The Structure of Multinational Sales under Demand Risk

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Abstract

This paper analyzes the effects of demand risk on the location and sales structure of multinational firms. We build a structural model of horizontal FDI with firms that are heterogeneous in terms of risk aversion and productivity. Firms decide on the location of their production plants, the set of countries to serve from these plants, and the volume of sales for each plant. These decisions hinge both on the expected demand for each market and the correlation structure of demand realizations across destination markets. *Ceteris paribus*, markets that offer better hedging opportunities to multinationals induce larger sales and are more attractive locations for production. We use firm-level data for German multinational companies to estimate firm-specific risk aversion coefficients as well as other model parameters. We find that multinationals are heterogeneously risk averse. Finally, in a counterfactual analysis, we show how a reduction in tariffs for goods imported into China changes the trade flows to the other countries, the sign of the change depending on the correlation structure.

Keywords: FDI, Multinational Enterprise, Demand Risk, Risk Aversion, Export Platform.

JEL Classification: F12, F23, L23.

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1 Introduction

The activity of multinational enterprises (MNEs) comprises a set of complex location and sales decisions. First, MNEs decide in which countries to establish production facilities through foreign direct investment (FDI); in doing so, they typically weigh the benefit of proximity to customers against the cost of setting up a foreign plant. Second, MNEs decide how much to produce in each foreign plant; in particular, the output of a foreign plant can serve the local and the neighboring markets if MNEs use their production facilities as export platforms.[1]

Crucially, MNEs make the investment and production decisions *before* observing the realization of demand in each market. In addition, such realizations can be correlated across the foreign markets served by the MNEs. In other words, the MNEs' activity is subject to the risk of unfavorable demand fluctuations which can be correlated across foreign markets. This is what we define as demand risk. If MNEs are risk averse, then the location and sales decisions hinge both on the expected demand for each market and the correlation structure of demand realizations across destination markets.

Demand risk is an important determinant of multinational activity. For example, the UNCTAD World Investment Report 2010 describes how MNEs adjusted their investment flows and organization of production in response to the demand fluctuations following the outbreak of the financial crisis. Specifically, FDI flows favored, in relative terms, countries less affected by the economic downturn.[2]

This paper addresses the question of how demand risk shapes investment and sales decisions of MNEs. For this purpose, we propose a structural model of horizontal FDI with firms that are heterogeneous in terms of productivity and risk aversion. MNEs decide about the locations of their production facilities, which countries to serve from each plant and the volume of production to sell in each market. They make all the above decisions under demand risk, i.e. before observing the

[1] According to the World Investment Report 2017, foreign affiliates of MNEs exported approximately 20% of their total output abroad in 2016.

[2] Though global FDI flows decreased after 2008, the ratio of FDI inflows into developed compared to developing countries substantially changed. Specifically, FDI flows in developed countries contracted by 44% in 2009, whereas those in developing and transition economies fell by 27%. Thanks to their rapidly expanding local demand and resilience to the crisis, the developing regions accounted for the majority of worldwide FDI inflows for the first time.

realizations of demand in the destination markets. With risk averse MNEs and correlated demand realizations, investment and sales decisions are interdependent and similar to a complex portfolio choice problem. In particular, each market in which the MNE sells its output yields a risky return which imperfectly correlates with the returns offered by other foreign markets. Thus, the sales depend on the expected return, related to the expected demand realization in the market, and the diversification opportunities, related to how the market demand correlates with that of the other markets. *Ceteris paribus*, markets that offer better hedging opportunities to multinationals induce larger sales, and the more risk averse the firm is, the more beneficial the diversification is.

Foreign plants serve as export platforms since they can originate sales to local and third markets. Such export platforms reduce the effective distance between the MNE and a destination market. This results in an expected demand increase in the market itself. Moreover, establishing the plant eases MNE's access to markets, which may be possibly correlated in a favorable fashion to the ones the MNE already sells to. However, setting up a foreign plant comes at a fixed cost. Thus, MNEs have to trade off the described increase of the expected demand paired with the reduction in demand risk against the fixed set-up cost. Due to complementarities, the attractiveness of each foreign plant depends on the set of other plants owned by the MNE. Hence, the location entry choice of MNEs is a complex combinatorial discrete choice problem with complementarities. In particular, with N locations and a given host country of the MNE, there are 2^{N-1} eligible location sets.

Several theoretical implications related to the MNEs' activities result from our model.

First, our model rationalizes why expected sales in a given market are not a sufficient statistic for the entry decisions of multinationals in this market. Standard models of horizontal FDI (Helpman, Melitz, and Yeaple, 2004) have the counterfactual implication that distance-adjusted market size determines a monotone ranking in terms of entry: all firms sell to close and large markets as they are associated with large expected sales. However, only more productive firms afford to sell to smaller and more distant markets as they command lower expected sales. By contrast, in our model the described ranking does not necessarily obtain because the attractiveness of establishing a plant in a foreign country depends also on the diversification opportunities offered by this location, which depend, in turn, on the characteristics of other MNE's locations. As a consequence, if a low productive MNE opens up a foreign production facility, say, both in France and China, a highly productive one does not necessarily set up a plant in these two countries too as also demand risk matters. These results hold when core productivity varies given the level of risk aversion and vice versa. Specifically, a larger degree of risk aversion does not automatically reduce the number of foreign locations a firm decides to enter.

Second, heterogeneity in risk aversion leads to country-firm-specific markups even when the elasticity of demand is constant. In fact, the firm chooses a quantity to ship in each country which reflects three factors: (i) country's demand variance and (ii) diversification potential, and (iii) the degree of risk aversion of the firm. As a result, the firm scales up or down the optimal quantity it would sell under no risk by a factor which reflects (i) – (iii), implying a different realized price in each of the markets.[3]

Third, demand risk diversification can impact on the outcomes of trade policies. A tariff reduction in a country which offers a good hedging potential can magnify the effect of a trade liberalization on trade flows compared to standard models.[4] Moreover, trade liberalization can give rise to third-country effects. In other words, sales flows may change also in countries which are not directly interested by the policy change, with the direction of the change depending on the sign of the correlation. To be specific, countries offering a demand hedge with respect to the market for which trade costs have been reduced experience an increase in imports, whereas markets whose demand is highly and positively correlated with the liberalized market are subject to negative spillovers.

The empirical analysis uses firm-level data on German multinationals operating in the manufacturing sector. The data represent the universe of German multinational firms holding an investment position in a foreign country and contain information about the balance sheet and location of the foreign affiliates. By exploiting the properties of the solution to the MNE's optimization problem

[3]In our framework, the price can be thought of as the residual equalizing the realized demand to the supply.

[4]On the contrary, a lower hedging potential or higher demand volatility may dampen the effect of a trade liberalization.

described in the present paper, we match the observed sales to the ones predicted by our model to obtain a measure of firm-specific absolute risk aversion. We find that the German multinational companies are risk averse. Moreover, the degree of risk aversion is heterogeneous across firms. The findings are consistent with our theoretical model which predicts that the level of correlation across foreign markets directly affects the composition of the sales portfolio of German multinationals. Compared to the risk neutral benchmark, firms tend to sell relatively more to the countries providing a better hedge. We estimate the risk aversion elasticity of aggregate sales to be 0.8 (in absolute value). We find that risk aversion varies across the different manufacturing sectors included in our analysis. Specifically, risk aversion correlates with the demand characteristics of the sector rather than with technological features. Furthermore, more risk averse firms operate in industries characterized by a relatively more disperse demand.

In a counterfactual analysis, we assess the effect of a tariff reduction on products exported to China. We find that the policy change increases the sales of German MNEs not only in China but also in the USA and Japan, whereas neighboring countries like Hong Kong and Singapore are negatively affected. Other, less correlated countries are less affected. We also demonstrate how a change in risk aversion of German companies (e.g. due to the entry of new firms or to the reduction of financial constraints) produces a larger variation in the sales toward those countries which are more correlated with Germany, whereas more distant regions are less influenced.

1.1 Related Literature

Our paper relates to the literature studying firm's incentives to conduct horizontal FDI versus export (the so-called proximity-concentration tradeoff) in the presence of uncertainty. The closest contribution to this paper is Tintelnot (2017) who proposes a structural model of firms engaging in multinational activities where they can use foreign affiliates as export platforms. His analysis assesses the costs involved in multinational production and the incentives of firms in designing their global operations under imperfect transferability of technology from the parent company to its subsidiaries. As Tintelnot (2017), we account for the importance of export platforms in shaping the multinational organization of production. However, we rather concentrate our attention on the role played by export platforms in affecting the sales structure of MNEs when the demand is risky and MNEs are risk averse. Indeed, the possibility of reaching markets different from the local one makes it possible for a firm to fully exploit the diversification opportunities offered by the foreign sales. The impact of technological and demand uncertainty on the choice between exporting and establishing a foreign production facility has been also addressed by Ramondo, Rappoport, and Ruhl (2013). In particular, they study the above tradeoff in the presence of country-specific shocks to the production costs and to the demand. The firm's dynamic choice between export and FDI hinges on the heterogeneous correlation existing between production costs across home and foreign countries. In particular, firms are more likely to select export over FDI in markets characterized by productivity shocks poorly correlated with those at home. In particular, as demand and costs are positively correlated, engaging in multinational activity entails high foreign production cost when the foreign demand is high and this partly offsets the benefits from FDI compared to exporting, which requires domestic inputs. With reference to the demand shocks, they find that firms are more likely to serve volatile locations by exporting activity. Differently from them, we focus on the demand side and highlight the importance of demand correlations across different markets in shaping entry and production choices. Other contributions investigating multinational activity under uncertainty are Rob and Vettas (2003), who discuss uncertain demand growth in foreign markets, and Chen and Moore (2010), who concentrate on idiosyncratic shocks to firm demand in the foreign market. With reference to the last paper, the authors find that more productive firms are more likely than less efficient ones to enter into tougher markets. Their result does not necessarily obtain in our framework since allowing for risk averse firms and demand interdependencies across countries break the monotonicity in the firms' entry choice with respect to productivity. Campa (1993), Goldberg and Kolstad (1995), and Russ (2007) introduce risk in the form of exchange rate fluctuations and find that firms take into account the exchange rate volatility when they solve the proximity-concentration tradeoff. Aizenman and Marion (2004) analyze the role of uncertainty on the choice between vertical and horizontal FDI, demonstrating how higher uncertainty should induce firms to favor horizontal over vertical FDI. This conclusion is in line with the idea that MNEs diversify their demand risk by using their production and sales structure. Ramondo and Rappoport (2010) explore the role of FDI flows both as an asset available to consumers for diversification and as a means for transferring technology across countries; the existence of multinational production affects the amount of goods available in each state of the world and reduces consumption risk as long as foreign affiliates are located in regions characterized by good hedging properties with respect to the world consumption risk.

The paper also closely relates to the growing literature on the role of demand risk in international trade. Specifically, Di Giovanni and Levchenko (2012) analyze the risk content of exports and show that cross-country specialization patterns depend both on the comparative advantage and the riskiness of those sectors in which they have a comparative advantage. Kramarz, Martin, and Mejean (2016) quantify the contribution of idiosyncratic demand shocks and the structure of trade to the volatility of exports, and link the volatility of exporters to the low level of diversification in the client portfolio held by a firm. Conconi, Sapir, and Zanardi (2016) show that firms learn about their profitability in a foreign market by entering there as exporters before engaging in FDI activities. Our model implicitly assumes immediate learning; upon entering into a foreign market all uncertainty about the demand realization unravels.

We also contribute to the growing literature regarding the relation between firms' preferences toward risk and international trade. In particular, De Sousa, Disdier, and Gaigné (2017) and Esposito (2017) analyze risk averse exporters in the presence of demand shocks. Our paper differs from these contributions along several dimensions. First, De Sousa et al. (2017) and Esposito (2017) focus on pure exporters.[5] MNEs typically face lower marginal costs compared with exporters; as a consequence, it is more likely that for the latter the benefits of diversification outweigh the

[5]In comparison with pure exporters, multinational enterprises typically have more opportunities of adjusting their sales across markets since they are present in several foreign countries. In this regard, the UNCTAD World Investment Report 2008 highlights how multinationals exhibited more stable sales than pure exporters during the crisis, in line with the idea that multinational firms benefit more extensively from diversification than other firms. Therefore, demand risk diversification plays a greater role for MNEs than for exporters. In addition, such a role can be assessed only in a framework which allows for the presence of export platforms. Not taking into account this possibility would lead to consider a (potentially) misspecified demand.

transportation costs. Second, we distinguish from De Sousa et al. (2017) since we allow for correlated expenditures across destination markets and abstract from the possible effects of skewed demand shocks; with regard to Esposito (2017), we focus on the risk affecting a firm both at the industry and macroeconomic levels, whereas he focuses on firm-specific demand shocks.[6] Riaño (2011) considers the investing and exporting decisions of risk averse managers in a framework where both productivity and demand are subject to firm-specific shocks. He proves that exporting increases the volatility of the firm's sales.

This paper also contributes to the literature on interdependent foreign markets. In Nguyen (2012), firms learn the demand realization in potential foreign destinations by exporting given the positive correlation of demands across countries. Albornoz, Calvo Pardo, Corcos, and Ornelas (2012) consider a model of experimenting exporters who learn about their own profitability by entering into foreign markets. Under the assumption that profits exhibit the same positive correlation across different foreign destinations, risk regarding profits reduces over time not only in the markets the firm is present in, but also in the other unexplored markets. With respect to the above contributions, we relax the assumption that demand correlations are positive. Vannoorenberghe (2012) shows that foreign and domestic sales are negatively correlated at the firm level, which supports the hypothesis that firms diversify by selling abroad. Vannoorenberghe, Wang, and Yu (2016) shows that volatility of exports increase (decrease) with the level of diversification of destination countries reached by a small (large) firm. This result is justified with the presence of fixed costs and short-run demand shocks. Our analysis extends the above contribution by highlighting the role of heterogeneity in risk aversion and the importance of multinational activity.

Finally, this paper is connected to the recent contributions on export platforms and multinational production. In particular, we model export platforms similarly to Tintelnot (2017) and Head and

[6] In addition, in our framework, the firms are heterogeneous in terms of risk aversion. Cucculelli and Ermini (2013) provide evidence that managers differ in risk attitudes in a sample of Italian manufacturing firms. In particular, they find that about 76% of the managers display a risk averse attitude, 17% a risk neutral attitude and the rest a risk loving attitude. Hence, 93% of managers in their sample exhibit a (weak) risk aversion. This heterogeneity is also correlated with firm's characteristics like size, age, and innovativeness. Moreover, different financial conditions can result in differences in hedging opportunities by other means than sales.

Mayer (2017).[7] Analogously to Ekholm, Forslid, and Markusen (2007) and Arkolakis, Ramondo, Rodríguez-Clare, and Yeaple (2018), we find the spillover effects of liberalization arising from the complexity of global value chains. Differently from their papers, we introduce demand-side spillovers affecting multinational production. However, to our knowledge, we are the first to highlight the importance of export platforms in enhancing sales diversification.

The remainder of the paper is structured as follows. Section 2 introduces the theoretical model and shows how risk aversion enters into firm's production and FDI decisions. Section 3 discusses the data used in the estimation. Section 4 describes the estimation procedure. Section 5 presents the main empirical results. Section 6 concludes.

2 Model

This section proposes a version of Chaney (2008) with N countries indexed by $d \in D \equiv \{1, \ldots, N\}$, and $I+1$ sectors indexed by $i = 0, \ldots, I$.

2.1 Demand

In each country d, there is a representative consumer whose total income equals Y_d. Her preferences are represented by the following quasi-linear utility function in the homogeneous good Q_{0d}

$$U_d = \sum_{i=1}^{I} \alpha_{id} \ln Q_{id} + Q_{0d}, \tag{1}$$

where $\alpha_{id} > 0$ is the absorption relative to the sector i and destination d, and Q_{id} denotes a Dixit-Stiglitz aggregate good i in country d, that is,

$$Q_{id} = \left[\int_{\omega \in \Omega_{id}} q_{id}(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}}. \tag{2}$$

The elasticity of substitution σ between any two varieties and ω' is larger than 1. The set Ω_{id} represents the varieties of Q_{id} sold in country d.

[7] In our framework, the choice of serving a foreign market from an affiliate is deterministic.

The absorption α_{id} is random. In particular, one can think of it as a shifter to consumer's preferences with respect to the aggregate good Q_{id}, describing fluctuations occurring at the industry and aggregate levels. For example, it can represent a change in the quality of the product produced in the industry i or an exogenous change in country d's total income or aggregate demand.

Realizations of absorptions in different countries can be correlated; they tend to move in the same (opposite) directions in countries either characterized by similar (opposite) tastes for a certain product or displaying more (less) integrated economies.

We assume that the vector of absorption $\boldsymbol{\alpha}_i = (\alpha_{i1}, \ldots, \alpha_{id}, \ldots, \alpha_{iN})$ has a bounded expected value, denoted by $\bar{\boldsymbol{\alpha}}_i = (\bar{\alpha}_{i1}, \ldots, \bar{\alpha}_{id}, \ldots, \bar{\alpha}_{iN})$, where $\bar{\alpha}_{id}$ is the expected absorption for the good Q_{id}. In addition, $\boldsymbol{\alpha}_i$ has a full-rank variance-covariance matrix Σ_i. The element in position (d, d') of the matrix Σ_i represents the long-run covariance between the absorption in countries d and d' and is denoted by $\Sigma_i(d, d')$. We assume that, if $d \neq d'$, then it holds

$$-1 < \frac{\Sigma_i(d, d')}{\sqrt{\Sigma_i(d, d)\Sigma_i(d', d')}} < 1. \tag{3}$$

The above restriction on Σ_i excludes the possibility that the cross-correlations between the demand realizations in two destination countries are perfect.[8]

The representative consumer observes the realizations of the vector α_{id} for $i = 1, \ldots, N$ and makes consumption decision accordingly.

The consumption bundle chosen by the consumer follows from the solution of the following utility maximization problem

$$\begin{aligned} &\max \sum_{i=1}^{I} \alpha_{id} \ln Q_{id} + Q_{0d} \\ &\text{s.t. } Q_{0d} + \sum_{i=1}^{I} \int_{\omega \in \Omega_{id}} p_{id}(\omega) q_{id}(\omega) d\omega = Y_d, \end{aligned} \tag{4}$$

from which we obtain $Q_{0d} = Y_d - \sum_{i=1}^{I} \alpha_{id}$ and $P_{id}Q_{id} = \alpha_{id}$, where P_{id} is the price index associated

[8] As the estimated industry variance-covariance matrix satisfies this requirement, the assumption is not stringent.

to Q_{id}.[9] In addition, the inverse demand for the variety is given by

$$p_{id}(\omega) = A_{id} q_{id}(\omega)^{-\frac{1}{\sigma}}, \quad \text{with } A_{id} \equiv \alpha_{id} Q_{id}^{-\frac{\sigma-1}{\sigma}} \text{ and } \Upsilon_{id} \equiv Q_{id}^{-\frac{\sigma-1}{\sigma}}, \tag{5}$$

where $p_{id}(\omega)$ is variety 's price in country d.

