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Market size, Competition, and the Product Mix of Exporters*

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PRELIMINARY DRAFT

Abstract

Recent empirical evidence has highlighted how the export patterns of multi-product firms dominate world trade flows, and how these multi-product firms respond to different economic conditions across export markets by varying the number of products they export. In this paper, we further analyze the effects of those export market conditions on the relative export sales of those goods: we refer to this as the firm's product mix choice. We build a theoretical model of multi-product firms that highlights how market size and geography (the market sizes of and bilateral economic distances to trading partners) affects both a firm's exported product range and its exported product mix across market destinations. We show how tougher competition in an export market - associated with a downward shift in the distribution of markups across all products sold in the market - induces a firm to skew its export sales towards its best performing products. We find very strong confirmation of this competitive effect for French exporters across export market destinations. Our theoretical model shows how this effect of export market competition on a firm's product mix then translates into differences in measured firm productivity. Thus, a firm operating a given technology will produce relatively more output per worker when it exports to markets with tougher competition. This productivity gain is further compounded by the effect of competition on the mix of exported products.

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1 Introduction

Recent empirical evidence has highlighted how the export patterns of multi-product firms dominate world trade flows, and how these multi-product firms respond to different economic conditions across export markets by varying the number of products they export.[1] In this paper, we further analyze the effects of those export market conditions on the relative export sales of those goods: we refer to this as the firm's product mix choice. We build a theoretical model of multi-product firms that highlights how market size and geography (the market sizes of and bilateral economic distances to trading partners) affects both a firm's exported product range and its exported product mix across market destinations. We show how tougher competition in an export market – associated with a downward shift in the distribution of markups across all products sold in the market – induces a firm to skew its export sales towards its best performing products. We find very strong confirmation of this competitive effect for French exporters across export market destinations. We also highlight how bilateral trade barriers/enhancers additionally skew a firm's export product mix, after controlling for export market conditions. Our theoretical model shows how this effect of trade barriers and export market competition on a firm's product mix then translates into differences in measured firm productivity. Thus, a firm operating a given technology will produce relatively more output per worker when it exports to markets with tougher competition, or when trade barriers fall. This productivity gain is also compounded by concurrent changes in the mix of exported products in response to those changes in its trading environment.[2]

Feenstra and Ma (2008) and Eckel and Neary (2009) also build theoretical models of multi-product firms that highlight the effect of competition on the distribution of firm product sales. Eckel and Neary (2009) also emphasize the ensuing link between competition and firm productivity. Both models incorporate the cannibalization effect that occurs as large firms expand their product range. In our model, we rely on the competition effects from the demand side, which are driven by variations in the number of sellers and their average prices across export markets. The cannibalization effect does not occur as firms produce a discrete number of products and thus never attain finite mass. The benefits of this simplification is that we can consider an open economy equilibrium with multiple asymmetric countries and asymmetric trade barriers whereas Feenstra and Ma (2008) and Eckel and Neary (2009) restrict their analysis to a single globalized

[1] See Mayer and Ottaviano (2007) for Europe, Bernard et al (2007) for the U.S., and Arkolakis and Muendler (2008) for Latin America.

[2] Bernard et al (2006) and Eckel and Neary (2008) also emphasize this channel between globalization and within-firm productivity changes in a world with symmetric countries. We discuss those papers in further detail below.

world with no trade barriers. Thus, our model is able to capture the key role of geography in shaping differences in competition across export market destinations.[3]

Another approach to the modeling of multi-product firms relies on a nested C.E.S. structure for preferences, where a continuum of firms produce a continuum of products. The cannibalization effect is ruled out by restricting the nests in which firms can introduce new products. Allanson and Montagna (2005) consider such a model in a closed economy, while Arkolakis and Muendler (2008) and Bernard et al (2006) develop extensions to open economies. Given the C.E.S. structure of preferences and the continuum assumptions, markups across all firms and products are exogenously fixed. Thus, differences in market conditions or proportional reductions in trade costs have no effect on a firm's product mix choice (the relative distribution of export sales across products). The latter can only be affected by variations in the delivered costs of the goods (differences in production costs and non-proportional delivery costs). Arkolakis and Muendler (2008) and Bernard et al (2006) document that those cost differences are substantial and that a large proportion of those differences can be attributed to production costs that do not vary across destinations: the distribution of within-firm product export sales is highly skewed, and the ranking of those export sales is highly correlated across export market destinations.[4] We find that the same patterns hold for French exporters. This motivates the concept of a firm's product ladder, starting with its core competency (its best selling product) followed by decreasing productivity/quality ladder for the ensuing products.[5] We also adopt this concept of a core competency and productivity/quality ladder; in our model with endogenous markups, the distribution of exported product sales will vary with market conditions – even after controlling for those cost differences.

Bernard et al (2006) and Baldwin and Gu (2009) also theoretically analyze the effects of a symmetric trade liberalization between symmetric countries. They find that such a liberalization will induce firms to reduce the number/mass of products they produce. Given the productivity differences along the product ladder, Bernard et al (2006) show that this reduction in product scope towards a firm's core competency also leads to within-firm productivity gains for non-exporters (including those firms that are induced to export for the first time).[6] When we restrict our model

[3] Nocke and Yeaple (2008) and Baldwin and Gu (2009) also develop models with multi-product firms and a pro-competitive effect coming from the demand side. These models investigate the effects of globalization on a firm's product scope and average production levels per product. However, those models consider the case of firms producing symmetric products whereas we focus on the effects of competition on the within-firm distribution of product sales.

[4] Arkolakis and Muendler (2008) examine the distribution of product export sales for Brazilian and Chilean firms, while Bernard et al (2006) report those patterns for U.S. firms.

[5] Eckel and Neary (2009) also adopt this modeling concept. Arkolakis and Muendler (2008) and Bernard et al (2006) additionally introduce a stochastic element of the productivity/quality ladder that is market specific.

[6] Eckel and Neary (2009) also find similar effects for an increase in the world market size, absent any trade costs.

to symmetric countries, we also obtain a similar prediction for the effects of trade liberalization. However, our model predicts that trade liberalization will additionally lead firms to skew both domestic and export sales towards their core products (for a given range of products in either market). This opens another channel for within-firm productivity gains from trade liberalization. Empirically, both the effects on product scope and the skewness of the product mix have been documented for the case of trade liberalization in North America. Baldwin and Gu (2009), Bernard et al (2006), and Iacovone and Javorcik (2008) all show how this trade liberalization has induced (respectively) Canadian, U.S., and Mexican firms to reduce the number of products they produce. Baldwin and Gu (2009) and Bernard et al (2006) further report that CUSFTA has induced a significant increase in the skewness of production across products (an increase in entropy). This could be due to an increase in export sales for the 'better' products relative to the marginal products only sold in the domestic economy – absent any changes in the competitive environment; but it could also be due to an increase in the skewness of both export and domestic sales towards the best performing products – which would be explained by an increase in competition due to trade liberalization. Iacovone and Javorcik (2008) show that this is indeed the case for Mexican firms: they report that the exports of a firm's 'better' products (higher export sales) expanded significantly more than those for worse performing products during the period of trade expansion from 1994-2003. Iacovone and Javorcik (2008) also compare the relative contributions of exported product scope and the export product mix (changes in exports of previously exported products) for Mexican exports to the U.S. following NAFTA. They find that changes in the product mix explain the preponderance of the changes in export patterns of Mexican firms. Importantly for the predictions of our model, they find that both expansions as well as contractions in exported product sales (for some firms/products) played an important role. Our theoretical model explains how a symmetric reduction in proportional trade costs induces firms to increase export sales for their best products while simultaneously reducing export sales of other products further down the ladder. The increase in the skewness of both export and domestic sales is driven by the effects of trade liberalization on the toughness of competition across markets.

