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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 foreign plants. Second, MNEs decide how much to produce in each foreign plant; in particular, the production in a given foreign plant serves the local and the neighboring markets since MNEs can use their production facilities as export platforms.[1]

Crucially, MNEs make the investment and sales decisions *before* observing the realization of demand in each market. 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 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 these plants, and the volume of sales for each plant. Firms make all the above decisions under demand risk, i.e. before observing the realizations of demand in the destination markets. With risk averse MNEs and correlated demand realizations, investment and sales decisions are interconnected and similar to a complex portfolio choice problem. In particular, each market in which the MNE operates in yields a risky return which is imperfectly correlated with the returns offered by other foreign markets. Thus, sales in each market depend on the expected return (expected sales) as well as the diversification opportunities offered by the market (the correlation of market demand with the demand of the other markets). Ceteris paribus,

[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 accruing to developed countries contracted by 44% in 2009, whereas those to developing and transition economies fell by 27%. For the first time, the developing regions accounted for most worldwide FDI inflows thanks to their rapidly growing local demand and their resilience to the crisis.

markets that offer better hedging opportunities to multinationals induce larger sales and the more so, the more risk averse the firm.

Foreign plants serve as export platforms since they can be used to sell to local and to third markets. Such export platforms reduce the effective distance between the MNE and the destination markets and, as a consequence, increase the expected demand for each market. However, setting up a foreign plant comes at a fixed cost. Thus, MNEs have to trade off the increase in expected demand and the additional diversification opportunities granted by establishing the plant against the fixed set-up cost. Due to complementarities, the attractiveness of each foreign plant depends on the 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 (e.g., 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 associate with large expected sales. However, only more productive firms 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. The attractiveness of establishing a foreign plant abroad depends also on the diversification opportunities offered by this location, which depend, in turn, on the characteristics of the set of other MNE's locations. For example, if a low productive MNE opens up foreign production facilities, say, both in France and China, a highly productive one does not necessarily set up a plant in these two countries, too. It is worth noting that these results hold when home productivity (risk aversion) varies given the level of risk aversion (home productivity). In particular, a larger degree of risk aversion does not automatically reduce the number of foreign locations a firm decides to sell to.

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 aspects: (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 have an impact on the outcomes of trade policies. A tariff reduction

[3] In our framework, the price is the residual which equalizes demand to supply.

in a country which offers good hedging potential can magnify the impact of trade liberation on trade flows compared to standard models.[4] Moreover, trade liberalization can introduce third-country effects. Sales flows change also in countries not directly interested by the policy change, with the direction of the change depending on the sign of the correlation; countries that offer a demand hedge with respect to the market for which trade costs have been reduced experience an increase in imports, whereas markets whose demand positively correlates with the liberalized market suffer from 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 of the foreign affiliates and the country where they are located. By exploiting the properties of the solution to the MNE's optimization problem 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. We estimate the average elasticity of aggregate sales with respect to risk aversion to be equal to 0.8 (in absolute value). At a more aggregate level, we find that risk aversion varies also across the different industries included in our analysis. More specifically, risk aversion correlates with the demand characteristics of the sector rather than with its technological features with more risk averse firms operating in industries characterized by a relatively more disperse demand. Compared to the risk neutral benchmark, firms tend to sell relatively more to the countries which provide a better hedge. In a counterfactual analysis, we assess the effect of a tariff reduction for imported products into 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 produces a larger variation in the sales toward those countries which are more correlated with Germany, whereas more distant regions are less involved.

Related Literature. The present paper relates to the literature studying firm's incentives to conduct FDI versus export. The closest contribution to our paper is Tintelnot (2016), who proposes a structural model of global production with export platforms to analyze the incentives of firms in designing their global operations.

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

We account for the presence of export platform, and we focus on their role on the MNEs' sales structure when the demand is risky and MNEs are risk averse; instead, Tintelnot (2016) highlights the imperfect transferability of technology for firms engaging in horizontal FDI in order to quantify the costs inherent in the multinational production. Ramondo, Rappoport, and Ruhl (2013) analyze the proximity-concentration trade-off in the presence of country-specific shocks to the production cost. The firm's choice between export and FDI hinges on the comovement of relative production costs and demand. They predict that trade is more relevant, relative to affiliate sales, between country pairs whose output fluctuations are less correlated. In addition, more volatile economies are served more by exporters. The empirical evidence of their paper supports the model prediction and the relevance of demand volatility in the proximity-concentration trade-off. Related to this work is the one of Rob and Vettas (2003), who investigate FDI choices under uncertain growing demand in foreign markets. Chen and Moore (2010) predict that more efficient firms are more likely than less efficient ones to enter into tougher markets when firms are characterized by heterogeneity in the total factor productivity. Their result does not necessarily obtain in our framework as we allow for risk averse firms and, as a consequence, for demand interdependencies across countries. Campa (1993), Goldberg and Kolstad (1995), and Russ (2007) introduce risk through exchange rate fluctuations and find that firms take into account the exchange rate volatility when they solve the proximity-concentration trade-off. 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.

Our paper also closely relates to the growing literature on the role of demand risk in international trade. 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. 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. Closely connected to our paper are De Sousa, Disdier, and Gaigné (2016) and Esposito (2016), who analyze risk averse exporters in the presence of demand shocks. Esposito (2016) and De Sousa et al. (2016) focus on pure exporters[5], our work differs from their contributions because we concentrate on multinational firms conducting their international activity via export platforms. 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 transportation costs. In addition, we distinguish from De Sousa et al. (2016) since we allow for correlated expenditures across destination markets and abstract from the possible effects of skewed demand shocks; with regard to Esposito (2016); instead, we consider a different type of shocks. In particular, we focus on the risk affecting the firms both at the industry and macroeconomic levels, whereas Esposito (2016) focuses on firm-specific demand shocks. In addition, in our framework, multinational firms are heterogeneous in terms of risk aversion.[6] One implication of such heterogeneity in risk aversion is that markups are firm-destination-specific. In particular, according to our theory, the markup over cost chosen by a firm in a destination reflects both the degree of firm's risk aversion and the premium required by the firm to serve the given destination market. Moreover, heterogeneous risk attitudes interplay with entry decisions and come as one of the factors breaking down the nesting structure of location sets.