For the following discussion, we let $\boldsymbol{\Sigma}_{A_i} \equiv \Upsilon_i' \boldsymbol{\Sigma}_i \Upsilon_i$ denote the variance of $\boldsymbol{A}_i = (A_{i1}, \ldots, A_{Ni})$.

2.2 Firms

Each firm produces exclusively one variety of the differentiated good Q_{id}. We index this variety by ω. Since there exists a one-to-one relation between firms and varieties, we drop any industry-related subscript.

Firms also differ with respect to the level of productivities $\boldsymbol{\varphi}$, risk aversion r, fixed entry costs $\boldsymbol{f}$, and origin country o. Hence, a firm is fully characterized by the vector of variables $(\omega, \boldsymbol{\varphi}, r, \boldsymbol{f}, o)$.

In this section, we consider an arbitrary firm so we suppress also the index referring to the variety ω it produces.

A firm can observe the above variables at no cost before making any choice. Its profits are determined by three simultaneous decisions. First, a firm makes a *location decision*, i.e. it picks the set of locations in which to establish a foreign affiliate.[10] We denote a location set by L with $L \in \mathcal{L} = 2^{N-1}$ as we assume that the firm is always present in its home country. Second, a firm makes a *shipment decision*, i.e. it chooses the optimal location as origin for shipping the variety in a given destination market. Third, a firm makes a *production decision*, i.e. it selects the quantity of the variety to sell in each destination. Crucially, the three decisions are made before observing the actual realizations of demand in the destination markets. Hence, a firm decides under demand risk. In particular, the fact that the produced quantity cannot be adjusted following the realization of the demand implies that a firm is exposed to price fluctuations in the destination markets.[11]

In the following paragraphs, we closely describe firm's technology and each decision.

[9] We assume that Y_d is large enough to avoid the possibility of incurring in a corner solution.
[10] Note that we assume that a parent company can maintain at most one foreign plant in each destination market.
[11] We discuss a relaxation of this assumption in Appendix G.

Technology and production costs. The firm has to pay a fixed entry cost f_l to set up a plant in the foreign location l. The fixed entry cost represents the firm-specific cost of building or acquiring a foreign plant in the country.[12]

In addition, the firm has a different level of productivity associated to each of its foreign plants. This assumption reflects two things. On the one hand, the firm can face productivity losses due to the imperfect transferability of technologies and production skills within its boundaries. On the other hand, the firm can possibly take advantage of the production infrastructure of its foreign affiliate.[13]

When firm produces in location l, it has to bear a variable production cost which is inversely proportional to the firm's location-specific productivity φ_l. The variable cost of producing q_l units in country l is, then, given by

$$C(q_l) = \frac{q_l}{\varphi_l}. \tag{6}$$

The firm can use its plant in location l to serve both the local and any other destination market. This means that the firm owns an export platform in country l. However, if the firm uses the production facility in country l to serve the foreign destination market d, then it has to pay an iceberg trade cost $\tau_{ld} > 1$.[14]

We denote the constant marginal cost of producing the variety in location l and shipping it to country d by $c_{ld} \equiv \tau_{ld}/\varphi_l$.

As in Tintelnot (2017), we abstract from the presence of any export fixed cost.[15] This restriction can be motivated by two considerations. First, MNEs tend to enter sequentially in foreign markets;[16] manufacturing firms generally start their activity abroad with exporting rather than operating a foreign production facility. When a firm sets up a foreign affiliate, the firm substitutes

[12] In other words, we do not distinguish between greenfield and brownfield investments.

[13] More concretely, existing contracts with foreign counterparts, lower input prices, or the adoption of advanced techniques can make a foreign affiliate more productive than its parent. Need for learning, institutional differences between foreign countries and home, or technology adjustment cost can lead to productivity losses in a foreign market.

[14] If $l = d$, then $\tau_{ll} = 1$.

[15] Estimating export entry costs would require us to observe data on multinational sales disaggregated by destination.

[16] See Conconi et al. (2016).

the origin of its trade flows for some of the foreign destination markets. This means that those destination markets, previously reached by the home production, can be served by the new production facility. Thus, the firm has already previously paid the fixed cost of exporting to the market. Second, one can think that part of the fixed export entry cost collapses into the fixed entry cost associated to the FDI.

Production decision. We assume that the firm does not observe the size of the aggregate demand in the destination markets before making any production decision. Hence, firm's profit is a random variable. As firm is risk averse, this implies that it does not only consider the (expected) profit in a prospective destination market but also its volatility and how it comoves with the profits in the other markets.

In line with this, sales across different destination markets can be seen as risky assets held as a sales portfolio by the firm, similarly to the standard setting of portfolio choice.[17] As the demand realizations are correlated across foreign markets, the sales of an affiliate not only depend on the local productivity, the size of the surrounding markets, and the cost of reaching them but also on the set of other locations where the firm is present, and the correlation structure in the destination markets. All these factors together affect the composition of the production portfolio chosen by the firm.

In the production decision, firm chooses how much to ship to each destination. We assume that firm's preferences are represented by a mean-variance utility function of profits in destination markets. This representation of preferences has been extensively used in the literature, and it can be also considered as a second-order Taylor approximation of a twice-differentiable increasing and concave utility function around the expected profits.[18]

Throughout this section, we drop the location subscript l from the quantity q_{ld} under the as-

[17] The crucial difference with respect to the standard setting of portfolio choice relates to the presence of non-linear shares due to the CES preferences. As a consequence, the expected returns of the firm's portfolio vary with the size of share chosen by the firm.

[18] See Eeckhoudt, Gollier, and Schlesinger (2005). In particular, the second-order Taylor approximation is exact if (i) the Bernoulli utility function is CARA and (ii) the distribution of the random variable is fully characterized by the first two moments.

sumption that the firm makes the optimal shipment choice (see successive paragraph). Given that, the realized profit of the firm selling to the destination countries $d = 1, \ldots, N$ is given by

$$
\begin{aligned}
\Pi(\boldsymbol{q}|L, \boldsymbol{\varphi}, r) &= \sum_{d} (p_d q_d - c_d q_d) && (7) \\
&= \sum_{d} \left(q_d^{\frac{\sigma-1}{\sigma}} \left(A_d - c_d q_d^{\frac{1}{\sigma}} \right) \right), && (8)
\end{aligned}
$$

where $\boldsymbol{q} = (q_1, \ldots, q_d, \ldots, q_N)$ denotes the amount of the variety shipped to the destination markets given the optimal shipment choice. Hence, the expected profit is given by

$$
\mathbb{E}[\Pi(\boldsymbol{q}|L, \boldsymbol{\varphi}, r)] = \sum_{d} \left(q_d^{\frac{\sigma-1}{\sigma}} \left(\mathbb{E}[A_d] - c_d q_d^{\frac{1}{\sigma}} \right) \right), \tag{9}
$$

whereas the variance of profits is given by

$$
\operatorname{var}\left(\Pi\left(\boldsymbol{q}|L, \boldsymbol{\varphi}, r\right)\right) = \sum_{d} \sum_{d'} \operatorname{cov}(A_d, A_{d'}) q_d^{\frac{\sigma-1}{\sigma}} q_{d'}^{\frac{\sigma-1}{\sigma}}. \tag{10}
$$

Note that the variance does not depend directly on production costs, as risk only relates to the fluctuations of demand in the destination markets.[19]

Conditional on the choice of the location, the utility function of the firm is then given by

$$
u(\Pi(\boldsymbol{q}|L, \boldsymbol{\varphi}), r) = \mathbb{E}\left[\Pi\left(\boldsymbol{q}|L, \boldsymbol{\varphi}, r\right)\right] - \frac{r}{2} \operatorname{var}(\Pi(\boldsymbol{q}|L, \boldsymbol{\varphi}, r)) \tag{11}
$$

where r is the firm's risk aversion. To find the optimal vector of quantities to ship to the foreign destination markets, the firm solves the following utility maximization problem

$$
V(L) \equiv \max_{\boldsymbol{q} \in \mathbb{R}_+^N} \mathbb{E}\left[\Pi(\boldsymbol{q}|L, \boldsymbol{\varphi}, r)\right] - \frac{r}{2} \operatorname{var}\left(\Pi\left(\boldsymbol{q}|L, \boldsymbol{\varphi}, r\right)\right), \tag{12}
$$

where $V(L)$ denotes the indirect utility function associated to the location set L.

[19]Other sources of risk, like unexpected change to the production costs, are not taken into account in this paper.

For $d \in D$ such that $q_d > 0$, the first-order necessary[20] and sufficient conditions[21] with respect to q_d is given by

$$\frac{\partial u(\Pi(\boldsymbol{q}|L,\boldsymbol{\varphi},r))}{\partial q_d} = \frac{\partial \mathbb{E}\left[\Pi(\boldsymbol{q}|L,\boldsymbol{\varphi},r)\right]}{\partial q_d} \tag{13}$$

$$-\frac{r}{2}\frac{\partial \mathrm{var}\left(\Pi\left(\boldsymbol{q}|L,\boldsymbol{\varphi},r\right)\right)}{\partial q_d} = 0, \tag{14}$$

where

$$\frac{\partial \mathbb{E}[\Pi(\boldsymbol{q}|L,\boldsymbol{\varphi},r)]}{\partial q_d} = \frac{\sigma-1}{\sigma}\mathbb{E}[A_d]q_d^{-\frac{1}{\sigma}} - c_d,$$

and

$$\frac{\partial \mathrm{var}(\Pi(\boldsymbol{q}|L,\boldsymbol{\varphi},r))}{\partial q_d} = \frac{2(\sigma-1)}{\sigma}\left(q_d^{-\frac{1}{\sigma}}\sum_{d'}\mathrm{cov}(A_d,A_{d'})q_{d'}^{\frac{\sigma-1}{\sigma}}\right).$$

Hence, for all d such that $q_d > 0$, it holds

$$q_d^{-\frac{1}{\sigma}}\frac{\sigma-1}{\sigma}\left(\mathbb{E}[A_d] - r\sum_{d'}\mathrm{cov}(A_d,A_{d'})q_{d'}^{\frac{\sigma-1}{\sigma}}\right) = c_d. \tag{15}$$

Proposition 1. *(Existence and Uniqueness). If the matrix $\boldsymbol{\Sigma}$ has cross-correlations bounded away from -1 and 1, there exists a unique solution to the firm's utility maximization problem.*

Proof. See Appendix A. □

Proposition 1 implies that the optimal production portfolio of firm exists and is unique given the set of locations of foreign affiliates. Since firm's realized sales are a random variable due to the presence of aggregate demand fluctuations, the proposition also implies that their mean and variance are well-defined and unique. As we will show later, this guarantees that the measure of firm's risk aversion implied by our model is well-defined and theoretically identified.

For arbitrary values of σ, the above non-linear system of equations (15) does not have a closed-form solution. However, to provide some intuition on the optimal level of quantities sold in each

[20]We notice that the utility function is not differentiable when $q_d = 0$. However, as export fixed costs are set to zero, the firm always sells a positive amount to each destination markets.

[21]We defer the discussion about the concavity of the objective function to a later stage.

destination, we show how the first order condition looks like for the case in which $\sigma = 2$. In particular, the first-order conditions for this case can be rewritten as

$$q_d = \left(\frac{\mathbb{E}[A_d]}{2c_d}\right)^2 \cdot \left(\frac{1 - r\frac{\sum_{d' \neq d} \operatorname{cov}(A_d, A_{d'}) q_{d'}^{\frac{1}{2}}}{\mathbb{E}A_d}}{1 + r\frac{\operatorname{var}(A_d)}{2c_d}}\right)^2 . \tag{16}$$

The first factor of the right hand side of equation (16) represents the quantity chosen by the firm if there is no risk aversion or uncertainty. If the expected market size in the market d is large relatively to the marginal cost of production inclusive of the trade costs, then the firm's sales to country d are large. The second part, instead, is the factor by which the firm optimally rescales the level of production shipped to country d due to the joint effect of risk aversion and demand risk. Specifically, this factor decreases with the specific risk associated to the destination d (captured by the variance $\operatorname{var}(A_d)$ in the denominator), whereas it increases with the opportunities of diversification offered by the market d (captured by the covariances $\operatorname{cov}(A_d, A'_d)$ in the numerator). Hence, countries characterized by larger variance or lower diversification potential attract smaller sales the more risk averse the MNE is.

Additionally, the first-order necessary and sufficient conditions in (15) can also be rearranged to obtain the risk aversion coefficient r implied by the solution to the firm's utility maximization problem.

Proposition 2. *(Risk aversion measure). The measure of risk aversion is a function of the optimal production portfolio, and is equal to*

$$r = \frac{\sum_d \left(\mathbb{E}p_d q_d - \tilde{p}_d q_d\right)}{\left(\boldsymbol{q}^{\frac{\sigma-1}{\sigma}}\right)' \boldsymbol{\Sigma}_A \boldsymbol{q}^{\frac{\sigma-1}{\sigma}}},$$

where $\mathbb{E}p_d$ is the expected price in country d, $\tilde{p}_d = \frac{\sigma}{\sigma-1} c_d$ is the price under certainty in country d, and $\boldsymbol{q}^{\frac{\sigma-1}{\sigma}}$ is a vector whose d component is $q_d^{\frac{\sigma-1}{\sigma}}$, where q_d is the optimal quantity sold in country d.

Proof. See Appendix B. □

In the representation of risk aversion offered in Proposition 2, the denominator is given by the variance of sales in the destination markets, whereas the numerator measures the risk premium a firm demands in terms of revenues as a compensation for the risk. Therefore, the risk aversion parameter shows the amount of extra markup a firm requires for a given level of riskiness of its sales portfolio. Given the heterogeneity in risk aversion, our model predicts that more risk averse firms charge higher markups, on average. Moreover, the adjustment of prices after the realization of demand shocks result in firm-destination-specific markups implied by the firm's choices. As the quantities shipped to each destination are different for similarly productive but differently risk averse firms, we can rationalize heterogeneous adjustment of prices to demand shocks.

Finally, the following results show the relation between the aggregate sales and the level of risk aversion.

Proposition 3. *(Risk Aversion and Aggregate Sales). The firm's aggregate sales are decreasing with risk aversion.*

Proof. See Appendix E. □

A more risk averse MNE tries to limit the demand risk it faces in its international activity by reducing the intensive margin of sales. It is worthwhile to notice that a change of risk aversion does not proportionately change the contribution of each destination to the MNE's sales portfolio. In particular, an increase of risk aversion induces the firm to substitute out relative risky destinations with safe ones (and vice versa).

Our framework assumes that a firm selects the optimal quantity rather than the optimal price to charge in each market. In Appendix F, we discuss how the results would differ when the firm sets the price instead.

As a reference point, it is useful to compare the case of risk aversion when (i) we remove the presence of export platforms, and (ii) we exclude risk.

No export platforms. Without export platforms, the system of equations (15) reads as

$$q_l^{-\frac{1}{\sigma}} \frac{\sigma - 1}{\sigma} \left(\mathbb{E}[A_l] - r \sum_{l'} \operatorname{cov}(A_l, A_{l'}) q_{l'}^{\frac{\sigma-1}{\sigma}} \right) = c_l, \tag{17}$$

where l is a location in which the MNE holds a production facility. From equation (17), we notice that the diversification opportunities that the firm can achieve in this case are just a subset of those achievable in the model with export platforms, fixing the location set. In particular, only the covariances associated to the markets in which the firm has established a foreign affiliate appear in (17). As the firm sells the variety produced in l only to the local market, the marginal cost simply reduces to $1/\varphi_l$. For the special case of $\sigma = 2$, we obtain an expression similar to (16). In particular, we have

$$q_l = \left(\frac{\mathbb{E}[A_l]}{2c_l} \right)^2 \cdot \left(\frac{1 - r \frac{\sum_{l' \neq l} \operatorname{cov}(A_l, A_{l'}) q_{l'}^{\frac{1}{2}}}{\mathbb{E} A_l}}{1 + r \frac{\operatorname{var}(A_l)}{2c_l}} \right)^2. \tag{18}$$

If a firm uses the foreign plant l as an export platform, then the quantity predicted by the model sold to location l is not correct when we do not consider export platforms. In particular, the factor that scales up or down the quantity the firm wants to sell under no risk aversion or no uncertainty just considers the sales realized locally by the different foreign facilities without taking into account the possibility of demand risk diversification offered by the other markets in which the MNE is not physically present.

No risk aversion. In this case, the solution to the optimization problem has a closed form. In particular, it holds

$$q_d = \left(\frac{\sigma - 1}{\sigma} \frac{A_d}{c_d} \right)^\sigma. \tag{19}$$

Equation (19) shows how the quantity shipped to each destination increases with the realized size of the market, the productivity of the origin production facility, and decrease with trade costs. Assume that location l serves the subset of destinations $\tilde{D}$.[22] Using equation (19), we obtain that

[22]How the MNE makes this decision is the object of the next paragraph.

the revenues r_l realized in a given location l are given by

$$r_l = \sum_{d \in \tilde{D}} p_d q_d = \kappa \varphi_l^{\sigma-1} \sum_{d \in \tilde{D}} \frac{\alpha_d}{P_d^{1-\sigma}} \tau_{ld}^{1-\sigma}, \tag{20}$$

where $\kappa \equiv \left(\frac{\sigma-1}{\sigma}\right)^{\sigma-1}$. The expression for the revenues realized in a given location is similar to the one in Tintelnot (2017). In particular, if there is only one industry, then $\alpha_d = Y_d$. In the equation (19), it is easy to see that the revenues realized in some location increase with the productivity of the location whereas decrease with the distance between the foreign affiliate and the customers in the destination markets.[23]

Shipment decision. This paragraph describes how the firm selects the optimal location for shipping its variety to a given destination market.

The shipment decision hinges on the firm's productivity vector $\boldsymbol{\varphi}$ given the locations in which it is present, and on the trade costs associated to the possible location-destination pairs. As the shipment cost is independent of demand risk, the optimal decision exclusively relies on firm's productivity and iceberg trade costs. In particular, as returns to scale are constant, a standard cost minimization argument implies that the destination d is served from the location l if the unit cost c_{ld} is the lowest possible one. In other words, $q_{ld} > 0$ only if $c_{ld} = \min_{l'}\{c_{l'd} : l' \in L\}$.[24] It is worth to note that the optimal location-destination pair strictly depends on the location set L chosen by the firm.

