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Gravity for FDI

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Detailed information on past workshops and the planning for the 2006 workshop are available at http://www.vwl.wiso.uni-goettingen.de/workshop. Do not hesitate to contact Dr. Carsten Eckel, *CeGE* (carsten.eckel@wiwi.uni-goettingen.de) for further questions.

Gravity for FDI [⋆]

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Abstract

We derive gravity equations from three different general equilibrium models incorporating multinational firms. We show that gravity equations are particularly adapted to the analysis of foreign affiliates' activities of multinational firms. However, the different theoretical models lead to different specifications and interpretations of the empirical results. This is particularly the case considering gravity equations derived from factor proportion models compared to those derived from proximity concentration theories.

Keywords: Gravity equation, multinational firms, heterogeneity.

JEL classification: F23, F12, C21

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1 Introduction

The gravity equation is probably one of the most often applied empirical techniques to analyze bilateral trade and factor flows. It is only recently that it has been applied to the empirical analysis of cross-border long term capital flows or cross-border multinational activities (Brainard, 1997; Braconier *et al.*, 2002; Egger and Pfaffermayr, 2004). Indeed, it usually provides a good fit. While country's market size affects positively the volume of affiliate sales, distance affects them negatively. Theoretically, distance raises the costs of exporting and influences positively the decision to set-up affiliates in foreign countries. Yet, there are *a priory* no raisons, why distance should matter for the volume of their sales.

This study goes beyond the existing literature by shedding light on the theoretical mechanisms through which distance influences negatively the volume of affiliates' sales. Moreover, it provides the theoretical underpinnings of the gravity equation applied to the analysis of cross-border multinational sales. To the best of our knowledge this question has not been examined in the context of foreign direct investment (FDI). We derive these equations from general equilibrium models that incorporate multinational firms. Even if the gravity equations look similar, we show that their underlying structures are different.

The first model refers to the proximity-concentration theory. Firms face a trade-off between concentrating their productions at home and setting-up affiliates abroad to reach arm-length consumers. We assume a n country model of monopolistic competition that uses the property of the CES utility function with symmetric firms. We show that the derived structural gravity equation looks similar to the Redding and Venables (2004) type of gravity equation, which is applied to international trade. In fact, the level of affiliate sales does not only depend on domestic characteristics (the size of the home market and the domestic price index) but it is also influences by the same host country determinants. In our model, the bilateral trade cost affects negatively foreign affiliate sales because we assume that affiliate production required the use of intermediate inputs that are imported from the domestic country. Hence, foreign production costs increase in distance.

We assume so far that firms are symmetric with respect to their variable production costs. This assumption might be too restrictive regarding the huge amount of heterogeneity found in firm-level database on multinational sales (Buch *et al.*, 2005). Our second model, which is also derived from the proximity-concentration theory, build on recent theoretical literature that has stressed the importance of firms' relative productivity level for their mode of entry on international markets (Helpman *et al.* 2004; Melitz 2003). As in Helpman *et al.* (2004), we show that the mode of entry into foreign markets depend on a threshold value of productivity. Thus the equilibrium is characterized by the coexistence of multinational firm, exporters and domestic firms. In fact, the most productive firms become multinationals, the less productive firms become exporters while the least productive firms serve domestic market. Moreover, we show that multinational foreign affiliates' sales depend on a set of home and host country characteristics (market size and price index). However, we assume that fixed costs of market entry increase with distance. Consequently, the productivity threshold value is also positively affected by distance costs. In equilibrium, we find that the number of affiliates active abroad decreases with distance but their average size increases. Thus, the typical gravity equation is derived with positive effects of home and host country's market size and a negative effect of distance on aggregate sales of foreign affiliates.

The last model is a two-country factor-proportion model of fragmentation.