Due to the presence of dependent values across foreign production locations and markets, our paper is also related to Morales, Sheu, and Zahler (2017). In their dynamic model, fixed entry costs depend on the past exporting activity of the firm, so that, at each time, firms face comparatively lower fixed costs if they have already entered into similar countries. In our model, correlation across market demand realizations and risk aversion are responsible for interdependency across countries. Related to this, we are also connected to the literature linking firm internationalization, experimentation, and learning. In particular, Conconi, Sapir, and Zanardi (2016) show that firms learn about their profitability in a foreign market by entering there as exporters. Our model implicitly assumes immediate learning; upon entering into a foreign market all uncertainty about the demand realization unravels. 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

[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.

[6]Cucculelli and Ermini (2013) provides 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.

destinations, risk regarding profits reduces over time not only in the markets the firm is present in, but also in the other unexplored markets. In Nguyen (2012), given the positive correlation of demands across countries, firms learn the demand realization in potential foreign destinations by exporting.

Finally, our paper is connected to the recent contributions on export platforms and multinational production. In particular, we model export platforms similarly to Tintelnot (2016) and Head and Mayer (2015).[7] Analogously to Ekholm, Forslid, and Markusen (2007) and Arkolakis, Ramondo, Rodríguez-Clare, and Yeaple (2013), we are able to describe 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.

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

We build a partial-equilibrium static version of Chaney (2008) with N countries indexed by $d \in D \equiv \{1, \ldots, N\}$, and $I + 1$ industries indexed by $i = 0, \ldots, I$.

2.1 Demand

Each country d admits 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,

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

The elasticity of substitution σ between any two varieties ω 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 shift to consumer's preferences with respect to the aggregate product Q_{id}, describing fluctuations occurring at the industry and at the 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. Furthermore, 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. Consumers observe the realization of α_{id} and make consumption decision accordingly.

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

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

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

Utility maximization implies $Q_{0d} = Y_d - \sum_{i=1}^{I} \alpha_{id}$, $P_{id}Q_{id} = \alpha_{id}$, where P_{id} is the price index of Q_{id}. In addition, the inverse demand for the variety ω is given by

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

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

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

2.2 Firms

Each firm produces exclusively one variety of the aggregate product 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 and identify a firm by the index of the produced variety.

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

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

Firm ω can observe the above variables at no cost before making any choice, and 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.[9] We denote a location set by $L(\omega)$ with $L(\omega) \in \mathcal{L} = 2^{N-1}$ 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.

In the following paragraphs, we describe firm's technology and each decision in greater details.

Technology and production costs. Firm ω has to pay a fixed entry cost $f_l(\omega)$ 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.

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 suffer from 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.[10]

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

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

The firm can use its plant in location l to serve both the local and any other destination market. Equivalently, 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 $\tau_{ld} > 1$.[11]

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

[9] Note that we assume that a parent company can maintain at most one foreign plant in each destination market.

[10] 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.

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

As in Tintelnot (2016), we abstract from the presence of any export fixed cost.[12] This restriction can be motivated by two considerations. MNEs tend to enter sequentially in foreign markets;[13] manufacturing firms generally start the activity in a foreign market with exporting rather than operating a foreign production facility. When a firm sets up a foreign affiliate, the firm substitutes 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. In addition, one can think that part of the fixed export entry cost collapses into the fixed entry cost.

Production decision. We assume that the firm does not observe the size of the aggregate demand in the destination markets. Hence, firm's profit is a random variable. As firm ω is risk averse, this implies that it does not only consider the (expected) profit in the prospective destination markets but also its volatility.

In line with this, sales across different destination markets can be seen as risky assets held as a production portfolio by the firm, similarly to the standard setting of portfolio choice.[14] 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 ω 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 widely 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.[15]

Throughout this section, we drop the location subscript l from the quantity $q_{ld}(\omega)$ under the assumption that the firm ω makes the optimal shipment choice (see successive paragraph). Given that, the realized profit

[12] Export entry costs are omitted for simplicity and tractability of the model and would require additional data on the export choices.

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

[14] 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.

[15] 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.

of the firm selling to the destination countries $d = 1, \dots, N$ is given by

$$\Pi(\boldsymbol{q}(\omega)|L(\omega), \boldsymbol{\varphi}(\omega), r(\omega)) = \sum_d (p_d(\omega)q_d(\omega) - c_d(\omega)q_d(\omega))$$
$$= \sum_d \left(q_d(\omega)^{\frac{\sigma-1}{\sigma}} \left(A_d - c_d(\omega)q_d(\omega)^{\frac{1}{\sigma}} \right) \right),$$

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

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

whereas the variance of profits is given by

$$\text{var}(\Pi(\boldsymbol{q}(\omega)|L(\omega), \boldsymbol{\varphi}(\omega), r(\omega)) = \sum_d \sum_{d'} \text{cov}(A_d, A_{d'})q_d(\omega)^{\frac{\sigma-1}{\sigma}} q_{d'}(\omega)^{\frac{\sigma-1}{\sigma}}.$$

Note that the variance does not depend directly on production costs, as risk only relates to the fluctuations of demand in the destination markets.[16]

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

$$u(\Pi(\boldsymbol{q}(\omega)|L(\omega), \boldsymbol{\varphi}(\omega)), r(\omega)) = \mathbb{E}[\Pi(\boldsymbol{q}(\omega)|L(\omega), \boldsymbol{\varphi}(\omega), r(\omega)] - \frac{r(\omega)}{2}\text{var}(\Pi(\boldsymbol{q}(\omega)|L(\omega), \boldsymbol{\varphi}(\omega), r(\omega)))$$

where $r(\omega)$ 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

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

where $V(L(\omega))$ denotes the largest attainable utility by the firm for the location set $L(\omega)$.