Location decision. As stated, firm has to pay a fixed cost f_l for entering location l and setting up a plant there. This cost is observed by the firm before making its location choice. In our framework, the sum of fixed costs is considered as the price of holding a portfolio of risky assets

[23] If we also drop the assumption that firms can use a foreign location as an export platform, then equation (19) reduces to

$$r_l = \kappa \varphi_l \frac{\alpha_l}{P_l^{1-\sigma}}.$$

[24] This analysis abstracts from any possible indeterminacy arising when $c_{ld}, c_{l'd} \in \arg\min_{l'}\{c_{l'd} : l' \in L\}$ for $l \neq l'$. As productivities can be thought as draws from a continuous distribution, such event has probability equal to 0.

associated to the locations from which it is possible to serve the local and foreign markets. The fixed costs enter as a constant in the utility of the firm. The observation implies that the sum of fixed costs associated to any location set can be separately subtracted from the value function obtained from the production and shipment decisions for that location set. As a consequence, in order to find the optimal location L^* for its multinational activity under demand risk, the firm solves the following discrete maximization problem

$$\max_{L \in 2^{N-1}} V(L) - \mathcal{F}(L), \quad \text{where } \mathcal{F}(L) = \sum_{l \in L} f_l. \tag{21}$$

2.3 Comparative Statics

In this section, we describe the effect of risk aversion on the MNE's production and location choice by means of some illustrative examples. First, fixing firm's productivity and chosen location set, we show how different demand correlation structures affect the firm's aggregate and relative sales across countries. Second, we conduct a trade liberalization exercise to show the existence of spillovers on trade flows to third countries when firms are risk averse. Finally, we consider how the location choice can be affected by the presence of risk aversion: in particular, to assess the effect of heterogeneous attitudes towards risk on the location decision, we analyze how firms with different levels of risk aversion and equal level of home productivity select different locations for establishing their foreign affiliates; we then conduct a similar exercise to show how differently productive firms, equally averse to risk, can select different location sets that do not necessarily nest.

The Role of Demand Correlations.

Throughout the subsection, we consider an economy consisting of three countries, A, B, and C. The variance of demand realizations, the (expected) market sizes, and the trade costs are equal for the three countries.[25] In addition, the firm holds its unique affiliate in country A. Given the above assumption, we represent the absolute and relative sales of a firm to each country for a given level of risk aversion.

Equally correlated economies. Assume that the demand correlations between A and B, B and C, and A and C are equal, positive but not perfect.[26] In the left panel of Figure 1, we notice how the absolute sales in country A are comparatively larger than those in countries B and C for any level of risk aversion. As the firm operates its affiliate in country A, it benefits from the proximity to the final customers. Hence, it ships a larger amount of the variety to the local market. Furthermore, given that the foreign countries B and C are symmetric, the firm sells the same amount to the two countries. In addition, a larger level of aversion to risk induces the firm to sell less to each country, as they are risky. The presence of risk aversion affects not only the absolute value of sales but also the relative shares among countries as it can be seen in the right panel of Figure 1. Indeed, a larger degree of risk aversion reduces the share of sales associated to country A and increases the shares of country B and C. The reason for that result is to be linked with the fact that a more risk averse firm exploits more extensively the diversification opportunities as they are more concerned with the demand risk.

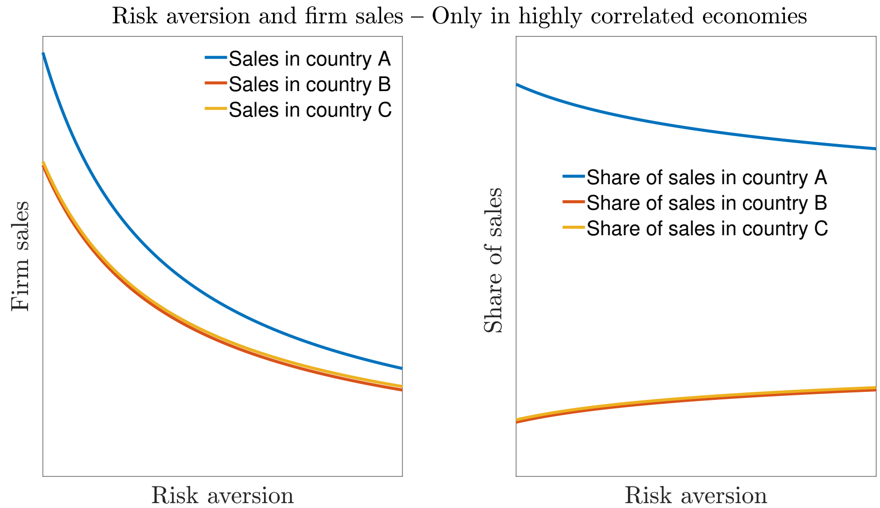
Differently correlated economies. Next, we consider the case in which the correlation of demand realizations between countries A and B, and A and C is lower than the correlation between countries B and C.[27] In this specification, the gap between sales in country A and countries B and C widens (see Figure 2). Though the structure of correlations has changed from the previous case, still countries B and C are symmetric so the firm ships the same amount to both countries.

[25] We do not focus on the distinction among safer and riskier markets but rather concentrate our attention on isolating the pure effect of diverse correlation structures on the sales structure. Notice that the assumption that the expected size and variance are the same across the markets means the three countries exhibit the same coefficient of variation. Moreover, because the variances are the same, the covariances are a sufficient statistic for the degree of integration between the economies of any pair of countries.

[26] This can be thought as the case of a German firm (affiliate in country A), producing only domestically and being able to serve additionally France (country B) and the UK (country C).

[27] This can be thought as the case of a German firm (affiliate in country A) producing only domestically and being able to serve additionally Japan (country B) and South Korea (country C).

Figure 1: Case 1, Equally correlated economies



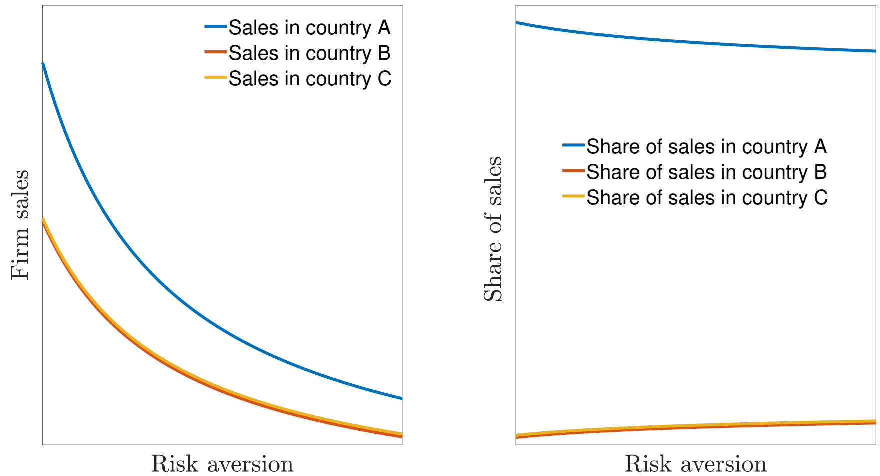
Additionally, we observe two things. First, country A displays a relatively poor demand correlation with both B and C; second, the demand correlation between countries B and C is now relatively large. The two observations together imply that, compared with the previous case, the firm wants to sell more to country A and reduces its exposure in countries B and C (see the left panel of Figure 2). Regarding the relative sales, a similar pattern to the previous case can be observed in the right panel of Figure 2. However, the adjustment of shares is now less remarkable than before as the countries B and C have a lower diversification potential.

Mixed case. In the last case, we assume that the demand correlation between A and B is larger than the correlations between countries A and C, and B and C.[28] Given the structure of demand correlation, country C now provides the firm with a better hedge to negative fluctuations in country A's demand compared to country B. In the left panel of Figure 3, it is possible to note that, when risk aversion is large enough, the country with the largest diversification potential, that is country C, attracts the largest share of sales in absolute terms so that diversification benefits outweigh the marginal cost benefits of selling in a foreign market. In other words, the benefit of diversification

[28] This can be thought as the case of a German firm (affiliate in country A) producing only domestically and being able to serve additionally France (country B) and Japan (country C).

Figure 2: Case 2, Poorly correlated economies

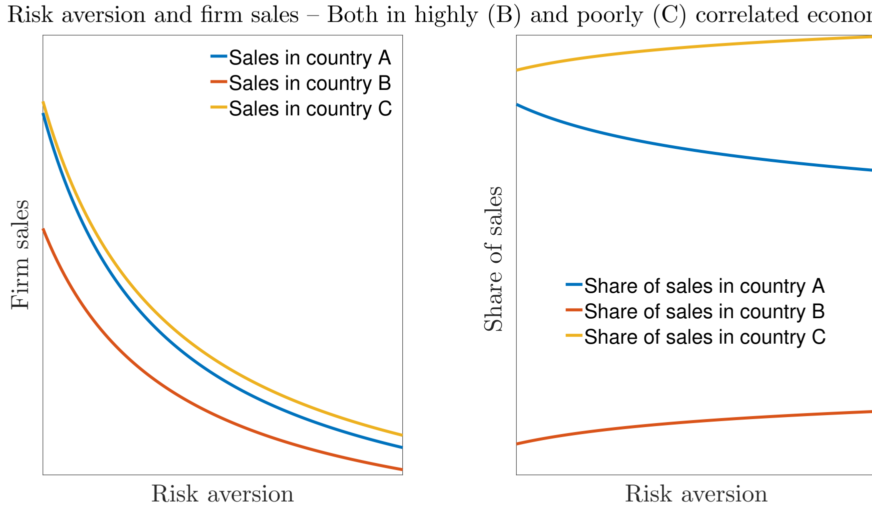
Risk aversion and firm sales – Only in poorly correlated economies



outweighs the gains of proximity to the customers. The right panel of Figure 3 shows that, when risk aversion increases, the shares of sales in B and C increase, whereas the share of sales in A decreases.

Figure 3: Case 3, Mixed case

Risk aversion and firm sales – Both in highly (B) and poorly (C) correlated economies



In the above examples, the diversification strategies of an MNE distort the sales distribution compared with the risk neutral model.[29] The distortion is particularly relevant either when risk aversion or diversification opportunities are large. Importantly, firms with different risk aversion value differently each destination market as each of them provides different hedging opportunities. The possibility of serving more conveniently a destination market can result into diverse location choices and reaction to trade policies as we will discuss later. Moreover, for a given level of risk aversion, the shares of sales in each location is not going to be affected by a change productivity. This finding plays an important role in separately identifying risk aversion and productivity separately.

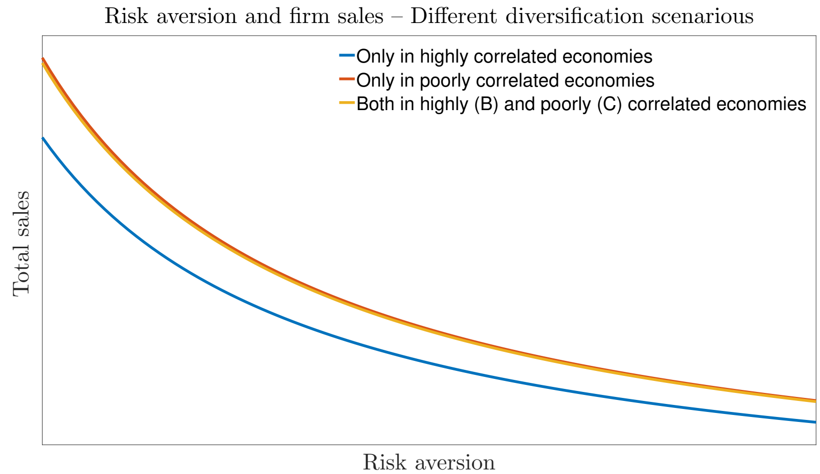
Finally, it is interesting to see under which correlation structure firms sells more (Figure 4). Comparing aggregate sales across the above scenarios, a multinational firm sells more on average when the dispersion of correlations among the available countries is the largest, as a consequence of the largest diversification opportunities. Thus, we expect firms to sell more in industries characterized by a wider spread of demand correlations. This observation is also in line with the evidence that exporters' sales decrease more than MNEs' sales during the crisis; as MNEs can typically reach a larger number of countries, they access to a more favorable correlation structure than exporters do. Therefore, this mechanism can explain why the sales of MNEs were more stable than those of pure exporters during the last crisis.

Liberalization Spillovers.

Next, we evaluate the effect of a bilateral trade liberalization when demand realizations are correlated and firms are risk averse. Similarly to the previous part, we consider a scenario with three countries and look at the effect of a tariff reduction for the good imported into country B from A. Without risk averse firms, a tariff reduction in country B does not affect sales in A and C. However, when we introduce risk averse firms and correlated demand shocks, spillovers can emerge as a byproduct. In the case of three countries, the effect of the described policy change depends on the sign of the correlation of demands among the three countries. When sales in country B increase,

[29] In the risk neutral model, the absolute sales are flat with respect to risk aversion. Moreover, the sales realized in country B and C represent a downward shift of the sales realized in country A, whose extent depends on the magnitude of the trade costs.

Figure 4: Diversification opportunities and aggregate firm sales



the spillover effects in countries A and C depend on the possibility to hedge the larger exposure to risk due to the sales increase in country B.[30] In particular, if the demand in C, which is a third country, is positively correlated with the demand in country B, the sales to the destination C drop. On the contrary, a negative correlation between country B and C determines a sales increase in country C due to the fact that firms can reduce their exposure to demand risk. Table 1 shows the change in sales in the three countries for each combination of correlation signs.

Similar demand-side spillovers emerge for any country-specific change, e.g., an improvement of investment climate in one particular country results in the reshuffling of trade flows in all correlated foreign markets.[31]

Table 1: Effects of trade liberalization

Reduction of τ_{AB}	Sales A	Sales B	Sales C
$\text{corr}(A,B) > 0$, $\text{corr}(B,C) > 0$	−	+	−
$\text{corr}(A,B) > 0$, $\text{corr}(B,C) < 0$	−	+	+
$\text{corr}(A,B) < 0$, $\text{corr}(B,C) > 0$	+	+	−
$\text{corr}(A,B) < 0$, $\text{corr}(B,C) < 0$	+	+	+

[30] For a discussion on the effect of a trade liberalization see Appendix H.

[31] Note that patterns in trade flows change are more complicated when more than three countries are involved as they depend on the entire structure of the variance correlations matrix.

Risk Aversion and Entry.

The above numerical exercises assume a fixed set of foreign affiliates in which the MNE operates. In what follows, we remove this restriction and consider the possibility that a firm self-selects into foreign locations. This exercise allows us to evaluate the impact of risk aversion and productivity on the entry choices.

In the trade literature studying the determinants of firm's entry in a foreign market (Helpman et al., 2004), the entry decision is typically described by a destination-specific productivity threshold. In particular, a firm engages in any foreign activity if and only if its level of productivity is large enough. Furthermore, a prediction of these models is that only sufficiently productive firms find it profitable to pay the fixed entry cost in a foreign location. In a multi-country environment where firms can establish a foreign plant in many locations, this prediction results in a hierarchical ordering of entry decisions. As a consequence, the location sets chosen by the firms constitute a sequence of nesting sets with respect to firm's productivity. In our model, since countries are no longer independent, firms decide on the set of foreign locations also accounting for the hedging opportunities the set provides. Therefore, we can rationalize the presence of non-hierarchical entry, as observed in the data (e.g. Yeaple (2009)).

To illustrate this point, we consider a world consisting of six countries. In all scenarios, country A is the origin country of the multinational firm.[32] First, we fix firm's productivity and look at the entry decisions for different values of risk aversion. In the numerical example, the sets of locations chosen by the firm are not nested as the upper panel of Table 2 shows. Moreover, a higher degree of risk aversion does not necessarily reduce the number of foreign locations the firm decides to be present in.

For a firm with a medium level of risk aversion, it is profitable to enter two locations – country B and country E, while a more risk averse firm enters three locations – C, D and F (see Table 2).

Analogously, given the level of risk aversion, changing the productivity can affect not only the number of entered locations but also the compositions of the optimal location set. Specifically,

[32] Costs of entry in the home country are set to zero.

Table 2: Entry decision and risk aversion

Risk aversion	Country A	Country B	Country C	Country D	Country E	Country F
Low risk aversion	Yes	No	No	Yes	Yes	No
Medium risk aversion	Yes	Yes	No	No	Yes	No
High risk aversion	Yes	No	Yes	Yes	No	Yes
Very high risk aversion	Yes	No	No	No	No	Yes
Productivity	**Country A**	**Country B**	**Country C**	**Country D**	**Country E**	**Country F**
Low productivity	Yes	No	No	Yes	Yes	No
Medium productivity	Yes	No	No	No	Yes	No
High productivity	Yes	No	No	No	Yes	Yes
Very high productivity	Yes	No	No	No	Yes	No

Note: "Yes" stands for entry to the market, "No" stands for no entry.

a more productive firm does not need to enter more locations. Additionally, a more productive firm does not necessarily enter all locations a less productive firm is present in. The reason behind this outcome hinges on the different attractiveness as demand-risk hedge offered by each location. More productive firms are less concerned about the costs of serving foreign locations due to their advantage in terms of marginal costs. Hence, they can benefit from the presence of demand risk diversification even if they enter into fewer locations. Instead, firms with low productivity have to bear larger marginal costs; in order to exploit the diversification potential of sales, they has to select into more foreign locations in order to reduce the distance from the customers. Therefore, the model predicts that small (large) firms enter relatively more (less) locations than predicted by the standard proximity-concentration tradeoff literature. This rationalizes the finding of Yeaple (2009).

3 Data

For the empirical analysis, our main data source is the Microdatabase Direct investment[33] (MiDi), which contains firm-level information about foreign affiliates of German multinational companies.[34] More specifically, the data include balance sheet variables of foreign companies in which German

[33]Deutsche Bundesbank (2016): Microdatabase Direct Investment 1999-2014. Version: 2.0. Deutsche Bundesbank. Dataset. http://doi.org/10.12757/Bbk.MiDi.9914.02.03

[34]The database is maintained by the Deutsche Bundesbank. For other research using the MiDi see Tintelnot (2017), who analyzes cost structure of vertical export platforms, Becker and Muendler (2008), who estimate responses of MNEs employment at the extensive and intensive margins.

MNEs have directly (or indirectly) at least 10% (50%) of the shares or voting rights. In addition to the standard balance sheet variables (as capital stock, labor and turnover), we observe the locations of foreign affiliates and the industries[35] they operate in.

The empirical estimation relies on 952 German multinational firms operating in 19 different industries[36] and 45 foreign countries[37] with 3,232 affiliates[38] in 2007. We consider only those foreign affiliates in which a German multinational holds the control rights. Table 3 shows the total sales and the number of firms present in each of the top 10 destinations.[39] The United States, Spain and France are the three countries from which German affiliates sell the most. It is worth noting that the number of entrants in a country cannot be perfectly mapped to the productivity level (or size) of the median entrant. In addition, Appendix D shows that the average distance of the foreign affiliates from Germany does not monotonically increase in the number of affiliates itself. These observations gives. These observations give us room for discussing the importance of demand factors in affecting the choice of foreign locations. Moreover, the relevance of foreign countries with respect to the aggregate sales differs for small-medium and large multinationals (see Appendix C for descriptive statistics). We note that the top countries in generating aggregate sales are Brazil and Japan for large MNEs, whereas they are Poland, Austria, Italy and Switzerland for small and medium MNEs. With respect to the entry pattern, the top locations are China and

[35] Industries are classified on 2-digit level NACE Rev. 1.1.