Our paper proceeds as follows. We first develop a closed economy version of our model in order to focus on the endogenous responses of a firm's product scope and product mix to market conditions. We also show how those choices translate into differences in observable firm performance measures. Even in a closed economy, increases in market size lead to increases in within-firm productivity as well as aggregate productivity gains via reallocations across firms. We then extend our model to an open economy. To fix intuition, we initially abstract from third country effects via geography and develop a 2-country model. We introduce both proportional and non-proportional trade costs across the product ladder – but then show how the consequences of both types of costs can be subsumed within a single trade cost index.[7] We then analyze the effects of multilateral trade liberalization when the trade costs are assumed to be symmetric. We then turn to the multi-country case with an arbitrary matrix of bilateral trade costs. The equilibrium connects differences in market size and geography to the toughness of competition in every market, and how the latter shapes the within-firm distribution of product export sales. Lastly, we empirically test those predictions, examining how market size, geography and trade barriers/enhancers affect that within-firm distribution of product export sales.

2 Closed Economy

We introduce multi-product firms in the model of Melitz and Ottaviano (2008). We start with a closed economy where L consumers each supply one unit of labor.

2.1 Preferences and Demand

Preferences are defined over a continuum of differentiated varieties indexed by $i \in \Omega$, and a homogenous good chosen as numeraire. All consumers share the same utility function given by

$$U = q_0^c + \alpha \int_{i\in\Omega} q_i^c di - \frac{1}{2}\gamma \int_{i\in\Omega} (q_i^c)^2 \, di - \frac{1}{2}\eta \left(\int_{i\in\Omega} q_i^c di \right)^2 , \quad (1)$$

where q_0^c and q_i^c represent the individual consumption levels of the numeraire good and each variety i. The demand parameters α, η, and γ are all positive. The parameters α and η index the substitution pattern between the differentiated varieties and the numeraire: increases in α and decreases in η both shift out the demand for the differentiated varieties relative to the numeraire. The parameter γ indexes the degree of product differentiation between the varieties. In the limit when $\gamma = 0$, consumers only care about their consumption level over all varieties, $Q^c = \int_{i\in\Omega} q_i^c di$. The varieties are then perfect substitutes. The degree of product differentiation increases with γ as consumers give increasing weight to the distribution of consumption levels across varieties.

The marginal utilities for all goods are bounded, and a consumer may thus not have positive demand for any particular good. We assume that consumers have positive demands for the numeraire

[7] Our empirical results strongly confirm the presence of non-proportional trade costs across the product ladder.

good ($q_0^c > 0$). The inverse demand for each variety i is then given by

$$p_i = \alpha - \gamma q_i^c - \eta Q^c, \tag{2}$$

whenever $q_i^c > 0$. Let $\Omega^* \subset \Omega$ be the subset of varieties that are consumed ($q_i^c > 0$). (2) can then be inverted to yield the linear market demand system for these varieties:

$$q_i \equiv L q_i^c = \frac{\alpha L}{\eta M + \gamma} - \frac{L}{\gamma} p_i + \frac{\eta M}{\eta M + \gamma} \frac{L}{\gamma} \bar{p}, \ \forall i \in \Omega^*, \tag{3}$$

where M is the measure of consumed varieties in Ω^* and $\bar{p} = (1/M) \int_{i \in \Omega^*} p_i di$ is their average price. The set Ω^* is the largest subset of Ω that satisfies

$$p_i \leq \frac{1}{\eta M + \gamma} (\gamma \alpha + \eta M \bar{p}) \equiv p_{\max}, \tag{4}$$

where the right hand side price bound $p_{\max}$ represents the price at which demand for a variety is driven to zero. Note that (2) implies $p_{\max} \leq \alpha$. In contrast to the case of C.E.S. demand, the price elasticity of demand, $\varepsilon_i \equiv |(\partial q_i / \partial p_i) (p_i / q_i)| = [(p_{\max}/p_i) - 1]^{-1}$, is not uniquely determined by the level of product differentiation γ. Given the latter, lower average prices $\bar{p}$ or a larger number of competing varieties M induce a decrease in the price bound $p_{\max}$ and an increase in the price elasticity of demand ε_i at any given p_i. We characterize this as a 'tougher' competitive environment.[8]

Welfare can be evaluated using the indirect utility function associated with (1):

$$U = I^c + \frac{1}{2} \left(\eta + \frac{\gamma}{M} \right)^{-1} (\alpha - \bar{p})^2 + \frac{1}{2} \frac{M}{\gamma} \sigma_p^2, \tag{5}$$

where I^c is the consumer's income and $\sigma_p^2 = (1/M) \int_{i \in \Omega^*} (p_i - \bar{p})^2 di$ represents the variance of prices. To ensure positive demand levels for the numeraire, we assume that $I^c > \int_{i \in \Omega^*} p_i q_i^c di = \bar{p} Q^c - M \sigma_p^2 / \gamma$. Welfare naturally rises with decreases in average prices $\bar{p}$. It also rises with increases in the variance of prices σ_p^2 (holding the mean price $\bar{p}$ constant), as consumers then re-optimize their purchases by shifting expenditures towards lower priced varieties as well as the numeraire good. Finally, the demand system exhibits 'love of variety': holding the distribution of prices constant (namely holding the mean $\bar{p}$ and variance σ_p^2 of prices constant), welfare rises with increases in

[8] We also note that, given this competitive environment (given N and $\bar{p}$), the price elasticity ε_i monotonically increases with the price p_i along the demand curve.

product variety M.

2.2 Production and Firm Behavior

Labor is the only factor of production and is inelastically supplied in a competitive market. The numeraire good is produced under constant returns to scale at unit cost; its market is also competitive. These assumptions imply a unit wage. Entry in the differentiated product sector is costly as each firm incurs product development and production startup costs. Subsequent production of each variety exhibits constant returns to scale. While it may decide to produce more than one variety, each firm has one key variety corresponding to its 'core competency'. This is associated with a core marginal cost c (equal to unit labor requirement).[9] Research and development yield uncertain outcomes for c, and firms learn about this cost level only after making the irreversible investment f_E required for entry. We model this as a draw from a common (and known) distribution $G(c)$ with support on $[0, c_M]$.

The introduction of an additional variety pulls a firm away from its core competency, which we model as higher marginal costs of production for those varieties. We think of these costs increases as also reflecting decreases in product quality/appeal as firms move away from their core competency. For simplicity, we maintain product symmetry on the demand side and capture any decrease in product appeal as an increased production cost. We label the additional production cost for a new variety a customization cost. A firm can introduce any number of new varieties, but each additional variety entails an additional customization cost (as firms move further away from their core competency). We index by m the varieties produced by the same firm in increasing order of distance from their core competency with $m = 0$ referring to the core variety. We then call $v(m, c)$ the marginal cost for variety m produced by a firm with core marginal cost c and assume $v(m, c) = \omega^{-m}c$ with $\omega \in (0, 1)$. This defines a firm-level 'competence ladder'. In the limit, as ω goes to zero, any firm will only produce at most its core variety and we are back to single product firms as in Melitz and Ottaviano (2008).

Since the entry cost is sunk, firms that can cover at least the marginal cost of their core variety survive and produce. All other firms exit the industry. Surviving firms maximize their profits using the residual demand function (3). In so doing, those firms take the average price level $\bar{p}$ and total number of varieties M as given. This monopolistic competition outcome is maintained with

[9] For simplicity, we do not model any overhead production costs. This would significantly increase the complexity of our model without yielding much new insight.

multi-product firms as any firm can only produce a countable number of products, which is a subset of measure zero of the total mass of varieties M.