For $d \in D$ such that $q_d > 0$, the first-order necessary[17] and sufficient condition[18] with respect to $q_d(\omega)$ is

[16] Other sources of risk, like unexpected change to the production costs, are not taken into account in the present paper.
[17] We notice that for the utility function is not differentiable when $q_d = 0$.
[18] We defer the discussion about the concavity of the objective function to a later stage.

given by

$$\frac{\partial u(\Pi(\boldsymbol{q}(\omega)|L(\omega),\boldsymbol{\varphi}(\omega),r(\omega))}{\partial q_d(\omega)} = \frac{\partial \mathbb{E}\left[\Pi(\boldsymbol{q}(\omega)|L(\omega),\boldsymbol{\varphi}(\omega),r(\omega))\right]}{\partial q_d(\omega)} - \frac{r(\omega)}{2}\frac{\partial \text{var}(\Pi(\boldsymbol{q}(\omega)|L(\omega),\boldsymbol{\varphi}(\omega),r(\omega))}{\partial q_d(\omega)} = 0$$

where

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

and

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

Hence, for all d such that $q_d(\omega) > 0$, it holds

$$q_d(\omega)^{-\frac{1}{\sigma}}\frac{\sigma-1}{\sigma}\left(\mathbb{E}[A_d] - r(\omega)\sum_{d'}\text{cov}(A_d,A_{d'})q_{d'}(\omega)^{\frac{\sigma-1}{\sigma}}\right) = c_d(\omega). \tag{3}$$

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 ω exists and is unique given the set of locations of foreign affiliates. As 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 (3) does not have a closed-form solution. However, for $\sigma = 2$, a closed-form solution can be found for all $d \in D$. In particular, the first-order conditions for this case can be rewritten as

$$q_d(\omega) = \left(\frac{\mathbb{E}[A_d]}{2c_d(\omega)}\right)^2 \cdot \left(\frac{1 - r(\omega)\frac{\sum_{d'\neq d}\text{cov}(A_d,A_{d'})q_{d'}(\omega)^{\frac{1}{2}}}{\mathbb{E}A_d}}{1 + r(\omega)\frac{\text{var}(A_d)}{2c_d(\omega)}}\right)^2. \tag{4}$$

The first factor of the right hand side of equation (4) represents the quantity chosen by the firm if there is no risk (aversion). 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 $\text{var}(A_d)$), whereas it increases with the opportunities of diversification offered by the market d (captured by the covariances $\text{cov}(A_d, A_d')$ in the numerator). Hence, countries characterized by larger variance or lower diversification potential attract smaller sales the more risk averse the MNE is.

The first-order necessary and sufficient conditions in (3) can also be rearranged to obtain the risk aversion coefficient $r(\omega)$ 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*

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

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

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).

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

No export platforms. Without export platforms, the system of equations (3) reads as

$$q_l(\omega)^{-\frac{1}{\sigma}} \frac{\sigma-1}{\sigma} \left(\mathbb{E}[A_l] - r(\omega) \sum_{l'} \text{cov}(A_l, A_{l'}) q_{l'}(\omega)^{\frac{\sigma-1}{\sigma}} \right) = c_l(\omega), \tag{5}$$

where l is a location in which the MNE holds a production facility. From equation (5), 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 appear in (5). As the firm sells the variety produced in l only to the local market, the marginal cost simply reduces to $1/\varphi_l(\omega)$. For the special case of $\sigma = 2$, we obtain an expression similar to (4). In particular, we have

$$q_l(\omega) = \left(\frac{\mathbb{E}[A_l]}{2c_l(\omega)} \right)^2 \cdot \left(\frac{1 - r(\omega) \frac{\sum_{l' \neq l} \text{cov}(A_l, A_{l'}) q_{l'}(\omega)^{\frac{1}{2}}}{\mathbb{E} A_l}}{1 + r(\omega) \frac{\text{var}(A_l)}{2c_l(\omega)}} \right) = \left(\frac{1}{2} \varphi_l(\omega) \mathbb{E}[A_l] \right)^2 \cdot \left(\frac{1 - r(\omega) \frac{\sum_{l' \neq l} \text{cov}(A_l, A_{l'}) q_{l'}(\omega)^{\frac{1}{2}}}{\mathbb{E} A_l}}{1 + \frac{1}{2} r(\omega) \varphi_l(\omega) \text{var}(A_l)} \right). \tag{6}$$

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) 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

$$q_d(\omega) = \left(\frac{\sigma-1}{\sigma} \frac{A_d}{c_d(\omega)} \right)^{\sigma}. \tag{7}$$

Equation (7) 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 $\tilde{D}$.[19] Using equation (7), we obtain that the revenues $r_l(\omega)$ realized in a given location l are given by

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

where $k := \left(\frac{\sigma-1}{\sigma}\right)^{\sigma-1}$. The expression for the revenues realized in a given location is similar to the one in Tintelnot (2016). In particular, if there is only one industry, then $\alpha_d = Y_d$. In the equation (7), it is easy to see that the revenues realized in some location depends positively on the productivity of the location, and negatively by the distance of the location from the customers in the destination markets.[20]

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

The shipment decision hinges on the firm's productivity vector $\boldsymbol{\varphi}(\omega)$ 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. Since each firm produces its variety using a constant returns to scale technology and there are no fixed export costs, a standard cost minimization argument implies that the destination d is served from the location l such that the unit cost c_{ld}, which includes the trade cost from l to d and the marginal production cost in l, is the lowest possible one. In other words, $q_{ld}(\omega) > 0$ only if $c_{ld} = \min_{l'}\{c_{l'd}(\omega) : l' \in L(\omega)\}$.[21] It is worth to note that the optimal location-destination pair strictly depends on the location set $L(\omega)$ chosen by the firm.

Location decision. As stated, firm ω has to pay a fixed cost $f_l(\omega)$ 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 considerable as the price of holding a portfolio of risky assets 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

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

[20] If we also drop the assumption that firms can use a foreign location as an export platform, then equation (7) reduces to

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

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

location set. As a consequence, in order to find the optimal location L^* for its multinational activity under demand risk, the firm ω solves the following discrete maximization problem

$$\max_{L(\omega)\in 2^{N-1}} V(L(\omega)) - \mathcal{F}(L(\omega)), \tag{8}$$

where $\mathcal{F}(L(\omega)) = \sum_{l\in L(\omega)} f_l(\omega)$.

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 other 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 on the location decision of heterogeneous attitudes towards risk, we analyze how firms with different levels of risk aversion and equal level of home productivity select different locations for the 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.

2.3.1 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.[22] 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.