[36] We aggregate the industries 1500 (manufacture of food products and beverages) and 1600 (manufacture of textiles). This consolidation is in line with NACE Rev. 1.1, which aggregates these two industries at the upper level DA (manufacture of food products, beverages and tobacco). Moreover, in order to fulfill the confidentiality requirements for the usage of the dataset, we exclude the industry 2300 (manufacture of other non-metallic mineral products).

[37] The set of countries consists of 26 European countries (Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Greece, Hungary, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom), 9 Asian countries (China, Hong Kong, India, Indonesia, Japan, Korea, Malaysia, Singapore, Turkey), 5 South American countries (Brazil, Chile, Colombia, Mexico, Peru), two African countries (South Africa, Tunisia), Canada and the United States in North America, and Australia in Oceania. These are the countries where at least three different German MNEs operate an affiliate. Given this set of countries, we account for 96% of the total affiliates of MNEs operating in 2007 and performing horizontal FDI. Furthermore, the share of the affiliates we consider generates 99% of the total affiliate sales.

[38] We aggregate the capital, labor and sales for the affiliates of one MNE operating within the same country. As production fragmentation does not provide us with any information about the effect of country characteristics on the incentive to diversify, our main results do not change.

[39] The ranking is built with respect to the total amount of sales.

Table 3: Descriptive statistics on foreign affiliates and parents by country

Countries	Total	Sales affiliate		Sales MNE		Employment MNE		Average	N
	sales	Average	SD	Average	SD	Average	Median	productivity	
United States	47.5	257	1340	1758	89960	4497	883	3.38	185
Spain	22.2	239	995	4201	15665	11419	1809	3.38	93
France	16.9	105	225	2522	11709	6673	1210	3.53	161
Brazil	16.6	238	1060	4685	809	13290	3255	3.71	70
United Kingdom	15.5	135	442	4151	15042	10772	1434	4.18	115
Czech Republic	13.9	104	694	2279	12622	6621	909	3.58	134
China	10.8	60	178	2002	8733	6290	1453	3.64	181
Poland	9.9	75	301	1705	9417	4495	778	3.91	132
Hungary	9.6	117	646	1838	5760	6324	1252	4.09	82
Mexico	9.2	196	877	7207	21378	18309	2644	3.49	47
Germany	577.2	594	3620	873	5522	2557	676	3.90	971

Note: Total sales are expressed in billion Euro. Sales of affiliate and MNE are expressed in million Euro.
Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Microdatabase Direct investment (MiDi), 1999-2014, authors' calculations.

France for large MNEs, the US and Poland for small MNEs.

Since our model describes the contribution of demand components at explaining the global production structure, we restrict our sample to those MNEs that conduct horizontal FDI. MiDi does not provide information about the type of FDI chosen by a firm. To restrict our sample only to the horizontal FDI positions, we use a standard proxy which considers an investment relation as horizontal if both parent and affiliate firms operate within the same industry.[40]

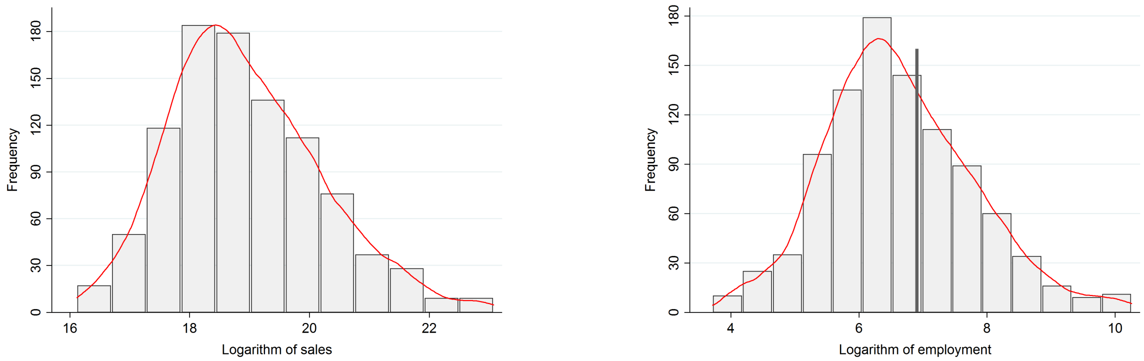
We integrate the information in AMADEUS database to complement the balance sheet data on the home plants of German multinational firms. In particular, we observe the level of home sales, the number of employees, and the level of capital of the parent companies.

Figure 5 shows the variation in MNE sales and employment. We notice that the set of firms in our analysis is not solely restricted to the largest German firms; the variability in the firm sales is particularly evident.

Table 4 shows some descriptive statistics about foreign affiliates operating in each industry. First, we can notice that the average and median sales of firms vary across industries, being particularly

[40]This assumption leaves us with 86% of the initial sample. Literature proposed also to proxy for horizontal FDI using the data on intrafirm trade. Unfortunately, MiDi does not contain this information explicitly. Nonetheless, intrafirm trade can be proxied by the share of affiliate current assets of which claims on the affiliated enterprises. This measure is less restrictive and includes our subsample. See Overesch and Wamser (2009), who use current assets claim to proxy for horizontal FDI in MiDi.

Figure 5: Distribution of German MNEs' sales and employment in 2007 in manufacturing



(a) Sales

(b) Employment

Note: Firms with employment level to the right of the bold vertical line are considered to be large firms (more than 1000 employees). Sales are expressed in the logarithm of million euros. Employment is expressed in the logarithm of the number of employees.
Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Microdatabase Direct investment (MiDi), 1999-2014, authors' calculations.

high in the manufacturing of auto, electrical machinery and basic metals. Moreover, these three industries are characterized by a large range of firm sales and sizes. With regard to foreign entry, producers operating in the chemical and transport sectors hold more affiliates on average (in the other industries, the average MNE is present only in one foreign country). Industries are quite dispersed in terms of share of multinational production. On average foreign affiliate sales generate 27.6% of the total sales of a German MNE. In some industries, the sales produced by affiliates are larger (auto, minerals, printing) whereas in other sectors most of the production is carried out by the parent firm in Germany (wood, machinery and basic metals). At the same time, foreign market participation cannot be perfectly mapped to the concentration of sales across affiliates. The largest level of sales concentration occurs in basic metals and textile, while this measure is lower in other transport and paper manufacturing. One of the hypothesis that can explain this result is that industry characteristics can affect the way an MNE spreads its sales across affiliates.

To estimate non-firm-specific parameters, such as trade costs, production indexes, and the co-

Table 4: Descriptive statistics on affiliates by industries

Industry	Sales		Employment		Number	Concentration	Foreign	N
	Average	SD	Average	SD	of affiliates	measure	share (%)	
Food and tobacco	185	589	356	469	1.6	0.36	29.7	116
Textile	38	49	240	287	1.5	0.42	28.8	50
Wearing and leather	70	84	440	435	1.5	0.48	26.4	33
Wood	69	115	363	321	1.0	0.40	19.8	14
Paper	120	182	351	395	1.2	0.35	23.2	40
Printing	88	210	342	634	2.4	0.37	32.6	94
Chemicals	271	1118	640	1939	3.7	0.43	29.9	433
Plastic	69	175	312	529	2.1	0.36	30.5	290
Minerals	95	130	488	755	2.2	0.38	33.4	136
Basic metals	376	1112	924	2496	1.3	0.49	22.6	79
Metal products	73	129	380	575	1.8	0.42	25.4	262
Machinery n.e.c.	135	377	516	1321	2.0	0.47	22.2	598
Electrical	377	2227	1644	8026	2.1	0.41	26.8	235
Communication	360	954	957	1437	1.9	0.39	30.4	90
Medical	65	101	308	444	2.0	0.46	27.7	207
Auto	1180	5950	2648	11347	3.3	0.38	34.8	319
Other transport	226	460	826	1670	2.6	0.46	25.4	65
Furniture	46	47	289	274	1.2	0.33	31.3	31

Note: Sales are expressed in million Euro.
Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Microdatabase Direct investment (MiDi), 1999-2014, authors' calculations.

variance matrix of country demands, we use data from UN databases and CEPII.[41]

4 Estimation

In this section, we describe the estimation procedure we follow to obtain estimates of the risk aversion coefficient of the MNEs. Given the location set L in which the affiliates of firm operate and the aggregate sales $\sum_d p_d q_d$ of the multinational group, we determine the firm-specific risk aversion parameter r. Our model yields uniqueness of the risk aversion measure for a given choice of the location set. The estimation of risk aversion requires additional parametrization and estimation of firm- and country-industry-specific parameters $(\boldsymbol{\varphi}, \boldsymbol{\tau}, \boldsymbol{\sigma}, \bar{\boldsymbol{\alpha}}, \boldsymbol{\Sigma}, \boldsymbol{Q})$.

First, we discuss the estimation of productivities, trade costs, and quantity indexes, and parametrize the other country-industry-specific parameters. Second, we show the procedure to derive the risk

[41] Trade flows and home production data are from the COMTRADE, INDSTAT and IDSB. Gravity dummies and distances are from CEPII. COMTRADE concordance tables provide industry-country trade flows in NACE Rev. 1.1 classification.

aversion coefficients.

4.1 Productivities and Industry Parameters

4.1.1 Productivities

German companies operating in different countries exhibit different productivity levels across affiliates. This observation can stem from the non-perfect cross-border transferability of technologies and different quality of inputs across countries. Hence, as to disentangle the role of demand from that of technology, we need to control for the heterogeneity in productivities across affiliates of one firm.

Since the estimates of productivities enter the risk aversion measure, we discuss the identification of the latter. Productivities and risk aversion affect firms' sales at a different levels. In our framework, productivities are affiliate-specific, whereas risk aversion coefficients are group-specific. In particular, for a risk neutral firm higher productivity in one affiliate makes it cheaper to serve all destination markets associated with this location. Therefore, without risk aversion, we expect higher sales to each destination market from the more productive affiliate. At the same time, risk aversion shapes sales flows due to the presence of demand correlations. When risk aversion is positive, an increase in the affiliate productivity results in a reshuffling of the sales portfolio and changes the sales shares in each destination market served from the affiliate in a way that is proportional to the hedging opportunities offered by the location. Moreover, a risk averse firm adjusts the sales realized in all other affiliates. Since we observe the affiliate sales of firms with different productivities, we can disentangle the effect of productivity on sales from that of diversification. We use the variation of sales at the affiliate level to capture the supply-side parameters, whereas we use the aggregate sales to determine the firm's risk attitude.

In the estimation of productivity, we control for firm- and market-specific demand parameters to obtain productivity estimates in the presence of a positive risk aversion. The equation we estimate at the affiliate level by industry reads as

$$\begin{aligned}\ln(sales_{jl\omega}) = \beta_1 + \beta_k \ln(capital_{jl\omega}) + \beta_\ell \ln(labor_{jl\omega}) + \beta_a \ln(age_{jl\omega}) \\ + \beta_c concentration\ measure_\omega + \beta_v coefficient\ of\ variation_l \\ + \beta_p premium_l + \xi_{jl\omega},\end{aligned} \tag{22}$$

where j denotes the affiliate, l the location of affiliate j, and $\xi_{jl\omega}$ the affiliate-multinational-specific productivity shock. From the previous specification, we obtain the productivity estimate $\hat{\varphi}_{jl\omega}$ according to $\hat{\varphi}_{jl\omega} = \exp(\hat{\xi}_{jl\omega} + \hat{\beta}_1)$.

We include a measure of sales concentration to capture the diversification incentives of a firm to take into account different degrees of risk aversion across firms.[42] Moreover, we include the coefficient of variation of the demand associated to the location where the affiliate operates in. We find a significant negative relation between aggregate sales and the volatility of destination market demand. Another problem can potentially arise from the fact that we estimate productivity using realized sales rather than expected sales (i.e. sales before the realization of the shocks). Indeed, higher sales to a destination can be just due to a higher realization of the market demand rather than to the level of productivity of the firm in the given market. Therefore, to proxy for the effect of the realized market size, we include the difference between the realized and expected market size.[43] We show in Section 5 that the productivity estimates are not correlated with the estimated risk aversion coefficients when controlling for other firm characteristics. Moreover, we find that German MNEs are, on average, more productive at home than in the host countries (see Figure 6).

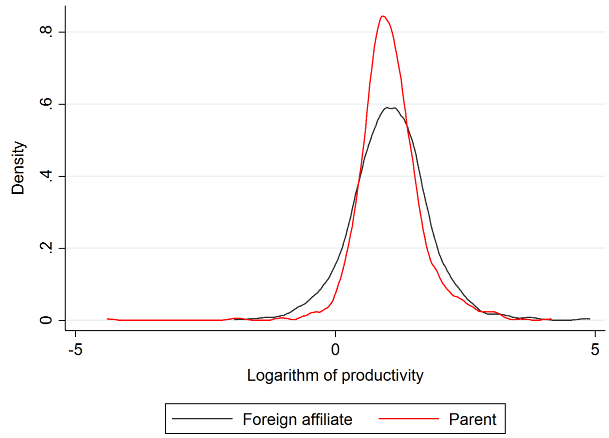
4.1.2 Industry Parameters

A set of parameters is common to all firms operating within an industry. For convenience, we distinguish between supply side parameters, i.e. trade costs, and demand side parameters, i.e. the elasticity of substitution, quantity indexes, variance-covariance matrix of market sizes, and expected

[42] The construction of the concentration measure of sales is discussed in the Appendix D.

[43] For the estimation of expected market size, see subsection 4.1.2.

Figure 6: Distribution of productivities of foreign affiliates
and parents (in logs)



Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Microdatabase Direct investment (MiDi), 1999-2014, authors' calculations.

market sizes.

The estimation of trade costs and quantity indexes is based on the methodology proposed by Anderson and van Wincoop (2003) for cross-sectional data. In particular, a partial equilibrium model for import flows at the industry level delivers the following equation:

$$\log\left(\frac{m_{d'd}}{M_d}\right) = (1-\sigma)\log\left(\tau_{d'd}\right) + (\sigma-1)\log(P_d) \quad \text{for } d, d' \in 1, ..., N, \tag{23}$$

where $m_{d'd}$ is import from d' to d, and M_d is the sum of total import and consumption in country d. Therefore, the share of country d' in total consumption in country d is described by trade costs between countries, the level of prices in country d, and the elasticity of substitution.

Similar to Anderson and van Wincoop (2003), we can estimate trade costs and price indexes only conditional on the elasticity of substitutions σ. As we do not estimate industry-specific elasticity of substitution, we assume $\sigma = 6$.[44]

[44]This value is in line with Head and Mayer (2004) and Chen and Novy (2011). Note that this value implies a markup equal to 17% in a risk neutral framework. Importantly, estimates of risk aversion parameters exhibits a low sensitivity to the choice of the elasticity of substitution. This is linked to the fact that risk aversion represents a ratio between the sales premium and variance, which are scaled by the same sigma. See Proposition 2.

We model trade costs as a function of the distance between the two countries, contiguity, and common language. More precisely, we have

$$\log(\tau_{d'd}) = \beta_1 \log(\text{dist}_{d'd}) + \beta_2 \text{contig}_{d'd} + \beta_3 \text{lang}_{d'd} \;\text{ for } d, d' \in 1, ..., N. \tag{24}$$

To estimate industry-specific price indexes, we introduce dummies as in Baldwin and Taglioni (2006). The final equation we are estimating is

$$\log\left(\frac{m_{d'd}}{M_d}\right) = \tilde{\beta}_1 \log(\text{dist}_{d'd}) + \tilde{\beta}_2 \text{contig}_{d'd} + \tilde{\beta}_3 \text{lang}_{d'd} + \gamma_d + \epsilon_{d'd}, \tag{25}$$

where $\tilde{\beta}_b = (\sigma - 1)\beta_b$ for $b = 1, 2, 3$, $\gamma_d = (\sigma - 1)\log(P_d)$, is a country dummy.

We assume that trade costs and price indexes are 2-digit industry-specific, and correspondingly use import flows at the 2-digit disaggregation level. Country-industry-specific quantity indexes are obtained from the industry i equilibrium condition in country d: $P_{id}Q_{id} = \alpha_{id}$.

Finally, we proxy the total expenditure parameter α_{id} using data on the industry-level consumption from the IDSB dataset. This dataset contains information about the output, export and import in a country at a 2-digit level. We obtain co-variance matrices from time-series data on total expenditure in 46 countries from 2002 to 2006.

We assume that α_{id} depends on its first lagged value. In particular, we assume that

$$\alpha_{id,t} = \alpha_{id,t-1}^{\beta} \exp^{IND_i + COUNTRY_d + \epsilon_{id,t}}, \tag{26}$$

where $\epsilon_{id,t}$ is an innovation term[45] with mean 1, and β captures the persistence in the evolution of α. We then estimate the following equation in logs

$$\log \alpha_{id,t} = \beta \log \alpha_{id,t-1} + IND_i + COUNTRY_d + \epsilon_{id,t}, \tag{27}$$

where we include control dummies for industry and country. From this equation we obtain a

[45] We do not restrict this shock term to be uncorrelated across countries and industries.

prediction for $\alpha_{id,t}$ given the value of $\alpha_{id,t-1}$. Hence, we compute the entry (d, d') of the variance-covariance matrix Σ_i in the following way

$$\Sigma_i(d, d') = \sum_{t=1}^{T} \frac{\left(\alpha_{id,t} - \bar{\alpha}_{id,t}\right)\left(\alpha_{id',t} - \bar{\alpha}_{id',t}\right)}{T-1}, \tag{28}$$

where $\bar{\alpha}_{id,t}$ and $\bar{\alpha}_{id',t}$ denote the expectations of $\alpha_{id,t}$ and $\alpha_{id',t}$ given the level of $\alpha_{id,t-1}$ and $\alpha_{id',t-1}$, respectively, and T is the number of years we are using for our estimation.

4.2 Risk Aversion

Uniqueness of the solution of the firm's problem ensures that aggregate sales across affiliates are a well-defined function of risk aversion. Therefore, we match theoretical sales, predicted by our structural model, with aggregate MNE sales, observed in the data.[46] We do not restrict risk aversion to be positive. For each firm, the matching proceeds as follows:

1. Guess the risk aversion parameter r.
2. Given the location set L observed in the data, solve the firm's utility maximization problem.
3. Obtain $\boldsymbol{q}$, and compute the implied aggregate theoretical sales $\sum_{d \in D} p_d q_d$.
4. Update r if the distance between theoretical and empirical sales is larger than the tolerance level.[47]

It is important to note that the updating of r is based on the characteristics of the solution to the utility maximization problem. Everything else equal, the firm's aggregate sales are strictly decreasing in risk aversion as shown in the Proposition 3.