The profit maximizing price $p(v)$ and output level $q(v)$ of a variety with cost v must then satisfy

$$q(v) = \frac{L}{\gamma}\left[p(v) - v\right]. \tag{6}$$

The profit maximizing price $p(v)$ may be above the price bound $p_{\max}$ from (4), in which case the variety is not supplied. Let v_D reference the cutoff cost for a variety to be profitably produced. This variety earns zero profit as its price is driven down to its marginal cost, $p(v_D) = v_D = p_{\max}$, and its demand level $q(v_D)$ is driven to zero. Hence, the threshold cost v_D summarizes the competitive environment across all varieties produced. Let $r(v) = p(v)q(v)$, $\pi(v) = r(v) - q(v)v$, $\lambda(v) = p(v) - v$ denote the revenue, profit, and (absolute) markup of a variety with cost v. All these performance measures can then be written as functions of v and v_D only:

$$\begin{aligned} p(v) &= \frac{1}{2}\left(v_D + v\right), \\ \lambda(v) &= \frac{1}{2}\left(v_D - v\right), \\ q(v) &= \frac{L}{2\gamma}\left(v_D - v\right), \\ r(v) &= \frac{L}{4\gamma}\left[\left(v_D\right)^2 - v^2\right], \\ \pi(v) &= \frac{L}{4\gamma}\left(v_D - v\right)^2. \end{aligned} \tag{7}$$

As expected, lower cost varieties have lower prices and earn higher revenues and profits than varieties with higher costs. However, lower cost varieties do not pass on all of the cost differential to consumers in the form of lower prices: they also have higher markups (in both absolute and relative terms) than varieties with higher costs.

Firms with core competency $v > v_D$ cannot profitably produce their core variety and exit. Thus $c_D = v_D$ is also the cutoff for firm survival and an equivalent measure of the 'toughness' of competition. We assume that c_M is high enough that it is always above c_D, so exit rates are always positive. All firms with core cost $c < c_D$ earn positive profits (gross of the entry cost) on their core varieties and remain in the industry. Some firms will also earn positive profits from the introduction of additional varieties. In particular, firms with cost c such that $v(m,c) \leq v_D \iff c \leq \omega^m c_D$ earn positive profits on their m-th *additional* variety and thus produce at least $m+1$ varieties. The total number of varieties produced by a firm with cost c is

$$M(c) = \begin{cases} 0 & \text{if } c > c_D, \\ \max\{m \mid c \leq \omega^m c_D\} + 1 & \text{if } c \leq c_D. \end{cases} \tag{8}$$

which is (weakly) decreasing for all $c \in [0, c_M]$. Accordingly, the number of varieties produced by a firm with cost c is indeed an integer number (and not a mass with positive measure). This number is an increasing step function of the firm's productivity $1/c$, as depicted in figure 1 below so that firms with higher core productivity produce (weakly) more varieties.

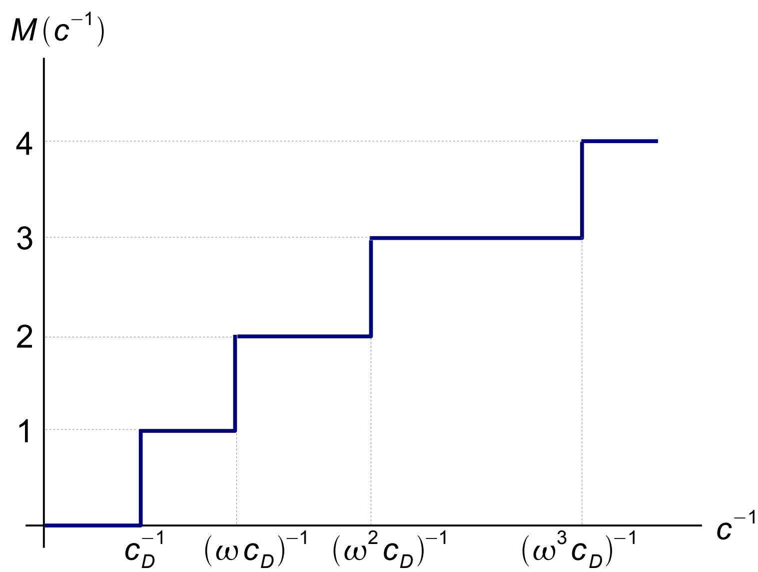

Figure 1: Number of Varieties Produced as a Function of Firm Productivity

Given a mass of entrants N_E, the distribution of costs across all varieties is determined by the optimal firm product range choice $M(c)$ as well as the distribution of core competencies $G(c)$. Let $M_v(v)$ denote the measure function for varieties (the measure of varieties produced at cost v or lower, given N_E entrants). Further define $H(v) \equiv M_v(v)/N_E$ as the normalized measure of varieties per unit mass of entrants. Then $H(v) = \sum_{m=0}^{\infty} G(\omega^m v)$ and is exogenously determined from $G(.)$ and ω. Given a unit mass of entrants, there will be a mass $G(v)$ of varieties with cost v or less; a mass $G(\omega v)$ of first additional varieties (with cost v or less); a mass $G(\omega^2 v)$ of second additional varieties; and so and so forth. The measure $H(v)$ sums over all these varieties.

2.3 Free Entry and Flexible Product Mix

Prior to entry, the expected firm profit is $\int_0^{c_D} \Pi(c)dG(c) - f_E$ where

$$\Pi(c) \equiv \sum_{m=0}^{M(c)-1} \pi\left(v\left(m,c\right)\right) \tag{9}$$

denotes the profit of a firm with cost c. If this profit were negative for all c's, no firms would enter the industry. As long as some firms produce, the expected profit is driven to zero by the unrestricted entry of new firms. This yields the equilibrium free entry condition:

$$\begin{aligned} \int_0^{c_D} \Pi(c)dG(c) &= \int_0^{c_D} \left[\sum_{\{m|\omega^{-m}c \le c_D\}} \pi\left(\omega^{-m}c\right) \right] dG(c) \\ &= \sum_{m=0}^{\infty} \left[\int_0^{\omega^m c_D} \pi\left(\omega^{-m}c\right) dG(c) \right] = f_E, \end{aligned} \tag{10}$$

where the second equality states that the expected firm profit equals expected variety profit accounting for core and non-core varieties.

The free entry condition (10) determines the cost cutoff $c_D = v_D$. This cutoff, in turn, determines the aggregate mass of varieties, since $v_D = p(v_D)$ must also be equal to the zero demand price threshold in (4):

$$v_D = \frac{1}{\eta M + \gamma}\left(\gamma\alpha + \eta M \bar{p}\right).$$

The aggregate mass of varieties is then

$$M = \frac{2\gamma}{\eta}\frac{\alpha - v_D}{v_D - \overline{v}}, \tag{11}$$

where the average cost of all varieties

$$\overline{v} = \frac{1}{M}\int_0^{v_D} v dM_v(v) = \frac{1}{N_E H(v_D)}\int_0^{v_D} v N_E dH(v) = \frac{1}{H(v_D)}\int_0^{v_D} v dH(v)$$

depends only on v_D.[10] Finally, the mass of entrants is given by $N_E = M/H(v_D)$, which can in turn be used to obtain the mass of producing firms $N = N_E G(c_D)$.

[10] We also use the relationship between average cost and price $\bar{v} = 2\bar{p} - v_D$, which is obtained from (7).

