{ij} = c_i^{(1-\sigma)} \tau_{ij}^{(1-\sigma)(1-\epsilon)} \left(\frac{\kappa}{\kappa-\sigma+1}\right) \left(\omega_{ij}^{MNE}\right)^{(\sigma-1)}$, of the affiliate is ambiguous. It reduce the average size of the affiliate through the intermediate inputs' channel but increase this size through the threshold productivity channel. We derive the average size of the affiliate in the equation below

$$\frac{\partial as_{ij}}{\partial D_{ij}} = c_i^{(1-\sigma)} \lambda_1^{(1-\sigma)(1-\epsilon)} \left(\frac{\kappa}{\kappa-\sigma+1}\right) [\left(\eta_1(1-\sigma)(1-\epsilon) D^{\eta_1(1-\sigma)(1-\epsilon)-1}\right) \left(\omega_{ij}^{MNE}\right)^{(\sigma-1)}$$

$$+ (\sigma-1) \left(\omega_{ij}^{MNE}\right)^{(\sigma-2)} \frac{\partial \omega_{ij}^{MNE}}{\partial D_{ij}} \left(D_{ij}^{\eta_1}\right)^{(1-\sigma)(1-\epsilon)}]$$

$$= \left[c_i^{(1-\sigma)} \left(\lambda_1 D_{ij}^{\eta_1}\right)^{(1-\sigma)(1-\epsilon)} \left(\frac{\kappa}{\kappa-\sigma+1}\right) (\omega_{ij}^{MNE})^{\sigma-1}\right]$$

$$\times \left[\underbrace{\left(\eta_1(1-\sigma)(1-\epsilon)D^{-1}\right)}_{<0} + \underbrace{(\sigma-1)(\omega_{ij}^{MNE})^{-1} \frac{\partial \omega_{ij}^{MNE}}{\partial D_{ij}}}_{>0}\right]$$

B Derivation of Equation (9)

We use the pareto distribution of productivity with the shape parameter κ and the scale parameter ω_{ij}^{Dom} to aggregate over foreign affiliate sales of firms k.

$$\begin{aligned}
AS_{ij} &= \int_{\omega_{ij}^{MNE}}^{\infty} (\omega_k \rho)^{\sigma-1} g(\omega) \frac{(1-\mu)Y_j}{P_j^{1-\sigma}} d\omega_k \\
&= \frac{\rho^{\sigma-1}(1-\mu)Y_j}{P_j^{1-\sigma}} \int_{\omega_{ij}^{MNE}}^{\infty} \omega_k^{\sigma-1} \left(\frac{\kappa}{\omega_k}\left(\frac{\omega_i^{Dom}}{\omega_k}\right)^{\kappa}\right) d\omega_k \\
&= \left[0 - \left(\frac{\kappa}{\sigma-\kappa-1}\right) \left(\omega_{ij}^{MNE}\right)^{(\sigma-1-\kappa)}\right] \left(\omega_i^{Dom}\right)^{\kappa} \frac{\rho^{\sigma-1}(1-\mu)Y_j}{P_j^{1-\sigma}} \\
&= \left(\frac{\omega_i^{Dom}}{\omega_{ij}^{MNE}}\right)^{\kappa} \left(\frac{\kappa}{\kappa-\sigma+1}\right) \left(\omega_{ij}^{MNE}\right)^{(\sigma-1)} \frac{\rho^{\sigma-1}(1-\mu)Y_j}{P_j^{1-\sigma}}
\end{aligned}$$

C Distance Costs' Effect on the Minimum Productivity Threshold

We use equation (8c) to derive the effect of distance on the critical level of productivity. We assume that fixed costs are a linear function of distance in a similar way as variable distance costs. Hence, $(1-\phi) f_{ij}^{MNE} = f D_{ij}$ and $\tau_{ij} = \lambda_1 D_{ij}^{\eta_1}$. Substituting this functional forms into equation (8c) gives:

$$\left(\omega_{ij}^{MNE}\right)^{\sigma-1}\left(1-\tau_{ij}^{1-\sigma}\right)\frac{(1-\mu)Y_j(1-\rho)}{P_j^{\sigma-1}\rho^{1-\sigma}}=fD_{ij}$$

$$\Leftrightarrow \omega_{ij}^{MNE}=\left(1-\left(\lambda_1 D_{ij}^{\eta_1}\right)^{1-\sigma}\right)^{\left(\frac{1}{1-\sigma}\right)}\Omega^{\left(\frac{1}{1-\sigma}\right)}fD_{ij}^{\left(\frac{1}{\sigma-1}\right)}$$

where $\Omega=\frac{(1-\mu)Y_j(1-\rho)}{P_j^{\sigma-1}\rho^{1-\sigma}}$.

We derive the effect of distance on the critical level of productivity as

$$\frac{\partial\omega_{ij}^{MNE}}{\partial D_{ij}}=\Omega^{\left(\frac{1}{1-\sigma}\right)}\left[\underbrace{\left(-\lambda_1\eta_1 fD_{ij}^{1-\sigma\eta_1}\right)\left(1-\left(\lambda_1 D_{ij}^{\eta_1}\right)^{1-\sigma}\right)^{\frac{\sigma}{1-\sigma}}}_{<0}+\underbrace{\frac{1}{\sigma-1}fD_{ij}^{\frac{2-\sigma}{\sigma-1}}\left(1-\lambda_1 D_{ij}^{1-\sigma}\right)^{\frac{1}{1-\sigma}}}_{>0}\right]$$

This first term gives the effect of variable distance costs on the productivity threshold. The effect is negative. The second term gives the effect of distance dependent fixed costs on the productivity threshold level. The effect is positive. The total effect of distance depends on f, λ_1 and σ. The productivity threshold decreases in f and increases in λ_1 and σ. Finally, rewriting the above equation, we show that the effect of distance on the productivity threshold is always positive for distances that are not too small.

$$\begin{aligned}\frac{\partial\omega_{ij}^{MNE}}{\partial D_{ij}}=&\,\Omega^{\left(\frac{1}{1-\sigma}\right)}fD_{ij}^{\frac{\sigma}{1-\sigma}}\left(1-\left(\lambda_1 D_{ij}^{\eta_1}\right)^{1-\sigma}\right)^{\frac{1}{1-\sigma}}\\&\times\left[\frac{1}{\sigma-1}-\eta_1\lambda_1^{1-\sigma}D_{ij}^{-\eta_1(\sigma-1)}\left(1-\left(\lambda_1 D_{ij}^{\eta_1}\right)^{1-\sigma}\right)^{-1}\right]\\=&\,\Omega^{\left(\frac{1}{1-\sigma}\right)}fD_{ij}^{\frac{\sigma}{1-\sigma}}\left(1-\left(\lambda_1 D_{ij}^{\eta_1}\right)^{1-\sigma}\right)^{\frac{1}{1-\sigma}}\left[\frac{1}{\sigma-1}-\frac{\eta_1\lambda_1^{1-\sigma}}{D_{ij}^{\eta_1(\sigma-1)}-\lambda_1^{1-\sigma}}\right]\end{aligned}$$

$$\frac{\partial\omega_{ij}^{MNE}}{\partial D_{ij}}>0\quad iff\quad D_{ij}>\left(\eta_1\lambda_1^{(1-\sigma)}(\sigma-1)+\lambda_1^{(1-\sigma)}\right)^{1/(\eta_1)}$$