5 Results

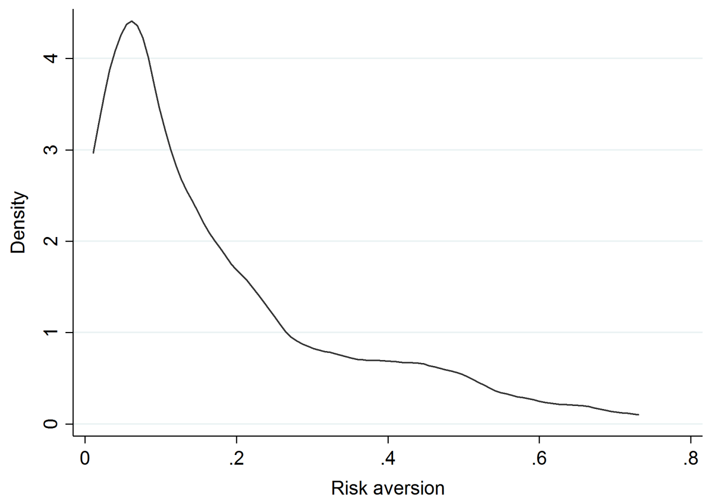
We perform the estimation of risk aversion coefficients for 952 MNEs in the sample in 2007.

[46] Note that we do not observe expected sales in the data. However, sales to each destination are decreasing with the level of risk aversion. This together with uniqueness of the solution allows us to match empirical sales.

[47] We assume convergence when the absolute difference between empirical and theoretical sales is less than 0.001%.

Figure 7 shows the distribution of the estimates of the risk aversion coefficients. We observe that estimated risk aversion coefficients are positive for all firms in the sample. The majority of MNEs display risk aversion coefficients ranging between 0 and 1. In particular, the average risk aversion coefficient in the sample is 0.34 (s.d. equal to 1.16).

Figure 7: Estimated density of risk aversion



	Mean	SD	p10	p25	p50	p75	p90	N
Risk aversion	0.34	1.16	0.01	0.04	0.11	0.31	0.72	952

Note: Outliers on the right tail are removed.
Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Microdatabase Direct investment (MiDi), 1999-2014, authors' calculations.

Table 5 shows that coefficients of risk aversion greatly differ across industries. The average risk aversion ranges from 0.10 in paper manufacturing sector to 1.39 in the manufacturing of basic metals sector.

The heterogeneity in risk aversion can be explained by several factors related to industry characteristics. In particular, the volatility of demand in the industry seems to play an important role. Figure 8 displays the spread in the coefficient of variation in each industry given countries in our sample. On average, larger risk aversion coefficients occur in industries with larger median coefficient of variation (basic metals, medical, electrical). In highly volatile industries, firms are

Table 5: Risk aversion across industries

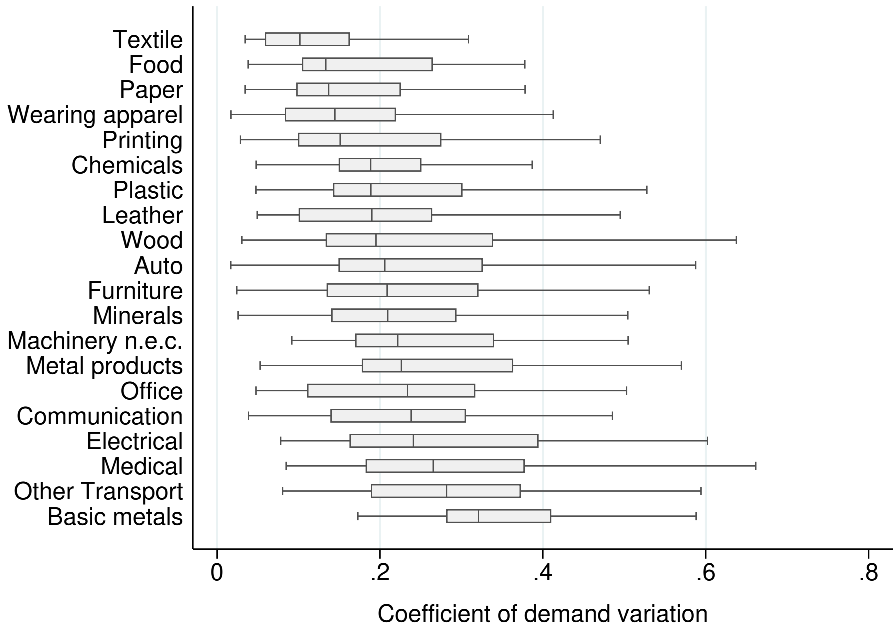
More risk averse industries	Risk aversion			Less risk averse industries	Risk aversion		
	Average	SD	N		Average	SD	N
Basic metals	1.39	4.98	34	Textile	0.20	0.19	20
Medical	0.79	0.93	68	Printing	0.18	0.30	26
Metal products	0.55	0.66	91	Machinery n.e.c.	0.18	0.92	196
Furniture	0.54	0.71	14	Wearing and leather	0.17	0.16	13
Electrical	0.35	0.49	75	Chemicals	0.14	0.42	90
Food and tobacco	0.34	0.70	44	Other transport	0.14	0.18	18
Plastic	0.31	0.33	93	Wood	0.13	0.14	7
Auto	0.25	0.78	73	Minerals	0.13	0.15	41
Communication	0.24	0.25	31	Paper	0.10	0.09	18

Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Microdatabase Direct investment (MiDi), 1999-2014, authors' calculations.

indeed more exposed to demand shocks. Therefore, for these industries, firms consider the demand risk as a more relevant factor. In terms of our model, this implies a larger level of risk aversion. Interestingly, risk aversion is poorly correlated with average industry size and sales of affiliates. In addition, estimated risk aversions is mainly connected to industry-specific demand characteristics rather than to technological variables.

Next, we evaluate the relation between risk aversion and firm-specific characteristics to assess how the risk attitude correlates with the other sources of firm heterogeneity. In Table 6, we present the results of the regression of the estimated risk aversion coefficients on a set of firm's characteristics. First, we find no significant correlation between risk aversion and productivity. This observation is important, as we regard the estimated productivities as an observable. Therefore, the coefficient of risk aversions obtained from our estimation do not reflect the effect of firm's productivity on sales. Second, we find that risk aversion negatively correlates with firm size. Third, we find a negative correlation between firm's age and risk aversion. Our interpretation is that larger or more experienced firms are better at dealing with market risk. Finally, a more risk averse firm tends to display a more diversified structure of sales. This finding suggests that firms take advantage of possible diversification opportunities more extensively when they are more concerned about the market turmoil. Moreover, the negative correlation between the concentration measure and risk

Figure 8: Distribution of coefficient of variation of demand,
product level



Source: UNIDO INDSTAT2 2016, authors' calculations.

aversion[48] is suggestive that the estimated risk aversion captures firm's attitude toward demand risk.

We test the theoretical prediction that aggregate MNE sales and risk aversion are negatively related.

In addition, we find a positive correlation between the share of debt in the firm's capital and the level of risk aversion.[49] The intuition for this finding relates to the fact that financially constrained firms are more risk averse when they compose their sales portfolio.

To assess the goodness of fit of our model to the real data, we compare the predicted trade flows with real data across different regions. Table 7 shows that the model predicts accurately trade flows in most regions. The underprediction of sales in North America and overprediction of sales in Asia and Oceania can be partly explained by the fact that trade costs are estimated outside the model.

[48]Note that this result is still valid when we consider other measure of concentration, like the Herfindal index.
[49]See Table 15 in Appendix J.

Table 6: Risk aversion and firm characteristics

	I	II	III
productivity	-0.0658	0.0223	-0.0829
	(0.0583)	(0.1368)	(0.0589)
size	-2.0699^{***}	-1.9597^{***}	-1.9176^{***}
	(0.0795)	(0.0801)	(0.0796)
age		-0.0819^{**}	-0.1330^{***}
		(0.0399)	(0.0206)
*productivity*age*		-0.0364	
		(0.0281)	
concentration			-0.6905^{***}
			(0.1429)
constant	-1.3460^{***}	0.9009^{***}	-0.5058^{**}
	(0.1922)	(0.2697)	(0.2181)
industry fixed effects	Yes	Yes	Yes
N	952	952	952

Note: We consider productivity of parent German firm. Risk aversion and productivity are taken in logs. Size is equal to 1 for MNEs with more than 1000 employees. Concentration measure is measured by Herfindal Index. Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Microdatabase Direct investment (MiDi), 1999-2014, authors' calculations.

We believe that an estimation procedure able to match the characteristics (e.g. the interdependence) of multinational trade flows across countries would provide more accurate results.[50]

Table 7: Regional trade flows of German multinationals (percentage shares)

Regions	Data	Model	*N*
Africa	1.1%	1.8%	47
Asia & Oceania	3.4%	10.9%	241
Europe	86.2%	82.2%	896
North America	7.3%	3.1%	205
South America	2.1%	1.9%	69

Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Microdatabase Direct investment (MiDi), 1999-2014, authors' calculations.

[50]In particular, estimating jointly productivities and firm's risk aversion may improve the ability of the model to match the empirical data.

Next, we estimate a proxy for the elasticity of MNE sales to the level of risk aversion.[51]

We find that a change of 1% in risk aversion produces a change of sales approximately equal to −0.8%.

Table 8: Sales response to exogenous change in risk aversion

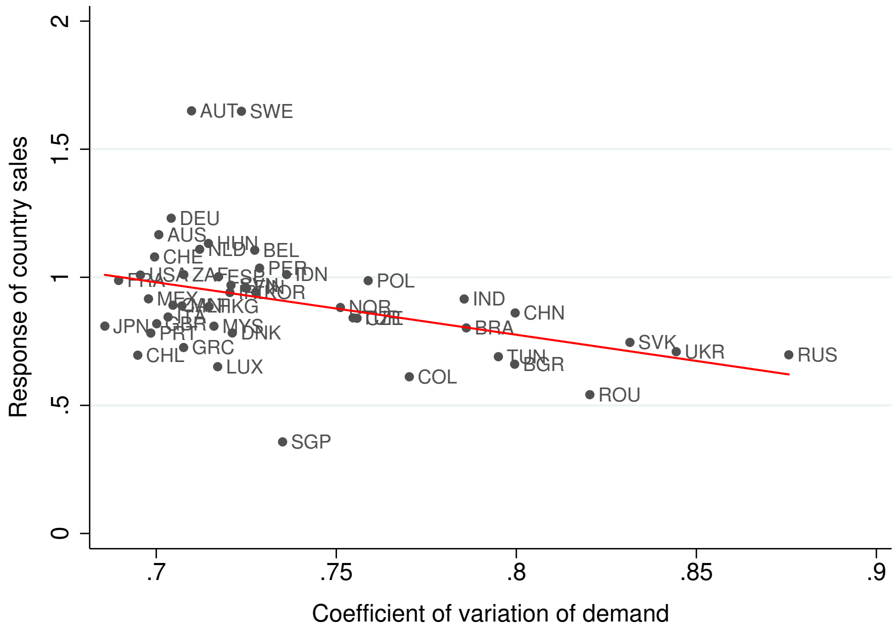
Change in risk aversion	Mean	p25	p50	p75
5% increase	−4.13%	−4.40%	−4.08%	−3.79%
1% increase	−0.85%	−0.92%	−0.85%	−0.78%
1% decrease	0.85%	0.79%	0.87%	0.93%
5% decrease	4.46%	4.12%	4.51%	4.82%

Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Microdatabase Direct investment (MiDi), 1999-2014, authors' calculations.

We conduct an analogous exercise to measure the sensitivity of countries' trade flows to changes in risk aversion. Figure 9 depicts the increase in sales of German multinationals to countries in response to a 1% decrease of risk aversion in the sample. Trade flows to all countries increase in absolute terms, which is in line with the result obtained in simplified setting in Section 2.3. Moreover, the magnitude of response is negatively correlated with the riskiness of the country. Safer markets gain more from the decrease in risk aversion, while more volatile economies still attract relatively lower trade flows. At the same time, changes in risk aversion affect to a larger extent countries whose economies are strongly co-moving with German economy. We observe that many developing economies are less sensitive to changes in risk aversion, which is again in line with the intuition provided in the comparative statics exercise: as risk aversion increases, multinationals are less prone to concentrate sales in similar countries and increase relative sales shares in less correlated countries.

[51] Changes of the degree of firm's risk aversion in the market can take place as a consequence of the entrance of a different population of firms in the market. Alternatively, changes in the level of financial constraints can also affect the attitude towards risk of the firms.

Figure 9: Sales response to exogenous increase in risk aversion, country level



Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Microdatabase Direct investment (MiDi), 1999-2014, authors' calculations.

5.1 Counterfactual: Trade Liberalization in China

In this section, we consider the effect of a trade liberalization occurring in China. In particular, we assume that the trade costs for the goods imported to this country decrease by 10%. The results are reported in Table 9.

Table 9 shows how the trade flows to China from German MNEs would increase by approximately 23%. A trade cost decrease has a first order effect on the import to China related to the fact that selling products to this destination market becomes cheaper. However, not only trade flows to China are affected but also those to other correlated countries. In particular, imports to the USA and Japan from German MNEs greatly increase. As the exposure to demand risk in China increased following the trade liberalization, German MNEs optimally reallocate their production favoring those countries that offer better hedge to the increased risk in China. On the contrary, countries like Hong Kong and Singapore are negatively affected by the policy change; though their demand

Table 9: Response of trade flows to a tariff decrease in China by 10%

Country	Change (in %)	Country	Change (in %)
China	22.94	EU	−0.73
USA	11.20	Ukraine	−0.95
Japan	6.05	Indonesia	−0.96
Australia	−0.01	Colombia	−1.27
South Africa	−0.04	Russia	−1.32
South Korea	−0.05	Mexico	−1.76
India	−0.16	Norway	−2.04
Brazil	−0.21	Singapore	−2.45
Turkey	−0.36	Peru	−2.90
Chile	−0.53	Hong Kong	−5.93

Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Microdatabase Direct investment (MiDi), 1999-2014, authors' calculations

sizes are significantly smaller than the Chinese one, the change is noticeable. We also evidence that the trade flows to the other EU countries would slightly decrease. Overall, the direction and magnitude of the change of imports depend on (i) how good a country is at providing hedging for the increase in the demand risk, (ii) the correlation structure among the countries in which the MNEs are present in, as predicted by our model.[52] In general, the structure of correlation makes prediction hard. Indeed, the reallocation patterns are rather complex as spillovers to one country can propagate to other correlated countries. If countries are relatively highly positively correlated countries, then a liberalization policy taking place in one of them negatively affects the others. Indeed, firms need to reduce their exposure to demand risk due to the increase in sales in one the countries.[53]

[52]On May 11 2017, China and US signed a trade agreement to remove some of the existing barriers in the trade across the two countries. The agreement could be mutually beneficial not only because firms operating in both countries can take advantage of the lower trade costs but also because of the favorable correlation structure.

[53]This might have also implications for Brexit. Countries in the EU might benefits in the case of an increase in tariffs for the goods imported in the UK.

6 Conclusions

In this paper, we develop a model of risk averse multinational firms conducting horizontal FDI and serving foreign markets through export platforms under demand risk.

Our theoretical model predicts that MNEs exploit the presence of demand correlations across foreign markets to hedge against the risk of unfavorable aggregate demand fluctuations. The quantity sold in a destination market differs from the one the firm would sell under no risk and, in particular, depends on the riskiness of the country, on its diversification potential, and the degree of risk aversion of the firm itself besides market size, distance, and production cost. As firms are heterogeneously risk averse, this implies that they set firm-country-specific markups even within a standard CES framework. We also find that third-country effects can follow a trade liberalization episode. In particular, countries that are not directly involved in the policy change can suffer or gain from a change in tariffs, depending on the structure of the correlation across demand realizations. Due to the interdependence across foreign markets and the presence of risk aversion, a nonstandard firm's entry policy obtains. Specifically, the size of the location sets in which a firm establishes its foreign production facilities does not necessarily vary monotonically both with risk aversion and home productivity.

The empirical analysis relies on the data on German multinational enterprises. Our main findings are consistent with the existence of diversification patterns in the sales structure of multinational enterprises. In particular, firms display strictly positive and heterogeneous degrees of risk aversion. This heterogeneity can be related to firm's characteristics, like size and age, and to the demand characteristics of the sector in which the firm operates in. In particular, firms in the relatively more volatile industries display a larger aversion toward risk. In two counterfactuals, we show (i) how a tariff reduction for goods imported into China would increase sales in less correlated economies and harm, instead, those countries whose demand are more correlated with the Chinese one, and (ii) how a reduction in risk aversion would result in a larger increase of sales in countries that are either less risky or whose economies are more correlated with Germany.

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A Existence and Uniqueness

Proposition 1. *(Existence and Uniqueness). If the matrix $\boldsymbol{\Sigma}$ has cross-correlations bounded away from -1 and 1, there exists a unique solution to the firm's utility maximization problem.*

Proof. Before delving into the proof of Proposition 1, we show an auxiliary lemma which turns out to be useful for the following discussion.

Lemma 1. *Let $(P1)$ denote the following problem*

$$\begin{aligned}\max_{\mathbf{q}\in\mathbb{R}_+^N} u(\Pi(\mathbf{q}|L,\boldsymbol{\varphi},r)) = &\sum_d \left(q_d^{\frac{\sigma-1}{\sigma}}\left(\mathbb{E}[A_d] - c_d q_d^{\frac{1}{\sigma}}\right)\right) \\ &- \frac{r}{2}\sum_d\sum_{d'} \mathrm{cov}(A_d, A_d') q_d^{\frac{\sigma-1}{\sigma}} q_{d'}^{\frac{\sigma'-1}{\sigma'}}\end{aligned}$$

Define $s_d = f(q_d;\sigma) \equiv q_d^{\frac{\sigma-1}{\sigma}}$. Then, the problem $(P2)$ defined as

$$\begin{aligned}\max_{\mathbf{s}\in\mathbb{R}_+^N} u(\Pi(\mathbf{s}|L,\boldsymbol{\varphi},r)) = &\sum_d \left(s_d\left(\mathbb{E}[A_d] - c_d s_d^{\frac{1}{\sigma-1}}\right)\right) \\ &- \frac{r}{2}\sum_d\sum_{d'} \mathrm{cov}(A_d, A_d') s_d s_{d'}.\end{aligned}$$

is equivalent to $(P1)$, i.e. $\boldsymbol{q}^*$ is a solution to $(P1)$ if and only if $\boldsymbol{s}^*$ is a solution to $(P2)$.

Proof. First, note that for $q_d \geq 0$ the function $f(\cdot)$ is a bijection. Consider the problems $(P1)$ and $(P2)$. If $s_d = q_d = 0$ for all d, then the statement follows. Assume that $q_d, s_d > 0$ for some d. Then, for such d, the first order conditions for $(P1)$ and $(P2)$ are respectively given by

$$\begin{aligned}\frac{\partial u(\cdot)}{\partial q_d} = &\frac{\sigma-1}{\sigma}\mathbb{E}[A_d] q_d^{-\frac{1}{\sigma}} \\ &- r\left(\frac{\sigma-1}{\sigma} q_d^{-\frac{1}{\sigma}} \sum_{d'} \mathrm{cov}(A_d, A_d') q_{d'}^{\frac{\sigma-1}{\sigma}}\right) - c_d = 0,\end{aligned} \tag{29}$$

and

$$\frac{\partial u(\cdot)}{\partial s_d} = \mathbb{E}[A_d] - r\sum_{d'} \mathrm{cov}(A_d, A_d') s_{d'} - \frac{\sigma}{\sigma-1} c_d s_d^{\frac{1}{\sigma-1}} = 0 \tag{30}$$

respectively.