2.4 Parametrization of Technology

All the results derived so far hold for any distribution of core cost draws $G(c)$. However, in order to simplify some of the ensuing analysis, we use a specific parametrization for this distribution. In particular, we assume that core productivity draws $1/c$ follow a Pareto distribution with lower productivity bound $1/c_M$ and shape parameter $k \geq 1$. This implies a distribution of cost draws c given by

$$G(c) = \left(\frac{c}{c_M}\right)^k, \; c \in [0, c_M]. \tag{12}$$

The shape parameter k indexes the dispersion of cost draws. When $k = 1$, the cost distribution is uniform on $[0, c_M]$. As k increases, the relative number of high cost firms increases, and the cost distribution is more concentrated at these higher cost levels. As k goes to infinity, the distribution becomes degenerate at c_M. Any truncation of the cost distribution from above will retain the same distribution function and shape parameter k. The productivity distribution of surviving firms will therefore also be Pareto with shape k, and the truncated cost distribution will be given by $G_D(c) = (c/c_D)^k, \; c \in [0, c_D]$.

When core competencies are distributed Pareto, then all produced varieties will share the same Pareto distribution:

$$H(c) = \sum_{m=0}^{\infty} G(\omega^m c) = \Omega G(c), \tag{13}$$

where $\Omega = \left(1 - \omega^k\right)^{-1} > 1$ is an index of multi-product flexibility (which varies monotonically with ω). In equilibrium, this index will also be equal to the average number of products produced across all surviving firms:

$$\frac{M}{N} = \frac{H(v_D)}{G(c_D)} = \Omega.$$

The Pareto parametrization also yields a simple solution for the cost cutoff c_D from the free entry condition (10):

$$c_D = \left[\frac{\gamma \phi}{L\Omega}\right]^{\frac{1}{k+2}}, \tag{14}$$

where $\phi \equiv 2(k+1)(k+2)\,(c_M)^k f_E$ is a technology index that combines the effects of better distribution of cost draws (lower c_M) and lower entry costs f_E. We assume that $c_M > \sqrt{[2(k+1)(k+2)\gamma f_E]\,/\,(L\Omega)}$ in order to ensure that $c_D < c_M$ as was previously anticipated. Note that, in the limit, when the marginal costs of non-core varieties becomes infinitely large ($\omega \to 0$), multi-product flexibility Ω goes to one (no multi product firms) and (14) boils down to the single-product case studied by Melitz and Ottaviano (2008). The average marginal cost across varieties is then

$$\overline{v} = \frac{k}{k+1} v_D$$

and the mass of available varieties (see (11) is

$$M = \frac{2(k+1)\gamma}{\eta} \frac{\alpha - c_D}{c_D}. \tag{15}$$

Since the cutoff level completely summarizes the distribution of prices as well as all the other performance measures, it also uniquely determines welfare from (5):

$$U = 1 + \frac{1}{2\eta}(\alpha - c_D)\left(\alpha - \frac{k+1}{k+2} c_D\right). \tag{16}$$

Welfare increases with decreases in the cutoff c_D, as the latter induces increases in product variety M as well as decreases in the average price $\bar{p}$ (these effects dominate the negative impact of the lower price variance).[11]

2.5 Competition, Productivity and Welfare

The variety measures (7) can be aggregated to the firm and industry levels to see how the toughness of competition affects firm and industry industry. Specifically, if we let

$$\begin{aligned} C(c) &= \sum_{m=0}^{M(c)-1} v(m,c)\, q(v(m,c)), \qquad Q(c) \equiv \sum_{m=0}^{M(c)-1} q(v(m,c)), \\ R(c) &\equiv \sum_{m=0}^{M(c)-1} r(v(m,c)), \qquad \Pi(c) \equiv \sum_{m=0}^{M(c)-1} \pi(v(m,c)), \end{aligned} \tag{17}$$

denote total firm cost (employment), output, revenue, and profit respectively, we can then compute industry average output per worker, revenue per worker, and markup as

$$\bar{Q} = \frac{\int_0^{c_D} Q(c)dG(c)}{\int_0^{c_D} C(c)dG(c)} = \frac{k+2}{k}\frac{1}{c_D}, \;\; \bar{P} = \frac{\int_0^{c_D} R(c)dG(c)}{\int_0^{c_D} Q(c)dG(c)} = \frac{k+1}{k+2}c_D, \;\; \bar{\Lambda} = \frac{\int_0^{c_D} \Pi(c)dG(c)}{\int_0^{c_D} Q(c)dG(c)} = \frac{c_D}{k+2} \tag{18}$$

[11] This welfare measure reflects the reduced consumption of the numeraire to account for the labor resources used to cover the entry costs.

where we have used the fact that all produced varieties share the same Pareto distribution (13). Expressions (18) show that a tougher competitive environment raises average output per worker while reducing average price and average markup. Empirically, physical units of output are often not accurately recorded (especially for multi-product firms) and productivity is then measured as value-added per worker deflated by the industry price index. This productivity measure corresponds to

$$\bar{\Phi} = \frac{\int_0^{c_D} \left[R(c)/\bar{P} \right] dG(c)}{\int_0^{c_D} C(c) dG(c)} = \frac{k+2}{k} \frac{1}{c_D}$$

Hence, as competition gets tougher not only physical productivity but also measured productivity increase.

These industry behavior is due to: the exit of less productive firms (given (15) and $N = MG(c_D)/H(v_D)$); the (weak) drop of varieties away from the core by surviving firms (given (8)); and the reallocation of firms' productive resources to the surving products closer to the core. To see this last channel at work, consider two varieties produced by a firm with cost c, index them m and m', and assume $m < m'$ so that m is closer than m' to the core. By (7) the ratio of employment between these two varieties evaluates to

$$\frac{(\omega^{-m} c)\, q(v\,(m, c))}{(\omega^{-m'} c)\, q(v\,(m', c))} = \frac{(c_D - \omega^{-m} c)}{(c_D - \omega^{-m'} c)} \omega^{-(m-m')}$$

As this expression is a decreasing function of c_D for $m < m'$, tougher competition leads to the reallocation of employment from variety m' to variety m closer to the core. The output, revenue, and profit ratios of m to m' also rise accordingly whereas the price ratio falls. In other words, within the firm the distributions of employment, output, revenue, and profit become more skewed towards the core whereas the distribution of prices flattens.

These within-firm reallocations improve firm productivity even for a given number of varieties produced. The productivity of a firm with cost c producing $M(c) = M$ varieties is given by

$$\frac{Q(c)}{C(c)} = \frac{\omega^M (\omega - 1)}{\omega (\omega^M - 1)} \frac{1}{c} \frac{M c_D - c \frac{\omega(\omega^M - 1)}{\omega^M (\omega - 1)}}{c_D - c \frac{\omega(\omega^M + 1)}{\omega^M (\omega + 1)}} \tag{19}$$

As shown in Appendix A, this measure is a decreasing functions of c_D, thus showing that the firm becomes more productive when competition gets tougher.

To sum up, recalling (14), we can conclude that increases in market size, technology improvements (a fall in c_M or f_E), or increases in product substitutability (a rise in γ) lead to decreases in the cutoff c_D and increases in both the mass of varieties produced (a rise in M), and the mass of surviving firms (a rise in N). Although the average number of varieties produced per firm remains constant at $M/N = \Omega$, each firm responds to tougher competition by decreasing the number of varieties produced $M(c)$ irrespective of its core cost c. The average number of varieties M/N remains constant due to the effects of selection as higher cost firms producing the fewest number of varieties exit. All surviving firms (weakly) drop varieties far from the core and reallocate labor resources among the remaining varieties close to the core. As a result, within-firm productivity increases due to the compounding effects of this reallocation of the product mix and the variety selection effect in terms of product scope. Also aggregate productivity increases due to both a within-firm and across-firm selection effect. Output and sales per variety increase for all surviving varieties, and the distribution of markups across these products shifts down. Finally, welfare increases due to higher productivity and product variety, and lower markups.