Multinational firms geographically fragment their production process into stages based on factor intensities and locate activities according to international differences in factor prices(Helpman, 1984; Markusen, 1984; Markusen, 2002). They invest abroad to reduce the overall cost of production and affiliates' sales are also encouraged by low distance costs. This type of multinational firm, also called vertical multinational firms, are likely to arise when their stages of production use different factor intensities and when countries have different factor endowments and/or factor-prices. As in the two preceding models, we derive a gravity equation where home and host countries' market size influence positively affiliate sales, while distance reduce them.

The paper is structured as follow. In the following sections, we derive the theoretical explanations for the gravity equation applied to multinational sales. In section 2, we derived a gravity equation from the proximity-concentration theories. In Section 3, we depart from the assumption of symmetric firm, and present a heterogeneity-based gravity equation. In Section 4, we derived a gravity equation consistent with factor-proportion theories. In Section 5, we discuss the estimation strategy and present the estimation results. We conclude in section 6

2 Foreign Production with Domestic Intermediate Inputs

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):

$$U_j = C_{A,j}^{\mu} C_{M,j}^{(1-\mu)} \tag{1}$$

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

$$C_{M,j} = \left[\sum_{i=1}^{R} n_i x_{ij}^{(\sigma-1)/\sigma} \right]^{\sigma/(\sigma-1)} \tag{2}$$

n_i is the number of varieties produced by firms from country i, while x_{ij} is country j's consumption of a single variety produced by a country i's firm. σ is the elasticity of substitution which is 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. All varieties are assumed to be symmetric. The price index in the manufacturing sector given in (3) corresponds to the CES sub-utility function.

$$P_{M,j} = \left[\sum_{i=1}^{R} n_i p_{ij}^{1-\sigma} \right]^{1/(1-\sigma)} \tag{3}$$

Given the total demand $(1-\mu)Y_j$ on differentiated products in country j which is derived from equation (1), the demand for each variety is given by equation (4)

$$x_{ij} = p_{ij}^{-\sigma}(1-\mu)Y_j P_j^{\sigma-1} \tag{4}$$

Quantities that are sold in foreign markets depend therefore on good i's own price in country j, on the price index in j and on j's market size.

Firm 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 equation (5) holds

$$\pi_i^{MNE} - \pi_i^{Ex} > 0 \Leftrightarrow (1-\rho)[p_{ij}^{MNE} x_{ij}^{MNE} - p_{ij}^{Ex} x_{ij}^{Ex}] > f_j, \tag{5}$$

f_j corresponds to the fixed costs for an additional plant in country j. The entry of multinational firms is determined by the level of the additional fixed costs but also the sales in the foreign market. As seen in equation (5), this depends on the prices of the exported good p_{ij}^{Ex} relative to the prices of the good produced locally p_{ij}^{MNE}.

Following the traditional literature on gravity equation, we assume that exports incur distance costs. We assume distance costs to be of iceberg-type. We denote distance costs between country i and j τ_{ij} [1] . Hence, $p_{ij}^{Ex} = p_{ii}\tau_{ij}$. However, we depart from the traditional literature and assume that multinational firms are not footloose. In fact, production of multinationals' affiliates rely on intermediate goods which are imported from the home country. The technology for producing a variety of an i firm in country j can be characterized by the variable cost function (6)

$$C_j = \left(\frac{w_j}{\alpha}\right)^{\alpha} \left(\frac{q_{ij}}{1-\alpha}\right)^{1-\alpha} \tag{6}$$

q_{ij} is the price for the intermediate good used in the foreign affiliate of firm i in country j. The cost function is derived from a Cobb-Douglas production function with cost share α for labor and $1-\alpha$ for the intermediate good. Like the price of differentiated manufacturing goods, the price of the intermediate good is 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 the marginal costs, $p_{ij} = c_{ij}/\rho$, prices of goods produced in foreign affiliates increase in distance costs. Consequently quantities sold decrease. Nevertheless, profits from producing abroad might be higher than from exporting. The value of total production in affiliates of country i's firms in country j is therefore

$$n_i p_{ij} x_{ij} = n_i p_{ii}^{1-\sigma} [(1-\alpha)\tau_{ij}]^{1-\sigma} (1-\mu) Y_j P_j^{\sigma-1} \tag{7}$$

[1] If $\tau_{ij} = 1$ then trade is costless, while $\tau_{ij} - 1$ measures the proportion of output lost in shipping from i to j.