Then, using the definition of s_d, we can write (30) as

$$\frac{\partial u(\cdot)}{\partial s_d} = \mathbb{E}[A_d] - r\sum_{d'}\text{cov}(A_d, A'_d)s_{d'} - \frac{\sigma}{\sigma-1}c_d s_d^{\frac{1}{\sigma-1}} = 0 \tag{31}$$

$$\Leftrightarrow \frac{\partial u(\cdot)}{\partial s_d} = \mathbb{E}[A_d] - r\sum_{d'}\text{cov}(A_d, A'_d)q_{d'}^{\frac{\sigma-1}{\sigma}} - \frac{\sigma}{\sigma-1}c_d q_d^{\frac{1}{\sigma}} = 0 \tag{32}$$

$$\Leftrightarrow \frac{\partial u(\cdot)}{\partial s_d} = \mathbb{E}[A_d]q_d^{-\frac{1}{\sigma}} - r\left(q_d^{-\frac{1}{\sigma}}\sum_{d'}\text{cov}(A_d, A'_d)q_{d'}^{\frac{\sigma-1}{\sigma}}\right) - \frac{\sigma}{\sigma-1}c_d = 0, \tag{33}$$

where the last equivalence follows from the fact that $q_d > 0$. So, if q_d solves (29), then s_d solves (30), and vice versa. This shows that problems $(P1)$ and $(P2)$ are equivalent given the definition of s_d, and admit the same solution, provided this solution exists. $\square$

Next, we consider the problem $(P2)$. We show that the solution exists and is unique. Then, using Lemma 1, we can extend this result to the original problem $(P1)$.

Existence. To show the existence of a solution, we use the notion of coercive function. Recall that a continuous function f is coercive if and only if

$$\lim_{\|\boldsymbol{s}\|\to\infty} f(\boldsymbol{s}) = +\infty.$$

Note that $u(\cdot)$ can be written as the sum of the expected profits and the variance of profits multiplied by a scalar r. These functions, taken with negative sign, are both coercive.[54] Moreover, the sum of coercive functions is coercive. We can then apply Proposition 2.1.1 in Bertsekas, Ozdaglar, and Nedić (2003) to conclude the existence of a solution to the utility maximization problem.[55]

Uniqueness. To show the uniqueness of a solution, it is enough to show that the utility function u is strictly concave in $\boldsymbol{s}$.

Let $\mathbf{H}_u$ denote the Hessian matrix associated to the firm's utility.

[54] Note that the expected profit function is the sum of the profit realized in each destination d, which is a continuous and concave function of s_d admitting a unique global maximizer, i.e. the solution under no risk aversion or uncertainty. Hence, the expected profit function is coercive when taken with the negative sign. Recall that cross-correlations are bounded away from 1. Hence, the variance of profits is coercive, being a continuous and convex function of $(s_d)_{d\in D}$ with a minimum.

[55] Indeed, maximizing a function is equivalent to minimizing its opposite.

Note that any element of the main diagonal is given by

$$\mathbf{H}_u(d,d) = \frac{\partial^2 u(\Pi(\boldsymbol{s}|L,\varphi,r))}{\partial s_d^2} = -\frac{\sigma}{(\sigma-1)^2} c_d s_d^{\frac{2-\sigma}{\sigma-1}} - r\mathrm{var}(A_d) < 0. \tag{34}$$

Moreover, the element outside the main diagonal can be written as

$$\mathbf{H}_u(d,d') = \frac{\partial^2 u(\Pi(\boldsymbol{s}|L,\varphi,r))}{\partial s_d^2} = -r\mathrm{cov}(A_d, A_{d'}). \tag{35}$$

Let

$$\mathbf{D}_u \equiv \mathrm{diag}\left(\left\{\frac{\sigma}{(\sigma-1)^2} c_d s_d^{\frac{2-\sigma}{\sigma-1}}\right\}_d\right). \tag{36}$$

Thus, the Hessian $\mathbf{H}_u$ can be written as

$$\mathbf{H}_u = -(\mathbf{D}_u + r\boldsymbol{\Sigma}_A). \tag{37}$$

Then, we note that matrix $\mathbf{D}_u$ is positive definite being a diagonal matrix with all diagonal elements positive. Moreover, $r\boldsymbol{\Sigma}_A$ is positive definite being the product of a positive scalar with a positive definite matrix. Hence, $\mathbf{D} + r\boldsymbol{\Sigma}_A$ is positive definite being the sum of two positive definite matrices[56] implying that $\mathbf{H}_u$ is negative definite.

□

B Risk Aversion Measure

Proposition 2. *(Risk aversion measure). The measure of risk aversion is a function of the optimal production portfolio, and is equal to*

$$r = \frac{\sum_d \left(\mathbb{E}p_d q_d - \tilde{p}_d q_d\right)}{\left(\boldsymbol{q}^{\frac{\sigma-1}{\sigma}}\right)' \boldsymbol{\Sigma}_A \boldsymbol{q}^{\frac{\sigma-1}{\sigma}}},$$

where $\mathbb{E}p_d$ is the expected price in country d, $\tilde{p}_d = \frac{\sigma}{\sigma-1} c_d$ is the price under certainty in country d, and $\boldsymbol{q}^{\frac{\sigma-1}{\sigma}}$ is a vector whose d component is $q_d^{\frac{\sigma-1}{\sigma}}$, where q_d is the optimal quantity sold in country d.

Proof. Let $s_d = q_d^{\frac{\sigma-1}{\sigma}}$.

[56] See Horn and Johnson (2012).

The first order optimality condition with respect to s_d is given by

$$\begin{aligned}\frac{\partial u(\Pi(\boldsymbol{s}|L,\varphi))}{\partial s_d} &= \frac{\partial \mathbb{E}(\Pi(\boldsymbol{s}|L,\varphi))}{\partial s_d} - \frac{r}{2}\frac{\partial \text{var}(\Pi(\boldsymbol{s}|L,\varphi))}{\partial s_d} \\ &= \mathbb{E}A_d - \frac{\sigma}{\sigma-1}c_d s_d^{\frac{1}{\sigma-1}} - r\text{var}(A_d)s_d \\ &\quad - r\sum_{d'\in D}\text{cov}(A_d, A_{d'})s_{d'} = 0 \\ &= \mathbb{E}A_d - \frac{\sigma}{\sigma-1}c_d s_d^{\frac{1}{\sigma-1}} - r\sum_{d}\text{cov}(A_d, A_{d'})s_d = 0.\end{aligned} \tag{38}$$

Hence, multiplying both sides of equation (38) by s_d, and summing over d the risk aversion coefficient r can be expressed as follows

$$r = \frac{\sum_d \left[\mathbb{E}A_d s_d - \frac{\sigma}{\sigma-1}c_d s_d^{\frac{\sigma}{\sigma-1}}\right]}{\sum_d\sum_{d'}\text{cov}(A_d, A_{d'})s_d s_{d'}} = \frac{(\mathbb{E}p_d q_d - \tilde{p}_d q_d)}{\left(\boldsymbol{q}^{\frac{\sigma-1}{\sigma}}\right)' \Sigma \boldsymbol{q}^{\frac{\sigma-1}{\sigma}}} \equiv \frac{SP}{SV}, \tag{39}$$

where $\tilde{p}_d = \frac{\sigma}{\sigma-1}c_d$ is the price firm would set under certainty, SP is the *sales premium*, and SV is the *sales variance*. □

C Small-Medium and Large Multinationals

Table 10: Descriptive statistics on foreign affiliates and parents of small-medium MNEs by country

Countries	Total sales	Sales affiliate		Sales MNE		Employment		N
		Average	Median	Average	Median	Average	Median	
United States	2.4	24	14	121	86	428	388	100
France	1.6	23	17	116	86	410	372	69
Poland	1.3	18	14	111	81	468	474	76
Austria	1.3	30	16	124	103	462	411	43
Belgium	1.3	84	32	371	148	563	559	15
Czech Republic	1.1	16	13	107	83	523	491	70
China	1.0	15	9	118	85	538	527	71
United Kingdom	1.0	20	13	151	115	501	460	49
Italy	0.9	34	20	179	116	420	447	27
Switzerland	0.7	19	13	103	84	366	352	37
Germany	55.0	90	60	118	83	445	417	612

Note: Total sales are expressed in billion Euro. Sales of affiliate and MNE are expressed in million Euro. In this table we consider subsample of multinationals with less then 1000 employees.
Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Microdatabase Direct investment (MiDi), 1999-2014, authors' calculations.

Table 11: Descriptive statistics on foreign affiliates and parents of large MNEs by country

Countries	Total	Sales affiliate		Sales MNE		Employment		N
	sales	Average	Median	Average	Median	Average	Median	
United States	45.1	531	73	3683	716	9286	2905	85
Spain	21.7	362	43	6438	848	17396	3117	60
Brazil	16.5	275	41	5443	982	15390	4010	60
France	15.3	167	63	4328	822	11370	2954	92
United Kingdom	14.5	219	48	7120	1310	18397	3840	66
Chezh Republic	12.8	199	40	4654	508	13290	2670	64
China	9.7	89	23	3218	685	10002	2809	110
Hungary	9.0	196	46	3204	718	10861	2755	46
Mexico	8.9	255	30	9602	912	24363	4081	35
Japan	8.6	346	109	7653	824	17767	3891	25
Germany	522.1	1454	344	2161	474	6158	2152	359

Note: Total sales are expressed in billion Euro. Sales of affiliate and MNE are expressed in million Euro. In this table we consider subsample of multinationals with more then 1000 employees.
Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Microdatabase Direct investment (MiDi), 1999-2014, authors' calculations.

D Firm Risk Aversion

This section discusses some evidence in the data and other contributions in the literature related to the assumption that firms might exhibit risk averse behavior.

Firms Diversification Strategies. In this paragraph, we discuss some patterns in the data which are in line with the idea that firms adopt diversification strategies on both the intensive and extensive margins of sales when carrying out their multinational activity.

The diversification of sales by firms operating in international markets has been widely discussed in the literature. Hirsch and Lev (1971) show that firms holding a more diversified foreign sales portfolio display also more stable sales. Vannoorenberghe (2012) provides evidence that foreign and domestic sales are negatively correlated at the firm level, which supports the hypothesis that firms hedge against demand risk in the home country by selling abroad. This finding contradicts the theoretical prediction provided by models considering only productivity, which imply a positive correlation of sales across destination markets. Fillat, Garetto, and Oldenski (2015) show that multinational profits benefits from geographical diversification of sales.

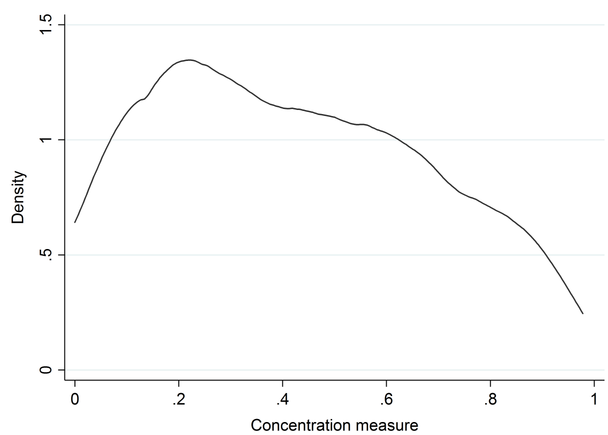
Using data on German multinationals, we find evidence in favor of sales diversification. In particular, for a firm present in at least two locations (home included), we compute the following measure of sales concentration as

$$\mathcal{C} = \frac{\sum_{j=1}^{J} \left(share_j - \frac{1}{J} \right)^2}{\frac{J-1}{J}}, \tag{40}$$

where J is the number of firm's locations and $share_j$ represents the ratio of firm sales in location j to total firm sales. Note that $\mathcal{C}$ equals 0 if sales evenly distribute across different locations (minimum level of concentration), and equals 1, if sales concentrate in one and only one location (maximum level of concentration). Moreover, the proposed measure takes into account the number of foreign locations a MNE is present in, as J differs across firms.

Figure 10 shows that firms tend to spread their sales across locations rather than concentrate their activities. We can notice that the mode of the concentration measure in the data is slightly above 0.2.

Figure 10: Distribution of concentration measure of sales, firm level

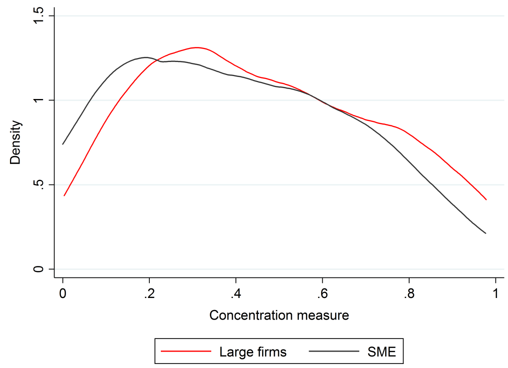


Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Microdatabase Direct investment (MiDi), 1999-2014, authors' calculations.

Moreover, as Figure 11 shows, the degree of sales concentration is directly related to firm size; smaller firms are typically more financially constrained so that holding a portfolio of well diversified financial assets is harder for this class of enterprises.[57] As a response to this, they diversify their sales across locations to reduce the degree of riskiness related to their activity.

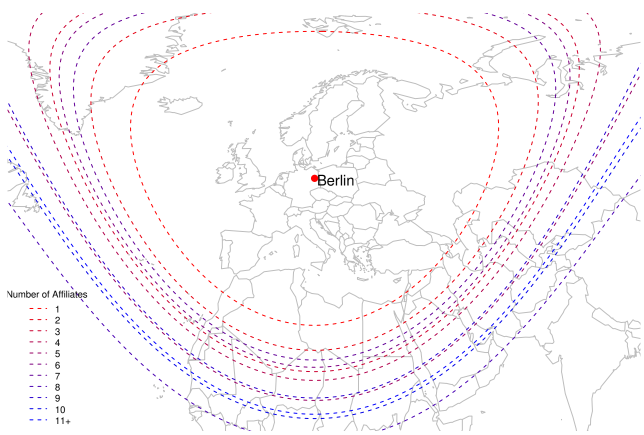
[57]In our data, the median liquidity ratio for a small (large) firm equals 1.33 (1.47). The median solvency ratio for a small (large) firm equals 35.85 (39.15). The median current ratio for a small (large) firm equals 1.19 (2.16). This shows that the small median firm is more financially constrained than the (large) median firm.

Figure 11: Distribution of concentration measure of sales by size of MNEs, firm level



Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Microdatabase Direct investment (MiDi), 1999-2014, authors' calculations.

Figure 12: Average distance of foreign affiliates from Germany



Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Microdatabase Direct investment (MiDi), 1999-2014, authors' calculations.

We also relate the total sales to the average correlation of the given location with all other markets present in our sample.[58] Table 12 shows that the sales are lower in those locations characterized by a larger average correlation, as expected.

[58]For country d, the average correlation in the sector i is given by $\sum_{d' \in D} \text{corr}(\alpha_{id}, \alpha_{id'})/|D|$.

Table 12: Location sales and average correlation

Dependent variable: log(sales)	Coefficient	SE
average correlation	-0.3865^{***}	0.1076
constant	17.8212^{***}	0.0348
N	1611	
R^2	0.0080	

Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Microdatabase Direct investment (MiDi), 1999-2014, authors' calculations.

In addition, diversification patterns cannot be explained by heterogeneity in firm efficiency as we find no correlation between the proposed measure of sales portfolio diversification and firm efficiency.[59]

On the extensive margin, figure 12 shows that the average distance from Germany of the affiliates does not monotonically increase with the number of countries the firm operates in. Hence, firms that can afford to pay several times the fixed costs of entry are not establishing themselves necessarily in more distant markets as predicted by the standard theory of proximity-concentration tradeoff.

Table 13: Average distance from Germany per number of affiliates hold by an MNE

Number of affiliates	Sample mean	SD	N
1	2795.74	3272.13	593
2	3271.36	2693.60	173
3	3676.50	2361.76	69
4	3843.34	2077.86	38
5	4223.96	2577.52	24
6	3593.86	2310.64	15
7	3455.94	1445.43	15
8	5006.77	1998.38	6
9	4177.81	1899.63	11
10	4569.92	1076.58	9
11+	4486.80	1186.02	18
Average Distance	3119.01	2994.77	971

Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Microdatabase Direct investment (MiDi), 1999-2014, authors' calculations.

Managers of Multinational Firms are Risk Averse. There are several papers showing that firms are run by risk averse agents. Cucculelli and Ermini (2013) elicit CEOs' risk attitude in

[59]Firm's productivity estimation is described in Section 4.1.1.

a sample of 178 manufacturing firms of different sizes. They find that most respondents exhibit an averse attitude toward risk.[60] Moreover, their measure of risk aversion varies with different firm characteristics like size and age.[61] In particular, managers of larger or older firms tend to be less risk averse. Other empirical papers like Esposito (2017), De Sousa et al. (2017), Herranz, Krasa, and Villamil (2015) analyze risk aversion in managerial behavior. In particular, the first two contributions provide empirical evidence of risk averse attitude of exporters.

In addition, several recent surveys show that managers are concerned about the volatility of demand in international markets and have a negative attitude toward risk. In particular, according to the Capgemini Survey 2011, demand volatility is the most relevant business challenge (40% of responses) in the agenda of managers of global companies.[62] These results are in line with the Capgemini Survey 2012, in which the fraction of responses indicating demand volatility as the most relevant concern topped 52%.[63] An analogous study conducted by McKinsey in 2010 shows that increasing volatility of customer demand is the most frequently mentioned challenge for companies operating in a global environment (37% of responses).[64] These surveys also point out that firms react to demand risk by adjusting their production and sales plans.

The outcomes of these surveys are also relatable to the consideration that managers can hardly perfectly diversify their endowment of human and physical capital across different firms.[65] Indeed, in most cases, the relation between a multinational company and a CEO tends to be exclusive. Moreover, the theoretical contribution of Nocke and Thanassoulis (2014) finds that risk aversion can be the outcome of credit constraints and diminishing marginal returns to scale of an investment in a pledgeable asset.

Managers' risk aversion can be also due to the fact that a part of managerial compensation

[60] 76.4% (93.2%) of respondents are (weakly) risk averse.

[61] The average sales, number of employees, and range of supplied products are significantly larger for those firms run by risk loving managers than for those run by (weakly) risk averse managers.

[62] Based on responses from 300 leading companies managers in Europe, North and Latin America, Asia. Demand risk result more important than other factors, like increasing material costs, meeting changing customer requirements, sustainability, etc.

[63] Based on responses from 350 leading companies managers in Europe, North and Latin America, Asia.

[64] Survey based on responses from 639 leading companies managers worldwide.