3 Open Economy

We now turn to the open economy in order to examine how market size and geography determine differences in the toughness of competition across markets – and how the latter translates into differences in the exporters' product mix. We allow for an arbitrary number of countries and asymmetric trade costs. Let J denote the number of countries, indexed by $l = 1, ..., J$. The markets are segmented, although any produced variety can be exported. This entails an additional customization cost (over and above the customization for the domestic market). We assume that firms everywhere face the same step cost ω^{-1} for varieties produced for their domestic market, but allow the additional customization cost for exports from country l to country h, $\left(\theta^{lh}\right)^{-1} \geq 1$, to vary across country-pairs. This leads to differences in the combined (inverse) step-cost $\left(\omega^{lh}\right)^{-1} \equiv \left(\theta^{lh}\omega\right)^{-1} \geq 1$ across country-pairs.

There is also an iceberg trade cost $\tau^{lh} > 1$ that varies across country-pairs and is incurred once for each variety that is exported from h to l. For notational convenience, we subsume the first customization cost $1/\theta^{lh}$ into this iceberg trade cost so that we can write the marginal cost of an exported variety from country $h \neq l$ to country l as $v_X^{lh}(m, c) = \left(\theta^{lh}\omega\right)^{-m} c$, with delivered cost $\tau^{lh} v_X^{lh}(m, c)$.[12] The step cost for varieties produced on each domestic market remains ω^{-1},

[12] While the iceberg cost is incurred in units of the transported variety, the customization cost is paid in units of labor. Moreover, while the former is arguably positively correlated with distance, the correlation between the latter

leading to the same marginal cost function for variety m, $v_D^l(m,c) = \omega^{-m}c$, as in the closed economy. Let $\omega^{lh} \equiv \theta^{lh}\omega \leq \omega$ denote the combined (inverse) step cost for exported varieties from l to h. Throughout our analysis, we allow for the possibility of $\theta^{lh} = 1$ $\left(\omega^{lh} = \omega\right)$, which is a natural benchmark of no step-differences between exported and domestic varieties. In that case, τ^{lh} is the only trade cost and there are no variations across destinations in relative delivered costs $\left[\tau^{lh}v_X^{lh}(m,c)\right] / \left[\tau^{lh}v_X^{lh}(m',c)\right] = \omega^{m'-m}$ for any two exported varieties m and m' by a given firm. Variations in θ^{lh} allow us to consider cases where that relative delivered cost will vary across destinations for a firm. We find strong confirmation of this effect in our empirical results.

3.1 Product Mix and Product Scope

Let $p_{\max}^l$ denote the price threshold for positive demand in market l. Then (4) implies

$$p_{\max}^l = \frac{1}{\eta M^l + \gamma}\left(\gamma\alpha + \eta M^l \bar{p}^l\right), \tag{20}$$

where M^l is the total number of products selling in country l (the total number of domestic and exported varieties) and $\bar{p}^l$ is their average price. Let $\pi_D^l(v)$ and $\pi_X^{lh}(v)$ represent the maximized value of profits from domestic and export sales to country h for a variety with cost v produced in country l.[13] The cost cutoffs for profitable domestic production and for profitable exports must satisfy:

$$\begin{aligned} v_D^l &= \sup\left\{c : \pi_D^l(v) > 0\right\} = p_{\max}^l, \\ v_X^{lh} &= \sup\left\{c : \pi_X^{lh}(v) > 0\right\} = \frac{p_{\max}^h}{\tau^{lh}}, \end{aligned} \tag{21}$$

and thus $v_X^{lh} = v_D^h/\tau^{lh}$. As was the case in the closed economy, the cutoff v_D^l, $l = 1, ..., J$, summarizes all the effects of market conditions in country l relevant for all firm performance measures. The profit functions can then be written as a function of these cutoffs:

$$\begin{aligned} \pi_D^l(v) &= \frac{L^l}{4\gamma}\left(v_D^l - v\right)^2, \\ \pi_X^{lh}(v) &= \frac{L^h}{4\gamma}\left(\tau^{lh}\right)^2\left(v_X^{lh} - v\right)^2 = \frac{L^h}{4\gamma}\left(v_D^h - \tau^{lh}v\right)^2. \end{aligned} \tag{22}$$

and distance is theoretically undetermined. We will come back to this issue in the empirical analysis.

[13] Recall that $v_X^{lh}(m,c) \geq v_D^l(m,c)$ with a strict inequality whenever $\theta^{lh} < 1$ and $m > 0$. In those cases, a firm that produces variety m at cost v for the domestic market cannot produce that same variety at cost v for the export market. Thus, in general, $\pi_D^l(v)$ and $\pi_X^{lh}(v)$ do not refer to domestic and export profits for the *same* variety m.

As in the closed economy, $c_D^l = v_D^l$ will be the cutoff for firm survival in country l. Similarly, $c_X^{lh} = v_X^{lh}$ will be the firm export cutoff (no firm with $c > c_X^{lh}$ can profitably export any varieties from l to h). A firm with core competency c will produce all varieties m such that $\pi_D^l\left[v_D^l(m,c)\right] = \pi_D^l\left(\omega^{-m}c\right) \geq 0$, and will export the subset of varieties m such that $\pi_X^{lh}\left[v_X^{lh}(m,c)\right] = \pi_X^{lh}\left[\left(\omega^{lh}\right)^{-m}c\right] \geq 0$. The total number of varieties produced and exported by a firm with cost c in country l are thus

$$M_D^l(c) = \begin{cases} 0 & \text{if } c > c_D^l, \\ \max\left\{m \mid c \leq \omega^m c_D^l\right\} + 1 & \text{if } c \leq c_D^l, \end{cases}$$

$$M_X^l(c) = \begin{cases} 0 & \text{if } c > c_X^{lh}, \\ \max\left\{m \mid c \leq \left(\omega^{lh}\right)^m c_X^{lh}\right\} + 1 & \text{if } c \leq c_X^{lh}. \end{cases}$$

We can then define a firm's total domestic and export profits by aggregating over these varieties:

$$\Pi_D^l(c) = \sum_{m=0}^{M_D^l(c)-1} \pi_D^l\left[v_D^l(m,c)\right], \qquad \Pi_X^{lh}(c) = \sum_{m=0}^{M_X^{lh}(c)-1} \pi_X^{lh}\left[v_X^{lh}(m,c)\right].$$