This equation for bilateral sales of foreign affiliates provides one basis for a gravity equation of FDI. It contains supply characteristics of the home country i of FDI and demand characteristics of the host country j. The term $(1-\mu)Y_jP_j^{\sigma-1}$ is host country j's market capacity. The term $n_ip_{ii}^{1-\sigma}$ measures what Redding and Venables (2003) refer to as the '*supply capacity*' of the home country. Following Redding and Venables (2003), we denote market capacity by m_j and supply capacity by s_i to derive

$$n_ip_{ij}x_{ij} = s_i[(1-\alpha)\tau_{ij}]^{1-\sigma}m_j \tag{8}$$

We denote bilateral sales of foreign affiliates with AS_{ij}. Distance costs, τ_{ij}, are an increasing function of geographical distance between country i and j, D_{ij} with $\tau_{ij} = \tau D_{ij}$ and τ being unit distance costs. Then, equation (8) can be written in log-linearized form as

$$ln(AS_{ij}) = \alpha_1 + ln(s_i) - \beta_1 ln(D_{ij}) + ln(m_j) \tag{9}$$

where $\alpha_1 = (1-\sigma)[ln(1-\alpha) - ln(\tau)]$ and $\beta_1 = (1-\sigma)$

3 Fixed Costs Increasing in Distance

As in the preceding section we consider two sectors of production, A and M. We assume consumers' preferences to be described by the same utility and sub-utility function as in equations (1) and (2).

We depart now from the assumption of symetric firm and incorporate Melitz's (2003) idea of heterogenous firms. We assume therefore that firms have different level 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 $1/a_k$. Profit maximization yields to a fixed markup over the marginal costs a_k of ρ. Thus, the price of firm k located in i and selling in country j, $p_{kij} = a_{kij}/\rho$ leads to firm specific quantities in j. Equation (4), which described the optimal quantity sold in country j by a firm located in country i in our symmetric firm model above translates into equation (10) that considers firm-specific productivity levels.

$$x_{kij} = p_{kij}^{-\sigma}(1-\mu)Y_j P_j^{\sigma-1} \tag{10}$$

Although denoted by the same variable, the price index, P_j, in country j is not the same as in the symmetric case described in equation (3). First, it is affected by the difference in productivity between firms and thus their different prices and quantities. Second, it is influenced by the channel firms choose to serve the market. In fact, firms from country i can serve consumers in market j through export or through affiliates' production. Depending on their productivity level $1/a_k$, firms decide through which channel they will supply foreign markets. For sake of simplicity, we present the aggregate variables in a continuous version using integrals instead of sums. Hence, the price index of country j (3) changes to (11).

$$P_j = \left[\int_0^{n_j} \left(p_{kij}^h\right)^{1-\sigma} dk\right]^{1/(1-\sigma)} \tag{11}$$

Where n_j is the number of firms selling goods in j and p_{kij}^h is the price of firm k in market j that depends on the mode of entry h. The subscript h, $h = Ex, MNE$, indicates whether a firm is an exporter or produces abroad.