[65] This form of idiosyncratic risk cannot be diversified since markets are incomplete.

schemes is linked to company performance. In particular, the value of bonuses and company's shares depends crucially on the market performance realized by the firm. In this regard, Perrino, Poteshman, and S. (2002) highlight that risk-reducing projects attract managers as they become more risk averse. Relatedly, Abdel-Khalik (2007) shows that managers want to reduce the volatility of firms they manage to avoid the reduction of company's market value, as this would reflect in a decrease of the value of their assets.

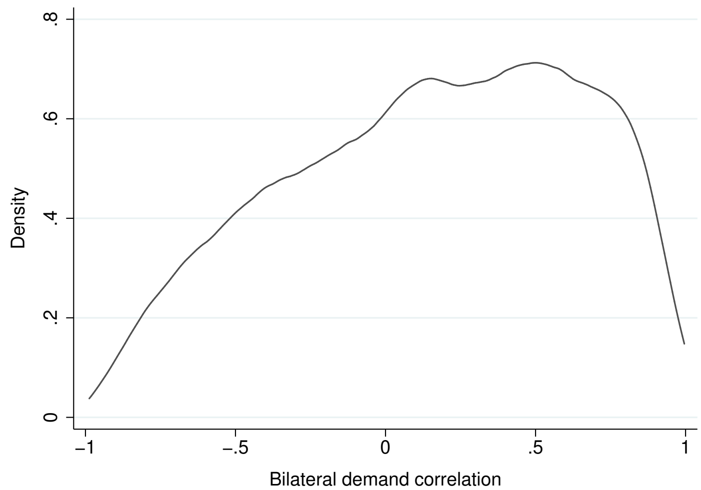
Demands are Imperfectly Correlated across Destination Markets. Both the World Trade Report 2008 and the World Investment Report 2008 highlight the importance of imperfectly correlated demands across countries during the 2007 crisis. While the Trade Report claims that exporters did not hedge during the crisis, the Investment Report states the opposite for multinational firms. In particular, at the aggregate level multinational firms moved their export and production toward those markets considered as more resilient to demand shocks. During the crisis, transition and developing economies worked as a good hedge for the declining demand in developed regions. In line with this observation, we find that German multinationals operating both in the OECD and non-OECD countries hold more diversified portfolios (in terms of sales) than those with production plants only in one type of the country. In particular, the median concentration for firms operating only in the non-OECD countries is 0.65, whereas the median concentration of firms operating only in the OECD countries is 0.38. Firms operating in both types of countries display a median sales concentration equal to 0.32. Moreover, the extent of sales diversification may be explained not only by the characteristics of the firms but also by the features of the countries, with particular emphasis on market volatility.

Additionally, we compute the variance-covariance matrix at the 2-digit industry-level of the consumption expenditure,[66] using production and trade data of the top 45 German export-destination countries for the period 2002 – 2006. Figure 13 shows the distribution of bilateral correlations at the industry level. As it can be noticed, the correlation of demands across countries is imperfect

[66] For a given industry, the consumption expenditure is given by the difference between total production and net exports.

for all industries, with the median correlation of demand being below 0.5.

Figure 13: Distribution of demand correlations, product level



Source: UNIDO INDSTAT2 2016, authors' calculations.

Therefore, the structure of demand correlations suggests that markets offer hedging opportunities to multinational firms.

E Risk Aversion and Aggregate Sales

Proposition 3. *(Risk Aversion and Aggregate Sales). The firm's aggregate sales are decreasing with risk aversion.*

Proof. The system of first-order necessary and sufficient conditions reads as

$$\mathbb{E}A_d - \frac{\sigma}{\sigma-1} c_d s_d^{\frac{1}{\sigma-1}} - r \sum_{d'} \operatorname{cov}(A_d, A_{d'}) s_{d'} = 0, \quad \forall d \in D. \tag{41}$$

Differentiating both sides with respect to r we obtain

$$\begin{aligned}
-\frac{\sigma}{(\sigma-1)^2} c_d s_d^{\frac{1}{\sigma-1}-1} \dot{s}_d - \sum_{d'} \operatorname{cov}(A_d, A_{d'}) s_{d'} \\
-r \sum_{d'} \operatorname{cov}(A_d, A_{d'}) \dot{s}_{d'} = 0, \quad \forall d \in D,
\end{aligned} \tag{42}$$

where $\dot{s}_d \equiv \frac{\partial s_d}{\partial r}$ for all $d \in D$. Hence, $\forall d \in D$

$$\frac{\sigma}{\sigma-1} c_d s_d^{\frac{1}{\sigma-1}-1} \dot{s}_d = -(\sigma-1) \left(\sum_{d'} \operatorname{cov}(A_d, A_{d'}) s_{d'} + r \sum_{d'} \operatorname{cov}(A_d, A_{d'}) \dot{s}_{d'} \right). \tag{43}$$

Again, using FOC we observe that

$$\frac{\sigma}{\sigma-1} c_d s_d^{\frac{1}{\sigma-1}} = \mathbb{E}A_d - r \sum_{d'} \operatorname{cov}(A_d, A_{d'}) s_{d'}, \quad \forall d \in D. \tag{44}$$

Combining equations (43) and (44) we obtain

$$\begin{aligned}
\left(\mathbb{E}A_d - r \sum_{d'} \operatorname{cov}(A_d, A_{d'}) s_{d'} \right) \dot{s}_d \\
= -(\sigma-1) \left(\sum_{d'} \operatorname{cov}(A_d, A_{d'}) s_{d'} s_d + r \sum_{d'} \operatorname{cov}(A_d, A_{d'}) \dot{s}_{d'} s_d \right)
\end{aligned} \tag{45}$$

for all d, which implies

$$\begin{aligned}
\mathbb{E}A_d \dot{s}_d = -(\sigma-1) \left(\sum_{d'} \operatorname{cov}(A_d, A_{d'}) s_{d'} s_d + r \sum_{d'} \operatorname{cov}(A_d, A_{d'}) \dot{s}_{d'} s_d \right) \\
+ r \sum_{d'} \operatorname{cov}(A_d, A_{d'}) s_{d'} \dot{s}_d.
\end{aligned} \tag{46}$$

Summing both sides over d we obtain

$$\begin{aligned}
\sum_d \mathbb{E}A_d \dot{s}_d = & -(\sigma-1) \left(\sum_d \sum_{d'} \operatorname{cov}(A_d, A_{d'}) s_{d'} s_d + r \sum_d \sum_{d'} \operatorname{cov}(A_d, A_{d'}) \dot{s}_{d'} s_d \right) \\
& + r \sum_d \sum_{d'} \operatorname{cov}(A_d, A_{d'}) s_{d'} \dot{s}_d.
\end{aligned} \tag{47}$$

where the left hand side is the derivative of the aggregate sales with respect to r. We want to show that this derivative is negative.

Let's consider the term outside the brackets of equation (47). Recall that

$$-\frac{\sigma}{(\sigma-1)^2} c_d s_d^{\frac{1}{\sigma-1}-1} \dot{s}_d = \sum_{d'} \operatorname{cov}(A_d, A_{d'}) s_{d'} + r \sum_{d'} \operatorname{cov}(A_d, A_{d'}) \dot{s}_{d'}. \tag{48}$$

Multiplying both sides of equation (48) by $\dot{s}_d$, we obtain

$$-\frac{\sigma}{(\sigma-1)^2} c_d s_d^{\frac{1}{\sigma-1}-1} (\dot{s}_d)^2 = \sum_{d'} \operatorname{cov}(A_d, A_{d'}) s_{d'} \dot{s}_d + r \sum_{d'} \operatorname{cov}(A_d, A_{d'}) \dot{s}_{d'} \dot{s}_d. \tag{49}$$

Summing over d and re-arranging, we obtain

$$\begin{aligned} \sum_d \sum_{d'} \operatorname{cov}(A_d, A_{d'}) s_{d'} \dot{s}_d = & - r \sum_d \sum_{d'} \operatorname{cov}(A_d, A_{d'}) \dot{s}_{d'} \dot{s}_d \\ & - \sum_d \frac{\sigma}{(\sigma-1)^2} c_d s_d^{\frac{1}{\sigma-1}-1} (\dot{s}_d)^2. \end{aligned} \tag{50}$$

We note that the left hand side of the above expression has to be negative since the right hand side is the sum of two negative terms, i.e.

$$\sum_d \sum_{d'} \operatorname{cov}(A_d, A_{d'}) s_{d'} \dot{s}_d < 0. \tag{51}$$

Incidentally we also notice that

$$r \sum_d \sum_{d'} \operatorname{cov}(A_d, A_{d'}) \dot{s}_d \dot{s}_{d'} + \sum_d \sum_{d'} \operatorname{cov}(A_d, A_{d'}) s_{d'} \dot{s}_d < 0. \tag{52}$$

Finally, note that $\mathrm{var}(\boldsymbol{A}'\boldsymbol{s} + r\boldsymbol{A}'\dot{\boldsymbol{s}})$ can be written as

$$\begin{aligned}\sum_{d}\sum_{d'} \mathrm{cov}(A_d, A_{d'}) s_d s_{d'} + 2r \sum_{d}\sum_{d'} \mathrm{cov}(A_d, A_{d'}) s_{d'} \dot{s}_d \\ + r^2 \sum_{d}\sum_{d'} \mathrm{cov}(A_d, A_{d'}) \dot{s}_{d'} \dot{s}_d = \\ \sum_{d}\sum_{d'} \mathrm{cov}(A_d, A_{d'}) s_d s_{d'} + r \sum_{d}\sum_{d'} \mathrm{cov}(A_d, A_{d'}) s_{d'} \dot{s}_d \\ + r \left(r \sum_{d}\sum_{d'} \mathrm{cov}(A_d, A_{d'}) \dot{s}_{d'} \dot{s}_d + \sum_{d}\sum_{d'} \mathrm{cov}(A_d, A_{d'}) s_{d'} \dot{s}_d \right) > 0.\end{aligned} \tag{53}$$

From equation (52) we notice that the term in the brackets is negative. Hence, the sum outside the brackets has to be positive since the variance is a positive number, i.e.

$$\sum_{d}\sum_{d'} \mathrm{cov}(A_d, A_{d'}) s_d s_{d'} + r \sum_{d}\sum_{d'} \mathrm{cov}(A_d, A_{d'}) s_{d'} \dot{s}_d > 0. \tag{54}$$

Hence, considering equations (47), (50) and (53), we conclude that aggregate sales are decreasing in r. □

F Price Setting

In this section, we assume that the firm maximizes its expected-utility function of profits realized in the destination market with respect to the price rather than quantity.

Recall that consumer utility is

$$U_d = \sum_{i=1}^{I} \alpha_{id} \ln Q_{id} + Q_{0d}, \tag{55}$$

with

$$Q_{id} = \left[\int_{\omega \in \Omega_{id}} q_{id}(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}}. \tag{56}$$

Utility maximization implies the following direct demand function for the variety

$$q_{id}(\omega) = \alpha_{id} p_{id}(\omega)^{-\sigma} P_{id}^{\sigma-1}, \tag{57}$$

where

$$P_{id} = \left[\int_{\omega \in \Omega_{id}} p_{id}(\omega)^{1-\sigma} d\omega\right]^{\frac{1}{1-\sigma}}. \tag{58}$$

Firm's profits as a function of the price $\boldsymbol{p} = (p_1, p_2, \ldots, p_d, \ldots, p_N)$ are given by

$$\begin{aligned} \Pi(\boldsymbol{p}|L, \boldsymbol{\varphi}, r) &= \sum_d p_d q_d - c_d q_d \\ &= \sum_d \alpha_d p_d^{1-\sigma} P_{id}^{\sigma-1} - c_d \alpha_d p_d^{-\sigma} P_d^{\sigma-1} \\ &= \sum_d \alpha_d P_d^{\sigma-1} p_d^{-\sigma} \left(p_d - c_d\right). \end{aligned} \tag{59}$$

From equation (59), expected profits $\mathbb{E}[\Pi(\boldsymbol{p}|L, \boldsymbol{\varphi}, r)]$ are given by

$$\mathbb{E}\Pi[(\Pi(\boldsymbol{p}|L, \boldsymbol{\varphi}, r))] = \sum_d \bar{\alpha}_d P_d^{\sigma-1} p_d^{-\sigma} \left(p_d - c_d\right), \tag{60}$$

whereas the variance $\mathrm{var}(\Pi(\boldsymbol{p}|L, \boldsymbol{\varphi}, r))$ is given by

$$\mathrm{var}(\Pi(\boldsymbol{p}|L, \boldsymbol{\varphi}, r)) = \sum_d \sum_{d'} \mathrm{cov}(\alpha_d, \alpha_{d'}) P_d^{\sigma-1} P_{d'}^{\sigma-1} p_d^{-\sigma} p_{d'}^{-\sigma} \left(p_d - c_d\right)\left(p_{d'} - c_{d'}\right). \tag{61}$$

Recall that the objective function of the firm is given by

$$u(\Pi(\boldsymbol{p}|L, \boldsymbol{\varphi}, r)) = \mathbb{E}[(\Pi(\boldsymbol{p}|L, \boldsymbol{\varphi}, r))] - \frac{r}{2}\mathrm{var}((\Pi(\boldsymbol{p}|L, \boldsymbol{\varphi}, r)). \tag{62}$$

The first order derivative of $\mathbb{E}[(\Pi(\boldsymbol{p}|L,\boldsymbol{\varphi},r))]$ with respect to p_d is given by

$$\begin{aligned}\frac{\partial \mathbb{E}[(\Pi(\boldsymbol{p}|L,\boldsymbol{\varphi},r))]}{\partial p_d} &= \bar{\alpha}_d P_d^{\sigma-1} p_d^{-\sigma}(1-\sigma) + c_d \bar{\alpha}_d \sigma p_d^{-\sigma-1} P_d^{\sigma-1} \\ &= \bar{\alpha}_d P_d^{\sigma-1}\left(p_d^{-\sigma}(1-\sigma) + c_d \sigma p_d^{-\sigma-1}\right).\end{aligned} \tag{63}$$

The expected profits have one critical point which corresponds to the standard constant markup over cost pricing. In particular, a firm maximizes the expected profits if $p_d = \frac{\sigma}{\sigma-1} c_d$ for all destination markets. This corresponds to the problem when a firm is not risk averse or there is no risk.

The first order derivative of $\text{var}(\Pi(\boldsymbol{p}|L,\boldsymbol{\varphi},r))$ with respect to p_d is given by

$$\begin{aligned}\frac{\partial \text{var}(\Pi(\boldsymbol{p}|L,\boldsymbol{\varphi},r))}{\partial p_d} &= 2\left(p_d^{-\sigma}(1-\sigma) + c_d \sigma p_d^{-\sigma-1}\right) \\ &\quad \cdot \sum_{d'} \text{cov}(\alpha_d, \alpha_{d'}) P_d^{\sigma-1} P_{d'}^{\sigma-1} p_{d'}^{-\sigma}(p_{d'} - c_d).\end{aligned} \tag{64}$$

Hence, the variance has two salient critical points: (i) $p_d = c_d$ for all destination markets, and (ii) $p_d = \frac{\sigma}{\sigma-1} c_d$ for all destination markets. The second critical point is irrelevant as it is a local maximum of the variance. Instead, the first critical point is a global minimum of the variance function. In particular, the firm can make the variance of profits equal to 0 if $p_d = c_d$ for all destination markets.

From the above analysis, we can draw the following conclusion. On the one hand a firm wants to maximize its expected profits by setting the standard constant markup over marginal cost implied by the CES preferences. On the other hand, the firm wants to minimize the variance by pricing at the marginal cost in each destination market.

Let $\zeta(p_d) \equiv \left(p_d^{-\sigma}(1-\sigma) + c_d \sigma p_d^{-\sigma-1}\right)$. Then, the optimality condition $\partial u(\Pi(\boldsymbol{p}|L,\boldsymbol{\varphi},r))/\partial p_d$ can be written as

$$\frac{\partial u(\Pi(\boldsymbol{p}|L,\boldsymbol{\varphi},r))}{\partial p_d} = \bar{\alpha}_d P_d^{\sigma-1}\zeta(p_d) \\ - r\zeta(p_d)\sum_{d'} \operatorname{cov}(\alpha_d,\alpha_{d'}) P_d^{\sigma-1} P_{d'}^{\sigma-1} p_{d'}^{-\sigma}\left(p_{d'}-c_{d'}\right) = 0. \tag{65}$$

Equation (65) can be also arranged in the following way

$$p_d = \frac{\sigma}{\sigma-1}c_d + r\frac{\left(p_d - \frac{\sigma}{\sigma-1}c_d\right)}{\bar{\alpha}_d}\sum_{d'} \operatorname{cov}(\alpha_d,\alpha_{d'}) P_{d'}^{\sigma-1}\frac{p_{d'}-c_{d'}}{p_{d'}^{\sigma}}, \tag{66}$$

which shows that the optimal price can be shifted upward or downward depending on the diversification potential of market d.

We focus on two cases: (i) the case in which $p_d = \frac{\sigma}{\sigma-1}c_d$ for all markets d, and (ii) the case in which $p_d \neq \frac{\sigma}{\sigma-1}$ for some market d.

Consider the case (i). The element (d,d') in the Hessian matrix associated to the utility function in (62) is given by

$$\mathbf{H}_u(d,d') = \left(\frac{\partial^2 u(\Pi(\boldsymbol{p}|L,\boldsymbol{\varphi},r))}{\partial p_d \partial p_{d'}}\right). \tag{67}$$

Then, if $d \neq d'$, the element of

$$\mathbf{H}_u(d,d') = 0, \tag{68}$$

when evaluated at $p_d = \frac{\sigma}{\sigma-1}c_d$ for all d.

Instead, if $d = d'$, the element of $\mathbf{H}_u(d,d)$, evaluated at $p_d = \frac{\sigma}{\sigma-1}c_d$ for all d, is given by

$$\frac{\partial^2 u(\Pi(\boldsymbol{p}|L,\boldsymbol{\varphi},r))}{\partial p_d^2} = \zeta'\left(c_d\frac{1}{\sigma-1}\right)P_d^{\sigma-1} \\ \cdot\left(\bar{\alpha}_d - r\sigma^{-\sigma}(\sigma-1)^{\sigma-1}\sum_{d'}\operatorname{cov}(\alpha_d,\alpha_d')P_{d'}^{\sigma-1}c_{d'}^{1-\sigma}\right), \tag{69}$$

as $\zeta\left(\frac{\sigma}{\sigma-1}c_d\right) = 0$. Moreover, $\zeta'\left(p_d\right) < 0$ for $p_d = \frac{\sigma}{\sigma-1}c_d$.

Hence, the a constant-markup over marginal cost is a local maximum if and only if $\mathbf{H}_u(d,d) < 0$

or, equivalently, if and only if

$$r < \min_{d\in\{1,\dots,N\}} \frac{\bar{\alpha}_d}{\sigma^{-\sigma}(\sigma-1)^{\sigma-1}\sum_{d'}\operatorname{cov}(\alpha_d,\alpha_{d'})P_{d'}^{\sigma-1}c_{d'}^{1-\sigma}} \tag{70}$$

for all $d \in D$.