Entry is unrestricted in both countries. Firms choose a production location prior to entry and paying the sunk entry cost. We assume that the entry cost f_E and cost distribution $G(c)$ are identical in all countries (although this can be relaxed).[14] We also assume the same Pareto parametrization (12) for core competencies in all countries. A prospective entrant's expected profits will then be given by

$$\begin{aligned} &\int_0^{c_D^l} \Pi_D^l(c)dG(c) + \sum_{h\neq j}\int_0^{c_X^{lh}} \Pi_X^{lh}(c)dG(c) \\ &= \sum_{m=0}^{\infty}\left[\int_0^{\omega^m c_D^l} \pi_D^l\left(\omega^{-m}c\right)dG(c)\right] + \sum_{h\neq j}\sum_{m=0}^{\infty}\left[\int_0^{\left(\omega^{lh}\right)^m c_X^{lh}} \pi_X^{lh}\left[\left(\omega^{lh}\right)^{-m}c\right]dG(c)\right] \\ &= \frac{1}{2\gamma(k+1)(k+2)\left(c_M\right)^k}\left[L^l\Omega\left(c_D^l\right)^{k+2} + \sum_{h\neq j} L^h\Omega^{lh}\left(\tau^{lh}\right)^2\left(c_X^{lh}\right)^{k+2}\right] \\ &= \frac{\Omega}{2\gamma(k+1)(k+2)\left(c_M\right)^k}\left[L^l\left(c_D^l\right)^{k+2} + \sum_{h\neq j} L^h\frac{\Omega^{lh}}{\Omega}\left(\tau^{lh}\right)^{-k}\left(c_D^h\right)^{k+2}\right], \end{aligned}$$

where we define $\Omega^{lh} \equiv \left[1-\left(\omega^{lh}\right)^k\right]^{-1}$ in an analogous way to Ω and use the relationship $c_D^h = \tau^{lh}c_X^{lh}$. Setting the expected profit equal to the entry cost yields the free entry conditions:

[14] Differences in the support for this distribution could also be introduced as in Melitz and Ottaviano (2008).

$$\sum_{h=1}^{J} \rho^{lh} L^h \left(c_D^h\right)^{k+2} = \frac{\gamma\phi}{\Omega} \qquad l = 1, ..., J. \tag{23}$$

where $\rho^{lh} \equiv \left(\Omega^{lh}/\Omega\right)\left(\tau^{lh}\right)^{-k} < 1$ is a measure of 'freeness' of trade to country h that incorporates both the 'physical' trade cost τ^h as well as the step differences between domestic and export market customization. The technology index ϕ is the same as in the closed economy case. We also allow for the possibility of internal trade cost so that τ^{ll} may also be above 1. If not, then $\rho^{ll} = 1$, since $\Omega^{ll} = \Omega$ by definition.

The free entry conditions (23) yield a system of J equations that can be solved for the J equilibrium domestic cutoffs using Cramer's rule:

$$c_D^l = \left(\frac{\gamma\phi}{\Omega} \frac{\sum_{h=1}^{J} |C_{hl}|}{|P|} \frac{1}{L^l} \right)^{\frac{1}{k+2}}, \tag{24}$$

where $|P|$ is the determinant of the trade freeness matrix

$$P \equiv \begin{pmatrix} \rho^{11} & \rho^{12} & \cdots & \rho^{1M} \\ \rho^{21} & \rho^{22} & \cdots & \rho^{2M} \\ \vdots & \vdots & \ddots & \vdots \\ \rho^{M1} & \rho^{M2} & \cdots & \rho^{MM} \end{pmatrix},$$

and $|C_{hl}|$ is the cofactor of its ρ^{hl} element. Cross-country differences in cutoffs now arise from two sources: own country size (L^l) and geographical remoteness, captured by $\sum_{h=1}^{J} |C_{hl}| \,/\, |P|$. Central countries benefiting from a large local market have lower cutoffs, and exhibit tougher competition, than peripheral countries with a small local market.

As in the closed economy, the threshold price condition in country l (20), along with the resulting Pareto distribution of all prices for varieties sold in l (domestic prices and export prices have an identical distribution in country l) yield a zero-cutoff profit condition linking the variety cutoff $v_D^l = c_D^l$ to the mass of varieties sold in country l :

$$M^l = \frac{2(k+1)\gamma}{\eta} \frac{\alpha - c_D^l}{c_D^l}. \tag{25}$$

Given a positive mass of entrants N_E^h in country h, there will be $G(c_X^{hl})N_E^h$ firms exporting $\Omega^{hl}G(c_X^{hl})N_E^h$ varieties to country l. Summing over all these varieties (including those produced and sold in l) yields[15]

$$\sum_{h=1}^{J} \rho^{hl} N_E^h = \frac{M^l}{\Omega \left(c_D^l\right)^k}.$$

The latter provides a system of J linear equations that can be solved for the number of entrants in the J countries using Cramer's rule:[16]

$$N_E^l = \frac{\phi\gamma}{\Omega\eta\,(k+2)\,f_E} \sum_{h=1}^{J} \frac{\left(\alpha - c_D^h\right)}{\left(c_D^h\right)^{k+1}} \frac{|C_{lh}|}{|P|}. \tag{26}$$

As in the closed economy, the cutoff level completely summarizes the distribution of prices as well as all the other performance measures. Hence, it also uniquely determines welfare:

$$U = 1 + \frac{1}{2\eta}\left(\alpha - c_D^l\right)\left(\alpha - \frac{k+1}{k+2} c_D^l\right).$$

which is a decreasing function of the c_D^l.

It is worthwhile pointing out that, across markets, market size has exactly the same effect on competition, hence on within-firm reallocations across varieties and productivity, as in the closed economy. Specifically, since the domestic cost cutoff c_D^l decreases monotonically as country size L^l increases according to (24), the toughness of competition in a market induces the same firm and product reallocations that were previously described for the closed economy: sellers drop their marginal varieties and focus on varieties closer to their core competency; they also re-allocate their labor resources towards the production of those 'core' varieties (lower m). Firm productivity increases due to these compounding effects. Inter-firm reallocations (the lowest productivity sellers exit) generate an additional aggregate productivity increase in the sellers population.

To see this the effect of intra-firm reallocations, consider a firm with cost c that sells M varieties from country l to country h. In this case firm output per worker (excluding output wasted in transit due iceberg frictions in the numerator but not the corresponding employment in the denominator)

[15] Recall that $c_D^l = \tau^{hl} c_X^{hl}$.

[16] We use the properties that relate the freeness matrix P and its transpose in terms of determinants and cofactors.

is:

$$\frac{Q_X^{lh}(c)}{C_X^{lh}(c)} = \frac{\sum_{m=0}^{M-1}\left[c_D^h - \tau^{lh}\left(\theta^{lh}\omega\right)^{-m}c\right]}{\sum_{m=0}^{M-1}\left[\tau^{lh}\left(\theta^{lh}\omega\right)^{-m}c\right]\left[c_D^h - \tau^{lh}\left(\theta^{lh}\omega\right)^{-m}c\right]} \tag{27}$$

$$= \frac{\left(\theta^{lh}\omega\right)^M\left(1-\theta^{lh}\omega\right)}{\left(\theta^{lh}\omega\right)\left(1-\theta^{lh}\omega^M\right)}\frac{M}{c\tau^{lh}}\frac{c_D^h - \frac{c\tau^{lh}}{M}\frac{\theta^{lh}\omega\left[1-\left(\theta^{lh}\omega\right)^M\right]}{\left(\theta^{lh}\omega\right)^M\left(1-\theta^{lh}\omega\right)}}{c_D^h - c\tau^{lh}\frac{\theta^{lh}\omega\left[1+\left(\theta^{lh}\omega\right)^M\right]}{\left(\theta^{lh}\omega\right)^M\left(1+\theta^{lh}\omega\right)}}$$

which boils down to $1/\left(c\tau^{lh}\right)$ for $M = 1$ whereas for $M \geq 2$ is indeed a decreasing function of c_D (see Appendix A).