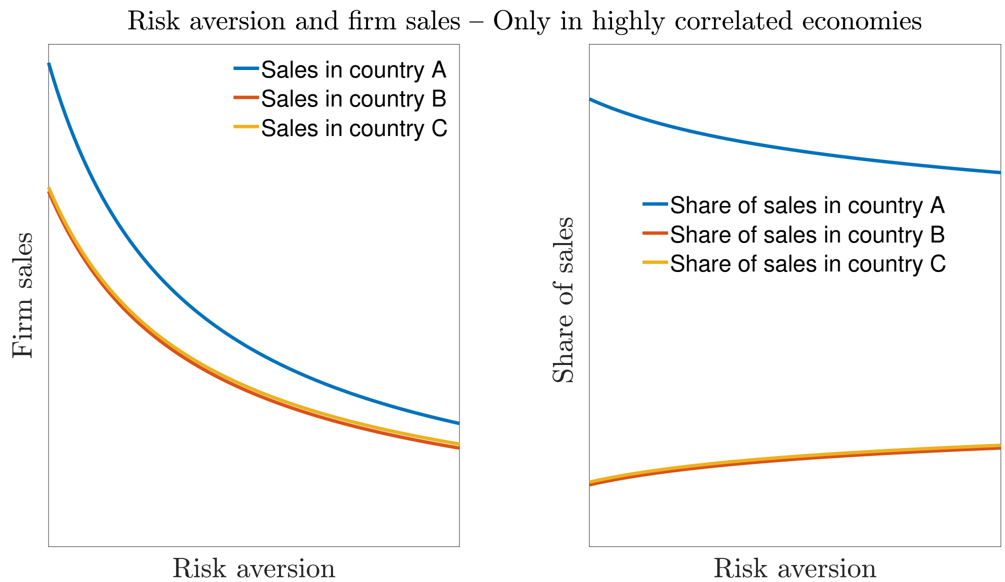
Equally correlated economies Assume that the demand correlations between A and B, B and C, and A and C are equal, positive but not perfect.[23] In the left panel of Figure , we notice how the absolute sales in country A are comparatively larger than those in countries B and C for any level of risk aversion. As the firm operates its affiliate in country A, it benefits from the proximity to the final customers. Hence, it ships

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

[23] 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).

a larger amount of the variety to the local market. In addition, given that the foreign countries B and C are symmetric, the firm sells the same amount to the two countries. In addition, larger level of aversion to risk induce the firms to sell less to each country, as they are risky. The presence of risk aversion affects not only the extensive margin of sales but also the intensive margin 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 more risk averse firms exploit more extensively the diversification opportunities as they are more concerned with the demand risk.

Figure 1: Case 1, Equally correlated economies

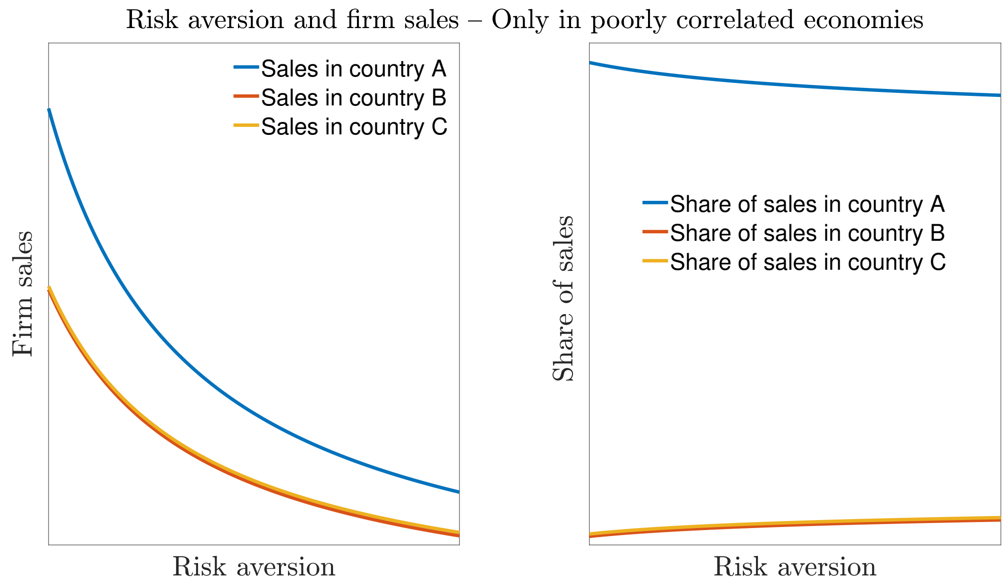


Differently correlated economies. Next, we consider the case in which the correlation of demand realizations between countries A and B, and A and C is lower than the correlation between countries B and C.[24] In this specification, the gap between sales in country A and countries B and C widens (see Figure 2). Though the structure of correlations has changed from the previous case, still countries B and C are symmetric so the firms ship the same amount to both countries. 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

[24] 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).

with the previous case, the firms want to sell more to country A and reduce their 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.

Figure 2: Case 2, Poorly correlated economies



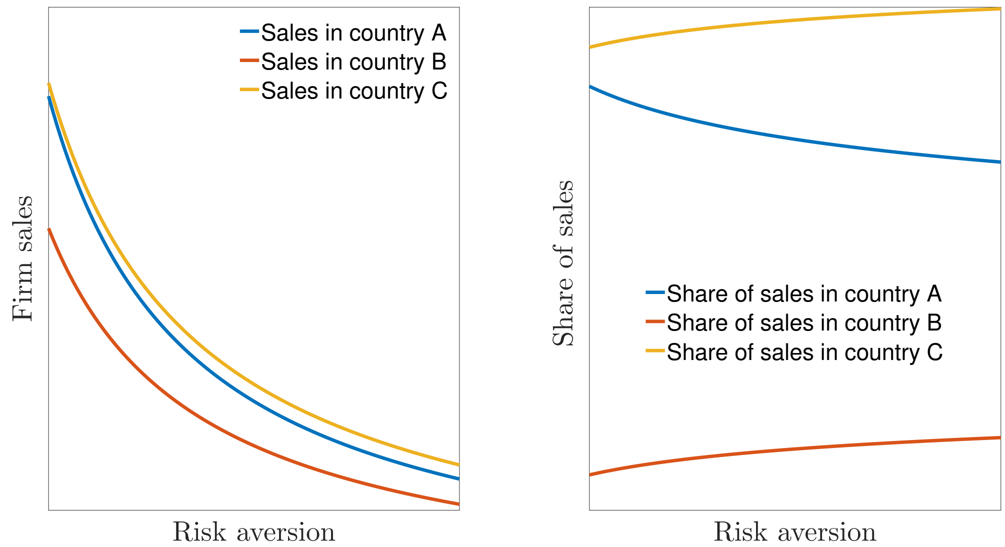
Mixed case. In the last case, we assume that the demand correlation between A and B is large than the correlations between countries A and C, and B and C.[25] Given the structure of demand correlation, country C now provides the firm with a better hedge to negative fluctuations in country A's demand 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 outweighs the gains of proximity to the customers. The right panel of Figure 3 shows that, as risk aversion increases, shares in B and C increase, whereas the share of sales in A decreases.