Profit maximization reveals a productivity threshold a_{ij}^{Ex}, above which firms are active in market j. Firms with higher productivity than the threshold value $(1/a_{kij} > 1/a_{ij}^{MNE})$ produce abroad, while firms with a lower productivity level $(1/a_{ij}^{Ex} < 1/a_{kij} < 1/a_{ij}^{MNE})$ choose exports. Firms with a productivity level of $1/a_{ij}^{Ex}$ export their goods and earns exactly zero profits. The critical productivity levels (a) for a firm producing only for the home market (b) for an exporting firm and (c) for an MNE are derived in equations (12) using the zero-profit conditions, respectively.

$$\left(a_{ij}^{Dom}\right)^{1-\sigma}\frac{(1-\mu)Y_j(1-\rho)}{P_j^{\sigma-1}\rho^{1-\sigma}}=f^{Dom} \tag{12a}$$

$$\left(a_{ij}^{Ex}\tau_{ij}\right)^{1-\sigma}\frac{(1-\mu)Y_j(1-\rho)}{P_j^{\sigma-1}\rho^{1-\sigma}}=f^{Ex} \tag{12b}$$

$$\left(a_{ij}^{MNE}\right)^{1-\sigma}(1-\tau_{ij})^{1-\sigma}\frac{(1-\mu)Y_j(1-\rho)}{P_j^{\sigma-1}\rho^{1-\sigma}}=f^{MNE}-f^{Ex} \tag{12c}$$

We assume the fixed costs of exporting f^{Ex} to be a fixed share γ of the fixed costs, f^{MNE}, associated with the production abroad. We assume further that fixed costs increase with t_{ij} in distance between the two countries i and j.

Following Helpman *et al.* (2004), we use the Pareto distribution to parameterize the distribution of firms with respect to their productivity. If productivity $1/a$ is Pareto distributed with shape parameter κ, sales in the domestic and in the foreign market are also Pareto distributed with shape parameter $\kappa-(\sigma-1)$. Affiliates sales of all firms from country i in the foreign market j, AS_{ij}, are thus given by equation (13).

$$AS_{ij}=\int_{(a_{ij}^{MNE})}^{\infty}\frac{(a_k/\rho)^{1-\sigma}}{P_j^{\sigma-1}}(1-\mu)Y_j dk. \tag{13}$$

The threshold productivity level, $1/a_i$, determines the size and the number of affiliate from country i in country j. Thus, affiliate sales are determined by home country supply characteristics, s_i, i.e. market size and price level in country i. The number of active firms in country i is proportional to the number of country i's affiliates in country j. Furthermore, as shown in equation (13), affiliate sales are determined by host country market capacity, m_j, determined by market size, $(1-\mu)Y_j$, and price level, P_j, in country j.

Thus, (13) shows that AS_{ij} depends on s_i and m_j in the same way as in the symmetric case. To see that foreign affiliate sales depend also on distance, we build the ratio $G(a_{ij}^{MNE})/G(a_{il})^{MNE}$ of foreign affiliate sales in two countries.

This ratio equals $(a_{ij}^{MNE}/a_{il}^{MNE})^{\kappa-(\sigma-1)}$ for every threshold level a_{ij}^{MNE} and a_{il}^{MNE}.

$$\begin{aligned} AS_{ij}/AS_{il} &= (a_{ij}^{MNE}/a_{il}^{MNE})^{\kappa-(\sigma-1)} \\ &= \left[\frac{f_{il}^{MNE}(1-\tau_{ij}^{(1-\sigma)})}{f_{ij}^{MNE}(1-\tau_{il}^{(1-\sigma)})}\right]^{\frac{\kappa-(\sigma-1)}{\sigma-1}} \end{aligned} \tag{14}$$

Foreign affiliate sales depends thus on both variable distance costs τ_{ij} and fixed costs f^{MNE}. We assume the variable distance costs to be a linear function of the unit distance costs τ and the bilateral physical distance D_{ij}. We also assume the fixed costs in country j f_{ij}^{MNE} to be a linear function of unit fixed costs f^{MNE} and the bilateral physical distance D_{ij}. For sake of simplicity, we normalize the bilateral distance between country i and l to one. Thus, we have $\tau_{il} = \tau$ and $f_{il}^{MNE} = f^{MNE}$.