3.2 Bi-Lateral Trade Patterns and the Margins of Export

We now investigate the predictions of this multi-country trade model for the composition of bi-lateral trade flows. A variety produced in country l at cost v for the export market to h generates export sales

$$r_X^{lh}(v) = \frac{L^h}{4\gamma}\left[\left(v_D^h\right)^2 - \left(\tau^{lh}v\right)^2\right]. \tag{28}$$

Then $EXP^{lh} = N_E^l\Omega^{lh}\int_0^{c_X^{lh}} r_X^{lh}(v)dG(v)$ represents the aggregate bi-lateral trade from l to h across the $N_E^l\Omega^{lh}G(c_X^{lh})$ exported varieties. This aggregate trade flow can be decomposed into the product of the number of exporting firms, $N_X^{lh} \equiv N_E^l G(c_X^{lh})$, the average number of exported varieties per firm, Ω^{lh}, and the average export flow per variety, $\bar{r}_X^{lh} \equiv \left[\int_0^{c_X^{lh}} r_X^{lh}(v)dG(v)\right]/G(c_X^{lh})$. This last term, capturing the product-intensive margin of trade only depends on the characteristics of the import market h:

$$\bar{r}_X^{lh} = \frac{L^h}{2\gamma\left(k+2\right)}\left(c_D^h\right)^2.$$

Lower trade barriers from l to h will clearly increase the export flow $r_X^{lh}(v)$ for any exported variety. However, the lower trade barriers will also induce new varieties to be exported to h. Since these new exported varieties will have the lowest trade volumes, these two effects will generate opposite forces on the average export flow $\bar{r}_X^{lh}$. Given our parametrization, these opposing forces exactly cancel out. We do not emphasize this exact result, but rather the presence of opposing forces generating the relationship between trade costs and average exports per variety. On the other hand, increases in importer country size generate unambiguous predictions for this intensive margin of trade: increases in country size toughen the selection effect for exported varieties (skewing the distribution towards varieties with higher trade volumes), and also generates increases in export flows $r_X^{lh}(v)$ for the varieties with the largest trade volumes (lower v).

Trade costs τ^{lh} as well as differences in importer characteristics generate ambiguous effects on the average number of exported varieties per firm: higher trade costs or tougher competition in h will both reduce the number of exported varieties by any given exporting firm. However, they will also generate a selection effect among firms: lower productivity firms exporting the smallest number of varieties exit the export market. Given our parametrization, these opposing forces cancel out, leaving the average number of exported varieties Ω^{lh} unchanged. Again, we emphasize the presence of competing forces for this margin of trade. However, changes in the additional step cost associated with customization for the export market in h do generate unambiguous predictions for the average number of exported varieties per firm: decreases in this additional cost will increase the average number of exported varieties, as all firms export more varieties.

Lastly, exporter and importer country characteristics, as well as trade barriers will have a predictable effect on the number of exporting firms:

$$N_X^{lh} = N_E^l G(c_D^h) \left(\tau^{lh}\right)^{-k}.$$

There are no countervailing forces at this final extensive margin: anything that makes it harder for firms from country l to break into the export market in h (higher trade barriers or tougher competition in h) will decrease the number of exporting firms. Holding those forces constant, an increase in the number of entrants (into production) in l will proportionally increase in the number of exporting firms to any given destination.

3.3 Exporters' Product Mix Across Destinations

We now focus on the predictions of our model for the within firm distribution of product sales across export destinations. Given (28), variety m exported by a firm with cost c from country l to country h generates export sales:

$$r_X^{lh}(m,c) = \frac{L^h}{4\gamma}\left\{\left(c_D^h\right)^2 - \left[\tau^{lh}\left(\theta^{lh}\omega\right)^{-m} c\right]^2\right\}. \tag{29}$$

Accordingly, for any two exported varieties to h, the ratio of export sales depends on the toughness of competition in h (inversely related to c_D^h) as well as on the bilateral trade and customization costs (τ^{lh} and θ^{lh}). Specifically, we have

$$\frac{d\ln r_X^{lh}(m,c)}{d\ln m} = \frac{2m\left[\tau^{lh}\left(\theta^{lh}\omega\right)^{-m}c\right]^2\ln\left(\theta^{lh}\omega^{lh}\right)}{\left\{\left(c_D^h\right)^2-\left[\tau^{lh}\left(\theta^{lh}\omega^{lh}\right)^{-m}c\right]^2\right\}} < 0$$

as $\theta^{lh}\omega^{lh} \in (0,1)$. Accordingly, in any given export market h varieties farther away from the core sell less than varieties closer to the core, the more so the tougher competition (smaller c_D^h). This is due to the fact that $d\ln r_X^{lh}(m,c)/d\ln m$ is negative and increasing in c_D^h. In other words, tougher competition skews export sales towards varieties closer to the core (lower m). This is the key prediction of our model that we bring to the data in the next section. Since tougher competition entails higher demand elasticities at any given price, the firm responds by lowering its markups across all exported products, which increases the relative sales of its better performing products selling at a lower relative price.[17]

Expression (29) generates also predictions for the response of export sales to differences in export costs. Holding the toughness of competition fixed, an increase in either trade or customization costs (higher τ^{lh} or lower θ^{lh}) skew export sales towards varieties closer to the core: $d\ln r_X^{lh}(m,c)/d\ln m$ is negative, decreasing in τ^{lh} and increasing in θ^{lh}.

In the case of the proportional trade cost τ^{lh}, this effect is driven by increases in demand price elasticities at higher cost levels since the ratio of delivered cost is unaffected by τ^{lh}. It is a feature of the linear demand system that price elasticity increases as a firm moves up its demand curve (this feature is shared with most other parametrization of demand that do not feature exogenous price elasticities). Thus, the effect of higher proportional trade costs is very similar to tougher competition: the higher delivered cost for some firms makes competition tougher for them at any given cutoff level c_D^h – and they respond by adjusting their markups downward on all exported goods. A higher customization cost increment $1/\theta^{lh}$ also generates a similar effect, inducing lower markups across exported products. However, this cost disproportionately hits products further away from the core, driving up their delivered costs relative to varieties closer to the core. This directly translates into higher relative export sales for the varieties closer to the core.

We note that our theoretical model does not restrict the pattern of correlation between trade and customization costs. If they were positively correlated, then higher trade costs would affect

[17] In equilibrium, a lower c_D^h in a country is associated with a downward shift in the distribution of markups across all products sold in that market (which we characterize as tougher competition). In the appendix, we show that this key prediction for the effects of tougher competition holds for a wide set of demand parametrizations.

disproportionately more varieties further away from the core due to the extra kick coming from customization costs. Higher trade costs would then lead to higher relative export sales for the varieties closer to the core. If trade and customization costs were instead negatively correlated, then higher trade costs would affect varieties further away from the core proportionately less due to the countervailing impact of customization costs. In this case, a higher trade cost for the core variety could even lead to lower relative export sales for the varieties closer to the core. In the end, which case is the most relevant one remains an empirical question that we will address in our empirical analysis.

In summary, we can test for differences in competition across export markets by examining the response of the skewness of exported sales for a given firm – after controlling for the bilateral trade costs. If a bilateral trade barrier exhibits either proportional trade costs (across the product line) or increasing trade costs, then higher levels of that trade barrier will induce higher relative export sales for varieties closer to the core – after controlling for the effects of market competition in that destination (common for exporters from any source country). On the other hand, if a bilateral trade barrier exhibits trade costs that increase less than proportionally along the product ladder, then it is possible for the trade barrier to induce lower relative export sales for varieties closer to the core. Crucially, our multi-country model tells us that cross-country differences in the 'toughness' of competition are determined by cross-country differences in own country size and geographical remoteness (see (24)). Since central countries with large local markets exhibit tougher competition than peripheral countries with small local markets, for each firm relative export sales should be higher for the varieties closer to the core in the former than in the latter.