In the above examples, the diversification strategies of an MNE distorts the sales distribution compared

[25] 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 3: Case 3, Mixed case

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

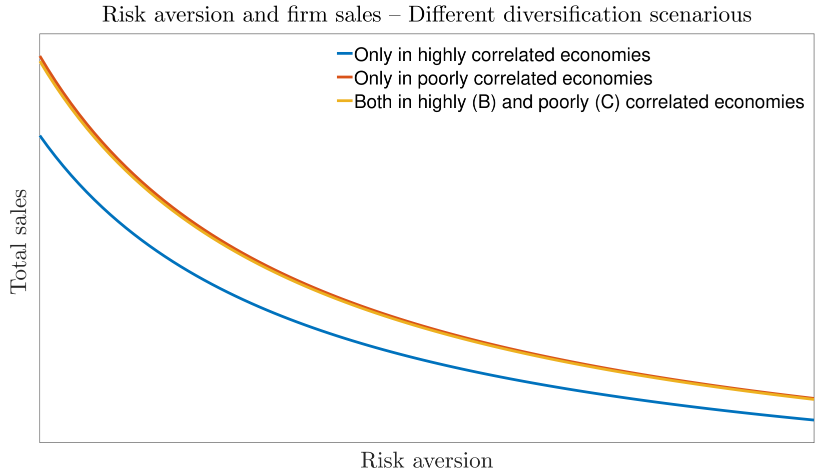


with the risk neutral model.[26] The distortion is particularly relevant either when risk aversion or diversification opportunities are large. Importantly, firms with different risk aversion value differently each destination market as each of them provides different hedging opportunities. The possibility of serving more conveniently a destination market can translate into diverse location choices and reaction to trade policies as we will discuss later.

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. Hence, we expect firms to sell more in those 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. Hence, the sales of MNEs were more stable than those of pure exporters.

[26] In the risk neutral model, the absolute sales are flat. 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



2.3.2 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 particular, 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, 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.[27] 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 fall. 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).

[27] For the proof see Appendix E.

Table 1: Effects of trade liberalization

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

2.3.3 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-select 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 (e.g., Helpman et al. (2004)), the firm's entry decision is typically described by a destination-specific productivity threshold. In particular, 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 assumption 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 (see Yeaple (2009)).

To illustrate this point, we consider a scenario consisting of six countries. In all scenarios, country A is the origin country of the multinational firm.[28] First, we fix firm's productivity level and look at the entry decisions for different levels 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 a 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, a more productive firm does not need to enter a larger number of 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

[28] 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.

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.

3 Data

For the empirical analysis, our main data source is the Microdatabase Direct investment[29] (MiDi), which contains firm-level information about foreign affiliates of German multinational companies.[30] More specifically, the data include balance sheet variables of foreign companies in which German 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[31] they operate in.

The empirical estimation relies on 952 German multinational firms operating in 19 different industries[32]

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

[30] The database is maintained by the Deutsche Bundesbank. For other research using the MiDi see Tintelnot (2016), who analyzes cost structure of vertical export platforms, Becker and Muendler (2008), who estimate responses of MNEs employment at the extensive and intensive margins.

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

[32] 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).

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

Countries	Total sales	Sales affiliate		Sales MNE		Employment MNE		Average productivity	N
		Average	SD	Average	SD	Average	Median		
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.

and 45 foreign countries[33] with 3,232 affiliates[34] 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.[35] The United States, Spain and France are the three countries in which German affiliates sell the most. It is worth noting that the number of entrants in the country cannot be perfectly mapped to the productivity level (or size) of the median entrant. This observation gives 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 MNEs. With respect to the entry pattern, the top locations are China and 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,

[33] 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.

[34] 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.

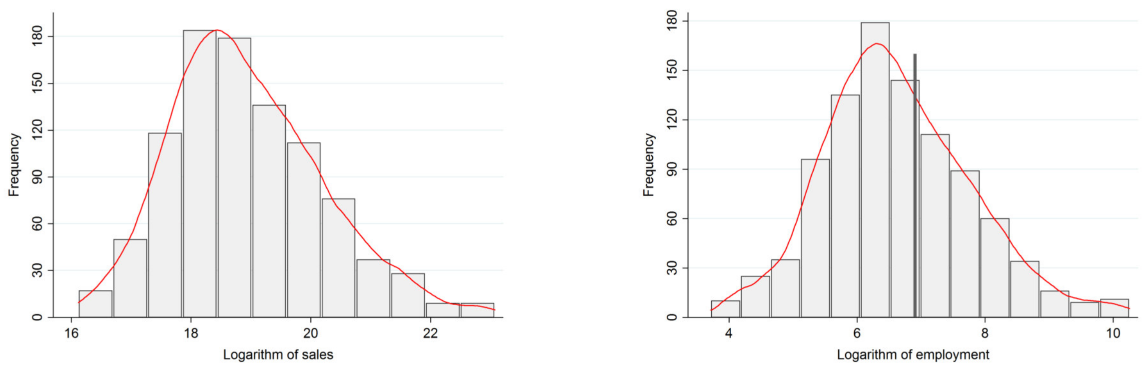
[35] The ranking is built with respect to the total amount of sales.

we use a standard proxy which considers an investment relation as horizontal if both parent and affiliate firms operate within the same industry.[36]

We use the AMADEUS database to obtain 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. In addition, we take into account also those German firms that have a plant exclusively in Germany.[37]

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.

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.

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 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

[36] 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.

[37] We restrict the sample of domestic German firms and German exporters to have a balance sheet with a total above 3 million Euros since MiDi does not contain information on firms below this threshold.

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.

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.

To estimate non-firm-specific parameters, such as trade costs, production indexes, and the co-variance matrix of country demands, we use data from UN databases and CEPII.[38]

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 $L(\omega)$ in which the affiliates of firm ω operate and the aggregate sales $\sum_{d\in L(\omega)} p_d(\omega)q_d(\omega)$ of the multinational group, we determine the firm-specific risk aversion

[38]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.

parameter $r(\omega)$. 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 $(\boldsymbol{\varphi}(\omega), \boldsymbol{\tau}, \boldsymbol{\sigma}, \bar{\boldsymbol{\alpha}}, \boldsymbol{\Sigma}, \boldsymbol{Q})$.