Consider now case (ii). For some destination d, the firm charges a price different from the constant markup over marginal cost. Then, we can rearrange equation (65) in the following way.

$$\begin{aligned}\frac{p_d-c_d}{p_d^\sigma} &= \frac{\bar{\alpha}_d}{r\operatorname{var}(\alpha_d)P_d^{\sigma-1}} - \sum_{d'\neq d} P_{d'}^{\sigma-1}\frac{\operatorname{cov}(\alpha_d,\alpha_{d'})}{\operatorname{var}(\alpha_d)}\frac{p_{d'}-c_{d'}}{p_d^\sigma} \\ &= \frac{\bar{\alpha}_d}{r\operatorname{var}(\alpha_d)P_d^{\sigma-1}} - \sum_{d'\neq d} P_{d'}^{\sigma-1}\beta_{d,d'}\frac{p_{d'}-c_{d'}}{p_{d'}^\sigma}\end{aligned} \tag{71}$$

where $\beta_{d,d'} \equiv \frac{\operatorname{cov}(\alpha_d,\alpha_{d'})}{\operatorname{var}(\alpha_d)}$. The left hand side of the above expression measures firm's market power.

A closed form solution for p_d cannot be obtained in this case. However, to get some intuition, let $\operatorname{cov}(\alpha_d,\alpha'_d)=0$ for all d,d' with $d\neq d'$. Then, the above expression reads as

$$\frac{p_d-c_d}{p_d^\sigma} = \frac{\bar{\alpha}_d}{r\operatorname{var}(\alpha_d)P_d^{\sigma-1}}. \tag{72}$$

Hence, larger and stabler markets allow the firm to increase the price for that market. A more risk averse firm tends to charge a lower price.

Assume also that $\sigma = 2$ similarly to De Sousa et al. (2017). Then, the solution[67] implied by equation (72) when $\sigma = 2$ is given by

$$p_d = \frac{rP_d\operatorname{var}(\alpha_d) + \bar{\alpha}_d\sqrt{\frac{rP_d\operatorname{var}(\alpha_d)(P_d r\operatorname{var}(\alpha_d)-4\bar{\alpha}_d c_d)}{\bar{\alpha}^2}}}{2\alpha_d} \geq 2c_d. \tag{73}$$

[67]When $\sigma = 2$ and all covariances are zero, the Hessian of the utility function is a diagonal matrix whose d element on the main diagonal is given by

$$\mathcal{H}_{d,d} = -\frac{64\bar{\alpha}_d^6 c_d^2 P_d^2 r\operatorname{var}(\alpha_d)}{\left(P_d r\operatorname{var}(\alpha_d) + \bar{\alpha}_d\sqrt{\frac{P_d r\operatorname{var}(\alpha_d)(-4\bar{\alpha}_d c_d + P_d r\operatorname{var}(\alpha_d))}{\bar{\alpha}^2}}\right)^6} < 0.$$

As the Hessian is negative definite, the first order conditions expressed by (65) are sufficient. From (73), We can observe that the firm charges a price which exceeds the standard constant markup over marginal cost price.

Moreover, when $\sigma = 2$ and all covariances are equal to 0, we are able to compare the price implied by the solution to the utility maximization problem under price choice with the price selected by the firm in equation (73). To see this, consider (16). In this case, we obtain

$$q_d = \left(\frac{\mathbb{E}[A_d]}{2c_d}\right)^2 \cdot \left(\frac{1}{1 + r\frac{\mathrm{var}(A_d)}{2c_d}}\right)^2. \tag{74}$$

Recall that $\mathbb{E}A_d = \bar{\alpha}_d Q_d^{-\frac{\sigma-1}{\sigma}}$. Hence, rearranging we obtain

$$q_d = \frac{\bar{\alpha}_d^2 Q_d}{(2c_d Q_d + r\mathrm{var}(\alpha_d))^2}. \tag{75}$$

Plugging into the equation (57), we obtain an expression for the expected price $\mathbb{E}p_d$

$$\mathbb{E}p_d = 2c_d + r\frac{P_d \mathrm{var}(\alpha_d)}{\bar{\alpha}_d} \tag{76}$$

which does not solve the first order conditions (65) with respect to price. Hence, the expected price implied under quantity choice differs from that chosen by the profit maximizing firm under price choice. Moreover, the expected price under quantity choice exceeds the risk-neutral price by an amount which represents the per-unit risk-premium the firm asks for selling the product in the destination market d.

Comparing the price expression from equation (76) with that of equation (73), we obtain

$$\mathbb{E}p_d \geq p_d \Leftrightarrow \mathrm{var}(\alpha_d) \geq \frac{4\bar{\alpha}_d c_d}{P_d r} \tag{77}$$

provided $\bar{\alpha}_d \geq 1$.

Hence, when uncertainty is a relatively large concern for the firm (either high risk aversion or high variance), the risk-premium in terms of extra markup required by the firm is larger in the quantity setting case. This hints at the fact that with large variance the firm is shipping a smaller amount of the good to the destination market than those expected under price choice. Under quantity choice the firm needs to plan in advance and pay the production costs upfront. Hence, the firm would be prefer to produce a relatively small quantity to reduce its exposure to adversarial demand fluctuations in the foreign markets.

G Different Timing

Recall that firm's problem consists of three decisions, as discussed in Section 2. Specifically, one of the assumptions of the model is that the firm decides on how much to sell in each destination market before observing the actual realizations of the demand. In this section, we relax this assumption in the following way.[68] We assume that the firm decides the level of production in each of its foreign affiliate before observing the demand shocks. However, the firm can optimally readjust its sales according to the demand realizations in the different markets in which it is operating, given the chosen level of production. As a preliminary, we notice that this different specification of the timing does not affect location and shipment decisions as presented in Section 2.

Assume that the firm has chosen a level of production q_l for $l \in L$. As discussed, the level of production in each plant reflects the plant productivity, the benefits (in terms of trade cost savings and market sizes of the destination markets) associated to the export platform, and the degree of firm's risk aversion.

Suppose that the firm has to decide on how much to sell in each destination market after having observed the demand realizations A_d in each market d. Then, the firm needs to solve

$$\max_{\boldsymbol{q} \in \mathbb{R}_+^{L+N}} \sum_d \sum_l (p_d - \tau_{ld}) q_{ld} \quad \text{s.t.} \quad \sum_d q_{ld} \leq q_l \quad \forall l \in L, \sum_l q_{ld} = q_d \quad \forall d. \tag{78}$$

[68]Notice that also other specifications are possible. For example, demand realizations might be observed by the firms after the entry has taken place. However, this would imply that risk aversion only affects entry choices, which is inconsistent with what we observe in the data.

The first set of constraints expresses the fact that the output sold in the different markets from the plant in country l cannot exceed the output therein produced. The second set of constraints states that the quantity sold in d equals the sum of outputs produced in the different locations and meant to be sold in the destination market d itself.

After the shocks have realized, the production costs are sunk. Hence, the firm only wants to maximize the difference between the price in each destination market and the trade costs associated to that market, given the capacity constraints set in the previous stage. As the firm considers the realized demand, we observe that $p_d = A_d q_d^{-\frac{1}{\sigma}}$. Notice that this specification of the problem complicates the analysis. When the firm makes the production and shipment decisions at the same time, then each destination market is served by one and only one location, as trade costs and marginal production costs are constant. However, when these decisions are separated, the amount of production carried out in one plant, which operates as a capacity constraint, can be insufficient to accommodate the total demand in a given destination market. In other words, the firm serves a destination market from the optimal origin as long as the built-up capacity suffices. Then, it has to resort to some stored capacity available in other plants. Moreover, the original location-destination paths that firm accounts for when selecting the optimal level of production can be no longer relevant, as the production costs are sunk. In particular, when maximizing its profits, the firm only considers the trade costs associated to each plant together with its capacity, and this fact potentially determines different location-destination paths from the original one.

Using $p_d = A_d q_d^{-\frac{1}{\sigma}}$ and the constraint $\sum_l q_{ld} = q_d$, firm's problem (78) can be written as

$$\max_{\boldsymbol{q}\in\mathbb{R}_+^{L+N}} \sum_d A_d \left(\sum_l q_{ld}\right)^{\frac{\sigma-1}{\sigma}} - \sum_d \sum_l \tau_{ld} q_{ld} \text{s.t.} \ \sum_d q_{ld} \leq q_l \quad \forall l \in L. \tag{79}$$

Then, the optimality conditions for the problem (79) are given by

$$\text{(i)} \quad \frac{\sigma-1}{\sigma} A_d \left(\sum_l q_{ld}\right)^{-\frac{1}{\sigma}} - \tau_{ld} - \lambda_l + \mu_{ld} = 0 \quad \forall l, d \tag{80}$$

$$\text{(ii)} \quad \lambda_l \left(-q_l + \sum_d q_{ld}\right) = 0 \quad \forall l \tag{81}$$

$$\text{(iii)} \quad \sum_d q_{ld} \leq q_l \quad \text{and} \quad \lambda_l \geq 0 \; \forall l \tag{82}$$

$$\text{(iv)} \quad \mu_{ld} q_{ld} = 0 \quad \forall l, d \tag{83}$$

$$\text{(v)} \quad \mu_{ld} \geq 0 \quad \wedge \; q_{ld} \geq 0, \tag{84}$$

where μ_{ld} is the multiplier associated to the non-negativity constraint for q_{ld} and λ_l is the multiplier associated to the capacity constraint in location l. Notice that the existence of a solution derives from Weierstrass theorem whereas uniqueness follows from concavity of the objective function and linearity of the constraint functions.

This timing does not affect qualitatively our major findings concerning the structure of multinational sales. The realized price in each market for the optimal $(q_{ld})_{l\in L, d\in D}$ differs from the standard markup over marginal cost and that they are heterogeneous with respect to firm and destination. To note this point, we write the set of conditions (80) in terms of q_d as a function of the parameters

$$q_d = \left(\frac{\sigma-1}{\sigma} \frac{A_d}{\tau_{ld} - \mu_{ld} + \lambda_l}\right)^{\sigma} \quad \forall l, d. \tag{85}$$

Then, it follows from the conditions in (85) that

$$\tau_{l'd} - \tau_{ld} = (\lambda_l - \lambda_{l'}) + (\mu_{l'd} - \mu_{ld}) \quad \forall l, l', d. \tag{86}$$

Hence, if the difference between the trade costs of serving market d from locations l and l' is large, then the value of relaxing the capacity constraint associated to the plant l compared with that associated to plant l' has to be large as well. In addition, notice that if $\tau_{ld} = \min_{l'} \tau_{l'd}$, then for any $l' \neq l$, then

$$\lambda_l - \lambda_{l'} + \mu_{l'd} - \mu_{ld} \geq 0. \tag{87}$$

This means that when a firm sells its product to a country in which it has a production facility, either it does from the location itself, in which case $\mu_{ld} = 0$, or it needs to be the case that the difference between λ_l and $\lambda_{l'}$ has to be relatively large. This might be the consequence of the fact that the firm has built a low level of capacity in the plant l itself in the previous stage.

In addition, we note that the quantity q_d depends negatively on the level of trade costs to serve the market d, positively on the market size and the capacity built-up in the previous period. Moreover, the quantity sold in a market under demand risk is not larger than the quantity sold under no risk if firm's capacity in l associated to the first scenario is lower than the one in the second one.

Finally, from equation (85), we can obtain an expression for the realized price. In particular,

$$p_d = \frac{\sigma}{\sigma - 1}(\tau_{ld} - \mu_{ld} + \lambda_l) \quad \forall d. \tag{88}$$

From the expression (88), though high marginal costs of production induce large prices, we observe that the price in this setting is potentially different from that emerging in the parallel model where we set the demand risk equal to zero.

H Liberalization

Proposition 4. *Suppose a firm sells its variety in the destination market $\tilde{d}$ from its foreign affiliate located in l. Then, a reduction in the trade cost $\tau_{l\tilde{d}}$ increases firm's sales to the destination market $\tilde{d}$.*

Proof. As discussed in the paper, for each firm there is a unique location-destination path which is optimal. For this reason, we suppress the subscript of the origin location l, assuming that the firm serves the foreign market $\tilde{d}$ in the optimal way.

Consider the first order condition (30) given by

$$\mathbb{E}[A_d] - r\sum_{d'}\text{cov}(A_d, A'_d)s_{d'} - \frac{\sigma}{\sigma-1}c_d s_d^{\frac{1}{\sigma-1}} = 0. \tag{89}$$

Then, for any d, we can differentiate both sides of the above equation with respect to $\tau_{\tilde{d}}$. We distinguish two cases. If $d = \tilde{d}$, then

$$-\frac{\sigma}{(\sigma-1)^2}c_{\tilde{d}} s_{\tilde{d}}^{\frac{2-\sigma}{\sigma-1}}\dot{s}_{\tilde{d}} - r\sum_{d'}\text{cov}(A_{\tilde{d}}, A_{d'})\dot{s}_{d'} = \frac{\sigma}{\sigma-1}s_{\tilde{d}}^{\frac{1}{\sigma-1}}\dot{c}_{\tilde{d}}. \tag{90}$$

If $d \neq \tilde{d}$, then

$$-\frac{\sigma}{(\sigma-1)^2}c_d s_d^{\frac{2-\sigma}{\sigma-1}}\dot{s}_d - r\sum_{d'}\text{cov}(A_{\tilde{d}}, A_{d'})\dot{s}_{d'} = 0. \tag{91}$$

By multiplying both sides of the above equations by $\dot{s}_d$ and adding them up side by side over destinations, we obtain

$$\sum_{\tilde{d}}\frac{\sigma}{(\sigma-1)^2}c_{d'} s_d^{\frac{2-\sigma}{\sigma-1}}\dot{s}_d^2 + r\sum_{\tilde{d}}\sum_{d'}\text{cov}(A_{\tilde{d}}, A_{d'})\dot{s}_d\dot{s}_{\tilde{d}} = -\frac{\sigma}{\sigma-1}s_{\tilde{d}}^{\frac{1}{\sigma-1}}\dot{s}_{\tilde{d}}. \tag{92}$$

Note that $\sum_{\tilde{d}}\sum_{d'}\text{cov}(A_{\tilde{d}}, A_{d'})\dot{s}_d\dot{s}_{\tilde{d}} > 0$ which is a positive quadratic form, being Σ_A positive definite. Hence, the left-hand side of equation (92) is positive, as it is the sum of positive numbers. Therefore, $\dot{s}_d < 0$. □

I Fixed Cost Estimation

Estimation of fixed costs can be carried out adapting the approach discussed in Tintelnot (2017). Consider the problem of a firm with risk aversion equal to r, core productivity φ, and fixed entry costs $\boldsymbol{f}$. Firm productivity in each foreign country l is $\gamma_l\varphi$ where γ_l is a country-specific shifter common to all firms. Hence, if a firm establishes a foreign affiliate in country l, its marginal cost equals $1/(\gamma_l \varphi)$. The firm selects the set $L \in 2^{N-1}$ if for all $L' \in 2^{N-1}$

$$V(L) - \mathcal{F}(L) \geq V(L') - \mathcal{F}(L'), \tag{93}$$

where $V(L)$ is the indirect utility function associated to the set L and $\mathcal{F}(L) = \sum_{l \in L} f_l$.

Hence, the probability that the firm selects the set L over all other location sets is given by

$$\begin{aligned} &\Pr(L|\varphi, r, \boldsymbol{\tau}, \boldsymbol{\gamma}, \mathbb{E}\boldsymbol{A}, \Sigma_A, \boldsymbol{\theta}_f) = \\ \int_{\boldsymbol{f}} \mathbb{1}&\left(V(L) - \mathcal{F}(L) \geq V(L') - \mathcal{F}(L') \;\; \forall L \in 2^{N-1}\right) dG_f(\boldsymbol{f}; \boldsymbol{\theta}_f), \end{aligned} \tag{94}$$

where G_f is the (differentiable) cdf of the fixed costs parametrized by the parameter vector $\boldsymbol{\theta}_f$.

Once firm enters in the chosen location set, productivity, risk aversion and the market characteristics (expected and realized sizes and variance of demand realizations, trade costs and shifters) determine the level of sales associated to each location. The theoretical revenues realized by the firm depend on r and all the above variables.

We assume that risk aversion and core productivities are distributed according to continuous parametric cdfs $G_r(r; \boldsymbol{\theta}_r)$ and $G_\varphi(\varphi; \boldsymbol{\theta}_\varphi)$, respectively, where $\boldsymbol{\theta}_r$ includes the parameters associated to the distribution of risk aversion, whereas $\boldsymbol{\theta}_\varphi$ includes those associated to the distribution of core productivities.

Hence, the contribution to the likelihood of firm i is given by the product of observing the chosen location sets multiplied by the densities of firm's revenues s_i in the different plants, i.e.

$$l_i(\boldsymbol{\theta}|L_i, s_i) = \int_{\varphi} \int_{r} \Pr(L_i|\varphi, r, \boldsymbol{\tau}, \boldsymbol{\gamma}, \mathbb{E}\boldsymbol{A}, \Sigma_A, \boldsymbol{\theta}_f) dG_s(s_i|L_i, \varphi, r) dG_r(r; \boldsymbol{\theta}_r) dG_\varphi(\varphi; \boldsymbol{\theta}_\varphi), \tag{95}$$

where $\boldsymbol{\theta} = (\boldsymbol{\theta}_f, \boldsymbol{\theta}_r, \boldsymbol{\theta}_\varphi)$ and G_s is the cdf of the revenues. As our model does not yield a closed-form solution for the revenues, the density of sales needs to be non-parametrically estimated.

The likelihood function implied by our model is then given by

$$l\left(\boldsymbol{\theta}|\{L_i\}_{i=1,\dots,I},\{s_i\}_{i=1,\dots,I}\right)=\prod_{i=1}^{I} l_i(\boldsymbol{\theta}|L_i,s_i), \tag{96}$$

where I equals to total number of firms in our sample. In order to obtain estimates of $\boldsymbol{\theta}$, we can maximize function in (96) subject to the constraint that the theoretical sales for each firm implied by our model match those observed in the data.

J Firm Characteristics and Risk Aversion

Table 14: Aggregate sales and risk aversion

Dependent variable: total group sales	Coefficient	SE
risk aversion	-0.5835^{***}	0.0133
productivity	0.6740^{***}	0.0283
number of affiliates	0.1478^{***}	0.0083
constant	2.7747^{***}	0.0954
industry fixed effects	Yes	Yes
N	952	

Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Microdatabase Direct investment (MiDi), 1999-2014, authors' calculations.

Table 15: Gearing and risk aversion

Dependent variable: gearing	Coefficient	SE
risk aversion	17.5022^{**}	8.5526
size	-21.2136	31.0504
*size*risk aversion*	-13.0365	10.4800
age	-4.4616	3.8717
constant	248.1135	37.3606
industry fixed effects	Yes	Yes
N	393	

Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Microdatabase Direct investment (MiDi), 1999-2014, authors' calculations.