Equation (15) shows three interesting results. First, foreign affiliates' sales in country j, AS_{ij}, are smaller than those in country l if the physical distance between i and j is larger than one and if fixed costs depend solely on distance ($f_{ij}^{MNE} > f^{MNE}$ and $\tau_{ij} = \tau$). Second, foreign affiliates' sales in country j, AS_{ij}, are larger than those in country l, if variable costs depend solely on distance ($\tau_{ij} > \tau$ and $f_{ij}^{MNE} = f^{MNE}$). If both variable and fixed costs depend on distance, distance affects foreign affiliates' sales negatively if $\tau^{1-\sigma} < \frac{D_{ij}-1}{D_{ij}-D_{ij}^{1-\sigma}}$, i.e. if distance is large, if the elasticity of substitution σ is large and if the level of variable distance costs τ is not too low.

Thus, AS_{ij} is a negative function of distance D_{ij} if $\tau^{1-\sigma} < \frac{D_{ij}-1}{D_{ij}-D_{ij}^{1-\sigma}}$. This function is non-linear. We assume the function takes the form $\lambda D_{ij}^{-\eta}$.

As in the symmetric firm case with specific intermediate goods, aggregate affiliate sales of firms from country i in country j are given by

$$AS_{ij} = s_i(\lambda D_{ij})^{\frac{\kappa-(\sigma-1)}{\sigma-1}} m_j \tag{15}$$

We derive thus our second gravity equation (16) applied to affiliates sales from a model with heterogenous firms and fixed costs increasing with distance.

$$ln(AS_{ij}) = \alpha_2 + ln(s_i) - \beta_2 ln(D_{ij}) + ln(m_j) \tag{16}$$

where $\alpha_2 = \frac{(\kappa-(\sigma-1)}{\sigma-1} ln(\lambda)$ and $\beta_2 = \eta\frac{(\kappa-(\sigma-1)}{\sigma-1}$

4 Factor-Proportion Theory

In this section, we derive a gravity type equation from a factor-proportion model of international trade. Multinational firms do not only produce in foreign countries in order to gain market access. They also geographically fragment their production processes into stages and locate activities according to international differences in factor prices. According to Hanson *et al.*, play an important role in location decisions. Multinational firms invest thus abroad to reduce the overall cost of production. This so called vertical foreign direct investment is likely to arise when these stages of production use different factor intensities and when countries have different factor endowments and/or factor-prices.

We follow the two countries model of Venables (1999) and assume two perfectly competitive sectors, A and MZ, each producing a homogenous goods. We assume good A to be freely traded between the two countries. This good is used as *numeraire* in the following. Consumers are assumed to have identical and homothetic preferences. We assume the technology of sector A to be characterized by the following unit cost function.

$$c(w, r) = c(\bar{w}, \bar{r}) = 1 \tag{17}$$

where the upper bar denotes the factor prices of the foreign country. Equation (17) shows that the unit-cost function is an increasing function of wage w and interest rate r.

The production of good M requires the use of an intermediate good Z. Both good M and Z uses two factors, labor and capital, in fixed relation. Sector MZ can be either integrated, when both good M and Z are produce within the same country, or fragmented in order to benefit from country's comparative advantage. We assume that both countries have fixed endowments of both factors. The unit cost function are given by

$$b_Z = \alpha w + (1-\alpha) r \qquad ; \qquad \bar{b}_Z = \alpha \bar{w} + (1-\alpha)\bar{r} \tag{18a}$$

$$b_M = \beta w + (1-\beta) r + \delta p_Z \qquad ; \qquad \bar{b}_M = \beta \bar{w} + (1-\beta)\bar{r} + \delta \bar{p}_Z \tag{18b}$$

The coefficients α and β are fixed factor inputs per unit output. δ denotes the input of the intermediate good Z, in the production of the final good M. The prices p_Z and $\bar{p}_Z$ are the minimum costs of supply of the intermediated good Z in the two countries. Thus, $p_Z \equiv \min[b_Z, \tau_Z \bar{b}_Z]$ and $\bar{p}_Z \equiv \min[\bar{b}_Z, \tau_Z b_Z]$, where τ_Z is the ad valorem trade cost.