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 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 parameters, whereas we use the aggregate sales to determine the firm's risk attitude.

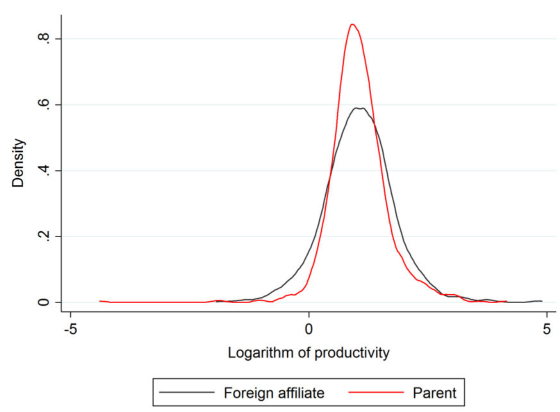
In the estimation of productivity, we control for firm- and market-specific demand parameters to obtain productivity estimates in the presence of a positive risk aversion. The equation we estimate at the affiliate level by industry reads as

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

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 the concentration measure to capture the diversification incentives of a firm. 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 observed realized sales rather than *ex-ante* 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 sales premium and the effect of the realized market size, we include the difference between the realized and expected market size[39]. 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).

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.

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

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 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:

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

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 indices only conditional on the elasticity of substitutions σ. As we do not estimate industry-specific elasticity of substitution, we assume $\sigma = 6$.[40]

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

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

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

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

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: $P_{id}Q_{id} = \alpha_{id}$.

[40] 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 are not sensitive to the choice of the elasticity of substitution.

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

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

where $\epsilon_{id,t}$ is an innovation term[41] with mean 1, and β captures the persistence in the evolution of α. We then estimate the following equation in logs

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

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

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

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[42]. We do not restrict risk aversion to be positive. For each firm, the matching proceeds as follows:

1. Guess the risk aversion parameter $r(\omega)$.

2. Given the location set $L(\omega)$ observed in the data, solve the firm's utility maximization problem.

3. Obtain $\boldsymbol{q}(\omega)$, and compute the implied aggregate theoretical sales $\sum_{d \in D} p_d(\omega) q_d(\omega)$.

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

[42] 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.

4. Update $r(\omega)$ if the distance between theoretical and empirical sales is larger than the tolerance level.[43]

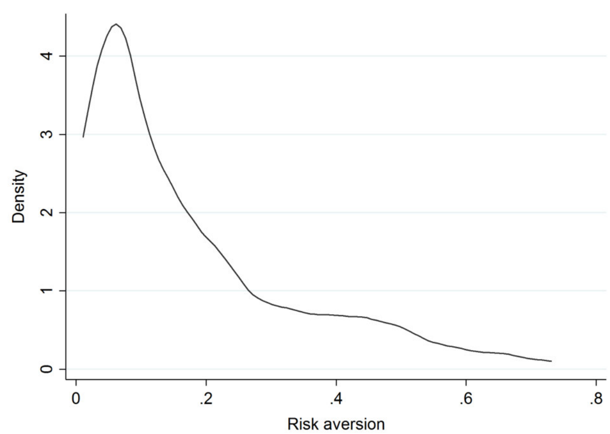
It is important to note that the updating of $r(\omega)$ is based on the characteristics of the solution to the utility maximization problem. Everything else equal, the firm's aggregate sales are strictly decreasing in risk aversion as shown in the Section 2.

5 Results

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

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 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.

[43]We assume convergence when the absolute difference between empirical and theoretical sales is less than $1e - 3\%$.

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

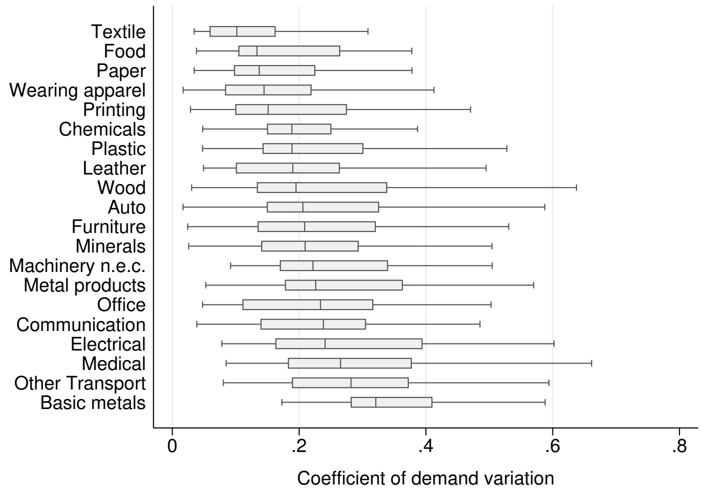
Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Micro-database Direct investment (MiDi), 1999-2014, authors' calculations.

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 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. Both observations are suggestive that our measure captures the attitude toward demand risk.

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 estimate productivities outside the model. Therefore, our measure of firm's productivity abstracts from the effect of risk aversion 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, when they are more concerned about market turmoil, firms take advantage of possible diversification opportunities more extensively. Moreover, the negative correlation between the concentration measure and risk aversion[44] is suggestive that the estimated

[44] Note that this result is still valid when we consider other measure of concentration, like the Herfindal index.

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



Source: UNIDO INDSTAT2 2016, authors' calculations.

risk aversion captures firm's attitude toward demand risk.

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 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.[45] 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. 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.

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.

Next, we estimate a proxy for the elasticity of MNE sales to the level of risk aversion. 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	25th percentile	50th percentile	75th percentile
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%