If trade costs τ_Z are high, MZ is integrated. Each country specializes in the production of the good for which it has a comparative advantage. We assume the domestic country to be relative capital abundant. It produces the capital-intensive good, while the host country produces the labor-intensive good. However, the technologies described above exhibit factor intensity reversals, so that it is not obvious which of good A or MZ uses capital more intensively. We follow Venables and assume that the domestic endowment ratio $(K/L)_H$ is more capital intensive than combined MZ production, but less than A production. As consequence, the domestic country produce both good A and good MZ, while the foreign country fully specializes in the production of good A.

Fragmentation is profitable, in contrast, if costs of shipping the intermediate good Z are very low. Since we assume that the production of Z is relatively more labor intensive than the production of M, MZ firms in the home country have outsourced the labor intensive stage of their production to the host country. Specialization along the relative factor endowments is cost-efficient and therefore profit maximizing in our perfectly competitive setting. If trade costs are very low, production of MZ is completely fragmented in a M stage conducted in the home country and a Z stage conducted in the host country.

Between these to points of full specialization, there is a range of trade cost levels, where integrated and fragmented production coexist, because the change from integrated MZ production to fragmented M production at home and Z production abroad occurs gradually with falling trade costs. Starting from a situation with full concentration of MZ production at home, falling trade costs increase the profitability to outsource the Z stage. If trade costs τ_Z are low enough, it is more profitable to produce Z in the foreign country for some firms. The fragmentation of their production and the outsourcing of their labor intensive stages to labor abundant countries increases labor demand there and reduces it at home. That changes factor prices in both countries which eliminates the gains of outsourcing. Thus, although trade costs have decrease, outsourcing incentives for firms that remain integrated have been eliminated by firms that outsourced their Z activities. Those firms activities increase costs of production abroad and decrease costs of production at home. The prevailing production structure includes integrated and fragmented firms.

Let θ be the share of Z production taking place fragmented in the host country. The share θ is determined by the factor-price ratios at home $(w/r)_H$ and abroad $(w/r)_F$ and the trade costs τ_Z. Factor costs and trade costs must support the same price for the intermediate good Z produced in both countries $p_Z = b_Z = \tau_Z \bar{b}_Z$. This equality of production costs holds for a whole range of trade cost levels τ_Z, because factor prices adjust. Thus, there is a whole range of trade cost levels where integrated and fragmented production coexist. Over this range the share of fragmented production θ rises with falling trade costs τ_Z $(\delta\theta/\delta\tau_Z < 0)$. Thus, the production of A decreases consequently in the host country as the production of Z increases. The host country exports A and Z to the home country. Given the fixed factor endowments, exports of A decreases when exports of Z increase.

Foreign production of the intermediate good Z results from the fragmentation of production in sector MZ. Since, Z is transferred within firms, its output can be seen as foreign affiliate output AS:

$$AS = \delta p_Z \theta (1-\mu) Y \tag{19}$$

Equation (19) gives the level of foreign affiliates' production which is entirely intermediate good's production. The amount of intermediate's production depends on the total demand for the final good M, on the *total* income, Y, in *both* countries, and on the fraction δ of intermediates good Z necessary to produce good M. A fraction θ of intermediate good's production is outsourced to the host country. As argued above, this fraction is a function of trade costs τ_Z. In addition, θ is affected by relative factor endowments differences $(K/L)_H/(K/L)_F$ and absolute income differences Y_H/Y_F between the two countries.