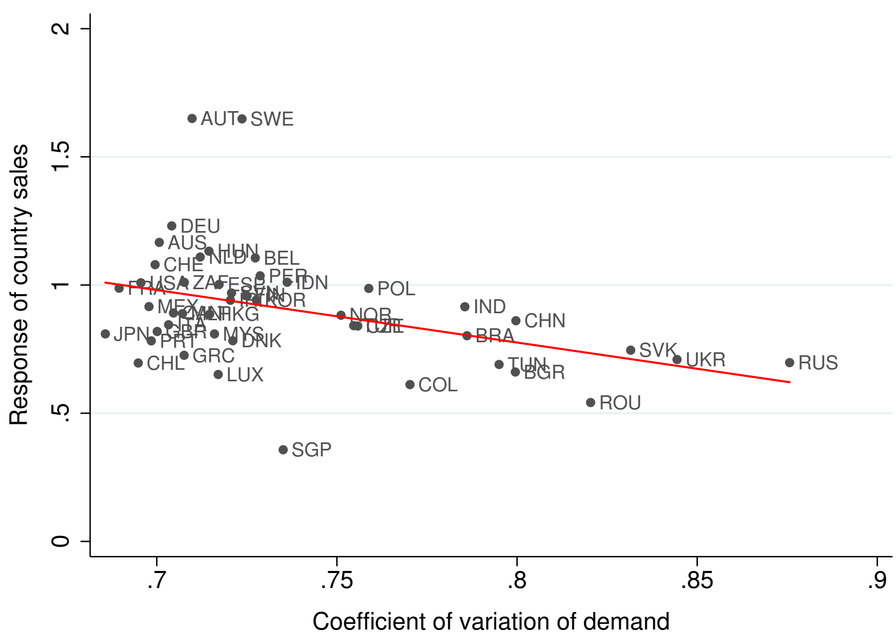
Source: Research Data and Service Centre (RDSC) of the Deutsche Bundesbank, Microdatabase Direct investment (MiDi), 1999-2014, authors' calculations.

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%

[45] See Table 13 in Appendix F.

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 remain less attractive and 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.

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.

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 **??** Table **??** 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

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.

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 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.[46] 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.

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.

[46] On May 11 2017, China and US signed a trade agreement to remove some of the existing 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.

Our theoretical model predicts that MNEs operating in foreign markets 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*

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

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

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

is equivalent to $(P1)$, i.e. $q_{ld}(\omega)$ is a solution for $(P1)$ if and only if $s_{ld}(\omega)$ is a solution for $(P2)$.

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

$$\frac{\partial u(\cdot)}{\partial q_d(\omega)} = \frac{\sigma-1}{\sigma}\mathbb{E}[A_d]q_d(\omega)^{-\frac{1}{\sigma}} - r(\omega)\left(\frac{\sigma-1}{\sigma}q_d(\omega)^{-\frac{1}{\sigma}}\sum_{d'}\mathrm{cov}(A_d,A'_d)q_{d'}(\omega)^{\frac{\sigma-1}{\sigma}}\right) - c_d(\omega) = 0, \tag{9}$$

and

$$\frac{\partial u(\cdot)}{\partial s_d(\omega)} = \mathbb{E}[A_d] - r(\omega)\sum_{d'}\mathrm{cov}(A_d,A'_d)s_{d'}(\omega) - \frac{\sigma}{\sigma-1}c_d(\omega)s_d(\omega)^{\frac{1}{\sigma-1}} = 0. \tag{10}$$

respectively. Then, using the definition of $s_d(\omega)$, we can write (10) as where the last equivalence follows from the fact that $q_d(\omega) > 0$. So, if $q_d(\omega)$ solves (9), then $s_d(\omega)$ solves (10), and vice versa. This shows that problems $(P1)$ and $(P2)$ are equivalent given the definition of $s_d(\omega)$, and admit the same solution, provided this solution exists. □

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 existence, we use the definition of coercive function. A continuous function f is coercive if

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

Note that $u(\cdot)$ can be written as the sum of the expected profits and the variance of profits multiplied by a scalar $r(\omega)$. These functions, taken with negative sign, are both coercive.[47] 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.[48]

Uniqueness: We show that the utility function is strictly concave in $s_d(\omega) = q_d(\omega)^{\frac{\sigma-1}{\sigma}}$.

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

Note that any element of the main diagonal is given by

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

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

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

Let

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

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

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

Then, we note that matrix $\mathbf{D}$ is positive definite being a diagonal matrix with all diagonal elements positive. Moreover, $r(\omega)\mathbf{\Sigma}_A$ is positive definite being the product of a positive scalar with a positive definite matrix. Hence, $\mathbf{D} + r(\omega)\mathbf{\Sigma}_A$ is positive definite being the sum of two positive definite matrices[49] implying that $\mathbf{H}_u$

[47] Note that expected profit function is the sum of the profit realized in each destination d, which is a continuous and concave function of $s_d(\omega)$ admitting a unique global maximizer, (i.e. the solution under no risk aversion/risk). 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 $(s_d(\omega)(\omega))_d$ with a minimum.

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

[49] See Horn and Johnson (2012).

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*

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

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

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

The first order optimality conditions order with respect to $s_d(\omega)$ are

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

$$\mathbb{E}A_d - \frac{\sigma}{\sigma-1}c_d(\omega)s_d(\omega)^{\frac{1}{\sigma-1}} - r(\omega)\sum_d \text{cov}(A_d, A_{d'})s_d(\omega) = 0. \tag{11}$$

Hence, multiplying both sides of equation (11) by $s_d(\omega)$, and summing over d the risk aversion coefficient r can be expressed as follows

$$r(\omega) = \frac{\sum\limits_d \left[\mathbb{E}A_d s_d(\omega) - \frac{\sigma}{\sigma-1}c_d(\omega)s_d(\omega)^{\frac{\sigma}{\sigma-1}}\right]}{\sum\limits_d\sum\limits_{d'}\text{cov}(A_d, A_{d'})s_d(\omega)s_{d'}(\omega)} = \frac{\left(\mathbb{E}p_d(\omega)q_d(\omega) - \tilde{p}_d(\omega)q_d(\omega)\right)}{\left(\boldsymbol{q}(\omega)^{\frac{\sigma-1}{\sigma}}\right)'\Sigma\boldsymbol{q}(\omega)^{\frac{\sigma-1}{\sigma}}} \equiv \frac{SP}{SV}, \tag{12}$$

where $\tilde{p}_d(\omega) = \frac{\sigma}{\sigma-1}c_d(\omega)$ is the price firm ω would set under certainty, SP is the *sales premium*, and SV is the variance of sales *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	Sales affiliate		Sales MNE		Employment		N
		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 Risk aversion and Aggregate Sales

Proposition 4. *(Risk Aversion and Aggregate Sales). The firm's aggregate sales are decreasing with risk aversion.*

Proof. Suppose the solution to the utility maximization problem is interior. Then the system of first-order necessary and sufficient conditions reads as

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

Differentiating both sides with respect to r we obtain

$$-\frac{\sigma}{(\sigma-1)^2}c_d(\omega)s_d(\omega)^{\frac{1}{\sigma-1}-1}\dot{s}_d(\omega) - \sum_{d'}\text{cov}(A_d, A_{d'})s_{d'}(\omega) - r(\omega)\sum_{d'}\text{cov}(A_d, A_{d'})\dot{s}_{d'}(\omega) = 0, \ \ \forall d \in D.$$