If θ is separable in a function of trade costs $f(\tau_Z)$ and a function g of relative factor endowment ratios and absolute income differences $g((K/L)_H/(K/L)_F, Y_H/Y_F)$, we have the first (negative) effect of trade costs on affiliate sales. The second effect results from price p_z, which is a minimum function given by $p_Z \equiv \min[b_Z, \tau_Z \bar{b}_Z]$. If both countries produce the intermediate good Z equality between both countries prices holds and thus $p_Z = b_Z = \tau_Z \bar{b}_Z$. It is easy to see that τ affects p_Z positively, and according to (19) p_Z has a positive effect on AS. However, the minimum function guarantees that the joint effect of the two trade cost effects on affiliate sales is negative. Sales of foreign affiliates decrease in trade costs τ.

Country size, given by Y_H and Y_F, have a positive effect on affiliate sales through Y. Y is a linear function h of Y_H. Yet, there is a second effect of country size on affiliate sales which works through θ. Whereas a large host country F affects affiliate sales AS positively ($\delta AS/\delta Y_F > 0$), a large home country affects AS negatively ($\delta AS/\delta Y_H < 0$). Thus, the supply effect in the vertical model is contrary to the supply effect in the horizontal model described above. If g is separable in a function g_1 which is a function of relative factor endowment ratios and g_2 which is a function of absolute income differences, we have the second effect of country size on affiliate sales. Assuming that the functions f, g_1 and g_2 are linear in their arguments, (19) can be restated as:

$$AS = \delta h(Y_H) g_1(Y_H/Y_F) \frac{f(\tau_Z)}{\tau_Z} g_2((K/L)_H/(K/L)_F) \tag{20}$$

Linearizing equation (20) and assuming that trade costs τ are a function of distance D, we derive a gravity equation, which is biased by the relative factor endowments ratio.

$$ln(AS) = \alpha_3 + \zeta_1 ln(Y_H) + \zeta_2 ln(Y_F) + \beta_3 ln(D) + \nu[ln((K/L)_H) - ln((K/L)_F)] \tag{21}$$

Although equation (21) looks similar to equations (9) and (16), the interpretation of the market and supply capacity is somewhat different. Since, affiliate production take place to reduce the overall costs of the firm, the size of the domestic country, Y_H, cannot be interpreted as a supply capacity. Y_H represents therefore the demand of the domestic country. The supply capacity of the domestic country affects affiliate sales negatively. The size of the foreign country Y_F represents the demand capacity of the foreign market with respect to the final good M. Yet, as argued above, Y_F also represents the supply capacity of the foreign country F. Finally, the relative factor endowment ratio of the two countries affects the amount of affiliate sales, because relative factor endowments determine the minimum price p_Z of good Z and thereby the fraction of output of the intermediate good produced in the home and in the foreign country.

5 Conclusion

We derive three gravity equations of affiliate sales of multinational firms, from different general equilibrium models. We show that gravity equation can best explain aggregate foreign multinational sales and come very close to the gravity equation applied to commodities. Foreign aggregate affiliate sales are positively determined by domestic supply capacity and foreign market capacity. They are however negatively affected by bilateral distance through two channels. First, if affiliates production relies on intermediate inputs that are produced domestically, in shipment of intermediate inputs input prices increase in trade costs which are function of physical distance. higher prices yield lower sales. In a symmetric model, lower aggregate foreign multinational sales results from lower average foreign affiliate sales. Second, if plant specific fixed costs increase with distance between partner countries, firms entry decision depends on distance-affected fixed costs. Then, lower aggregate foreign multinational sales in more distant countries results from fewer active affiliates. Both effects are very plausible and their empirical analysis is let for future research.

Gravity equation derived from the factor-proportion theory look similar, but cannot be interpreted in exactly the same way. Market and supply capacities' parameters derived from the factor-proportion model have different interpretation. In fact, fragmentation of production is carried out mostly because of factor cost differentials. Thus, the demand for final goods does not really matter for the location of multinational production. Moreover, gravity equations lead to somewhat different specification when applied to the empirical analysis. In particular, the factor-proportion specification entails a *bias* which must be taken into account in the empirical analysis.

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