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

$$\frac{\sigma}{\sigma-1}c_d(\omega)s_d(\omega)^{\frac{1}{\sigma-1}-1}\dot{s}_d(\omega) = -(\sigma-1)\left(\sum_{d'}\text{cov}(A_d, A_{d'})s_{d'}(\omega) + r(\omega)\sum_{d'}\text{cov}(A_d, A_{d'})\dot{s}_{d'}(\omega)\right). \quad (13)$$

Again, using FOC we observe that

$$\frac{\sigma}{\sigma-1}c_d(\omega)s_d(\omega)^{\frac{1}{\sigma-1}} = \mathbb{E}A_d - r(\omega)\sum_{d'}\text{cov}(A_d, A_{d'})s_{d'}(\omega), \ \ \forall d \in D. \quad (14)$$

Combining equation (13) and (14) we obtain

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

for all d, which implies

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

Summing both sides over d we obtain

$$\begin{aligned}\sum_d \mathbb{E}A_d\dot{s}_d(\omega) = -(\sigma-1)&\left(\sum_d\sum_{d'}\text{cov}(A_d, A_{d'})s_{d'}(\omega) + r(\omega)\sum_d\sum_{d'}\text{cov}(A_d, A_{d'})\dot{s}_{d'}(\omega)\right)\\ &+r(\omega)\sum_d\sum_{d'}\text{cov}(A_d, A_{d'})s_{d'}(\omega)\dot{s}_d(\omega).\end{aligned} \quad (15)$$

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 in the brackets. Recall that

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

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

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

Summing over d and re-arranging, we obtain

$$\begin{aligned}\sum_d\sum_{d'}\text{cov}(A_d, A_{d'})s_{d'}(\omega)\dot{s}_d(\omega) = &-r(\omega)\sum_d\sum_{d'}\text{cov}(A_d, A_{d'})\dot{s}_{d'}(\omega)\dot{s}_d(\omega) \\ &-\sum_d\frac{\sigma}{\sigma-1}c_d(\omega)s_d(\omega)^{\frac{1}{\sigma-1}-1}(\dot{s}_d(\omega))^2.\end{aligned} \tag{16}$$

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.

$$\sum_d\sum_{d'}\text{cov}(A_d, A_{d'})s_{d'}(\omega)\dot{s}_d(\omega) < 0. \tag{17}$$

Incidentally we also notice that

$$r(\omega)\sum_d\sum_{d'}\text{cov}(A_d, A_{d'})\dot{s}_d(\omega)\dot{s}_{d'}(\omega) + \sum_d\sum_{d'}\text{cov}(A_d, A_{d'})s_{d'}(\omega)\dot{s}_d(\omega) < 0. \tag{18}$$

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

$$\begin{aligned}
\sum_d \sum_{d'} \text{cov}(A_d, A_{d'}) s_d(\omega) s_{d'}(\omega) + 2r(\omega) \sum_d \sum_{d'} \text{cov}(A_d, A_{d'}) s_{d'}(\omega) \dot{s}_d(\omega) \\
+ r(\omega)^2 \sum_d \sum_{d'} \text{cov}(A_d, A_{d'}) \dot{s}_{d'}(\omega) \dot{s}_d(\omega) = \\
\sum_d \sum_{d'} \text{cov}(A_d, A_{d'}) s_d(\omega) s_{d'}(\omega) + r(\omega) \sum_d \sum_{d'} \text{cov}(A_d, A_{d'}) s_{d'}(\omega) \dot{s}_d(\omega) \\
+ r(\omega) \left(r(\omega) \sum_d \sum_{d'} \text{cov}(A_d, A_{d'}) \dot{s}_{d'}(\omega) \dot{s}_d(\omega) + r(\omega) \sum_d \sum_{d'} \text{cov}(A_d, A_{d'}) s_{d'}(\omega) \dot{s}_d(\omega) \right) > 0
\end{aligned} \tag{19}$$

From equation (18) 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.

$$\sum_d \sum_{d'} \text{cov}(A_d, A_{d'}) s_d(\omega) s_{d'}(\omega) + r(\omega) \sum_d \sum_{d'} \text{cov}(A_d, A_{d'}) s_{d'}(\omega) \dot{s}_d(\omega) > 0. \tag{20}$$

Hence, considering equations (15), (16) and (19), we conclude that aggregate sales are decreasing in $r(\omega)$. □

E Liberalization

Proposition 5. *A trade cost reduction in a destination country increases the sales flows accruing to it.*

Proof. Define $Y_d(\omega) \equiv \sum_{d'} \text{cov}(A_d, A_{d'}) s_{d'}(\omega)$ and denote with the dot sign the derivative w.r.t. τ_d.

Then, $\begin{cases} -\frac{\sigma}{(\sigma-1)^2} c_d(\omega) s_d(\omega)^{\frac{2-\sigma}{\sigma-1}} \dot{s}_d(\omega) - r(\omega)\dot{Y}_d(\omega) & = \frac{\sigma}{\sigma-1} s_d(\omega)^{\frac{1}{\sigma-1}} \dot{c}_d(\omega) \\ -\frac{\sigma}{(\sigma-1)^2} c_{d'}(\omega) s_{d'}(\omega)^{\frac{2-\sigma}{\sigma-1}} \dot{s}_{d'}(\omega) - r(\omega)\dot{Y}_{d'}(\omega) & = 0 \qquad \text{for} \quad d' \neq d. \end{cases}$

By adding up over d and premultiplying the result by $\dot{s}_d(\omega)$, we obtain

$$\sum_{d'} \frac{\sigma}{(\sigma-1)^2} c_{d'}(\omega) s_{d'}(\omega)^{\frac{2-\sigma}{\sigma-1}} \dot{s}_{d'}(\omega)^2 + r \sum_{d'} \dot{Y}_{d'} \dot{s}_{d'}(\omega) = -\frac{\sigma}{\sigma-1} s_d(\omega)^{\frac{1}{\sigma-1}} \dot{s}_d(\omega).$$

Therefore, $\dot{s}_d(\omega) = \frac{ds_d(\omega)}{d\tau_d} < 0$. □

F Firm Characteristics and Risk Aversion

Table 12: 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 13: 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.