4 Empirical analysis

4.1 Trade data and dependent variables

We test these predictions using comprehensive firm-level data on annual shipments by all French exporters to all countries in the world for a set of more than 10,000 goods. Firm-level exports are collected by French customs and include export sales for each 8-digit (combined nomenclature) product by destination country.[18] A firm located in the French metropolitan territory must report this detailed export information so long as the following criteria are met: For within EU exports, the

[18] We thank the French customs administration for making this data available to researchers at the CEPII.

firm's annual trade value exceeds 250,000 Euros;[19] and for exports outside the EU, the exported value to a destination exceeds 1,000 Euros or a weight of a ton. Despite these limitations, the database is nearly comprehensive. In a given year (on average), 102,300 firms report exports across 225 destination countries (or territories) for 11,578 products. This represents data on over 2 million shipments per year. We restrict our analysis to export data for 2003, and to manufacturing, mostly eliminating firms in the service and wholesale/distribution sector to ensure that firms take part in the production of the goods they export.[20] This leaves us with data on over a million shipments by firms in the whole range of manufacturing sectors. We also drop observations for firms that the French national statistical institute reports as having an affiliate abroad. This is intended to avoid the issue that multinational firms may find it optimal to locate the production of some of their best product in their local production facility for certain destination countries, following the lines of Helpman et al. (2004). We therefore concentrate on the ones that do not have this possibility, in order to reduce noise in the rankings.

We use three main measures to capture the skewness of a firm's export sales (within destinations). The first measure is closest to the modeling assumptions and assumes a product ladder that does *not* vary across destinations (for a given firm). We thus rank all the products exported by a firm according to the value of exports to the world[21], and use this ranking as an indicator for the product rank m_i . As we briefly mentioned in the introduction, this ranking is highly correlated with a similar ranking of products across destinations based on export sales to that destination. The Spearman rank correlation between these measures is .68.[22] Naturally, this correlation might be partly driven by firms that export only one product to one market, for which the global rank has to be the local rank. In table 1, we therefore investigate the robustness of this figure by gradually restricting the sample to firms that export many products to any markets. The bottom line is that this correlation remains quite stable: for firms exporting at least 50 products and to at least 50 countries, the figure is still .58. Another possibility is that this correlation is different across income levels of importing countries. Restricting the sample to the top 50 or 20% richest importers as we do in the regressions later, the correlation hardly changes at all (.69 and .71 respectively).

[19] If that threshold is not met, firms can choose to report under a simplified scheme without supplying export destinations. However, in practice, many firms under that threshold report the detailed export destination information.

[20] Some large distributors such as Carrefour account for a disproportionate number of annual shipments.

[21] We experimented using the number of countries served for the global ranking of products inside firms, with very little difference in results.

[22] Arkolakis and Muendler (2008, page 27) report a correlation coefficient between global and local ranks of .577 (.596) for Brazil (Chile). Eckel et al. (2009) report a rank correlation of .76 between home and export sales of Mexican firms.

Table 1: Spearman Correlations Between Global and Local Rankings

Firms exporting at least:	# products				
to # countries	1	2	5	10	50
1	67.93%	67.78%	67.27%	66.26%	59.39%
2	67.82%	67.74%	67.28%	66.28%	59.39%
5	67.55%	67.51%	67.2%	66.3%	59.43%
10	67.02%	67%	66.82%	66.12%	59.46%
50	61.66%	61.66%	61.64%	61.53%	58.05%

Although high, this correlation still highlights substantial departures from a steady global product ladder. A natural alternative is therefore to use the country specific rank as an indicator for the product rank m_i . In this interpretation, the identity of the core (or other rank number) product can change across destinations. Our assumptions on the delivered costs across the product ladder then hold for a specific rank in the product ladder, and not for a particular product. We can thus use either the product global rank, or the within destination product rank to generate export sales ratio $r_X^{lh}(v_X^h(m,c))/r_X^{lh}(v_X^h(m',c))$ for $m < m'$. Since many firms export few products to many destinations, increasing the higher product rank m' disproportionately reduces the number of available firm/destination observations. For most of our analysis, we pick $m = 0$ (core product) and $m' = 1$, but also report results for $m' = 2$.[23] Thus, we construct the ratio of a firm's export sales to every destination for its best performing product (either globally, or in each destination) relative to its next best performing product (again, either globally, or in each destination). The local ratios can be computed so long as a firm exports at least two products to a destination (or three when $m' = 2$). The global ratios can be computed so long as a firm exports its top (in terms of world exports) two products to a destination. We thus obtain these measures that are firm-destination specific, so long as those criteria are met. We use those ratios in logs, so that they represent percentage differences in export sales. We refer to the ratios as either local or global, based on the ranking method used to compute them. Last we also constrain the sample so that the two products considered belong to the same 2-digit product category (there are 97 of those). This setting seems slightly less noisy and we retain it for the rest of our regressions.[24]

Our third measure seeks to capture changes in skewness over the entire range of exported products (instead of being confined to the top two or three products). We use several different skewness statistics for the distribution of firm export sales to a destination: the standard deviation

[23] We also obtain very similar results for $m = 1$ and $m' = 2$.

[24] Results available upon request show that this restriction makes very little difference to the estimates.

of logged sales, a Herfindhal index, and a Theil index (a measure of entropy). Since these statistics are independent of the identity of the products exported to a destination, they are "local" by nature, and do not have any global ranking counterpart. These statistics can be computed for every firm-destination combination where the firm exports two or more products. The Theil and standard deviation statistics have the attractive property that they are invariant to truncation from below, when the underlying distribution is Pareto; this distribution provides a very good fit for the within-firm distribution of export sales to a destination. A graphical way to summarize how those product level sales are distributed close to Pareto is to compute the average share of the first, second... product in the total sales of firms, and graph this average share against rank. Bernard, Redding and Schott (2006) do this for firms producing exactly 4, 6, 8 and 10 products. Figure 2 does a similar exercice looking at shares of the top 50 products in total exports of firms that export between 50 and 100 products.[25] Although there are clearly departures from Pareto at both ends of the distribution, the tightness of the relationship is quite striking. In figure 3, we describe this distribution inside the firm, and report results from *within firm-destination regressions* of log rank on log size (for the 7570 French firms exporting more than 10 products and less than 50 in our sample). The median fit is .906, and the median coefficient is -.352.

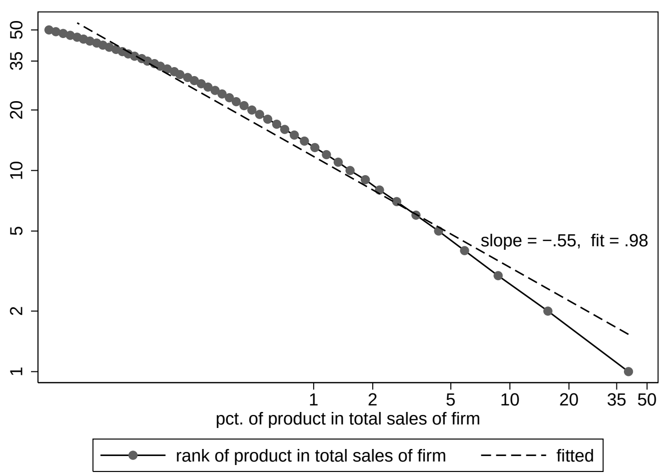

Figure 2: Average share of product sales depending on the rank of the product.

[25] In order to avoid the mechanical effect that firms exporting one product have a 100% share on top product (at least 50% for two products...), which drives the coefficient up (in absolute value).

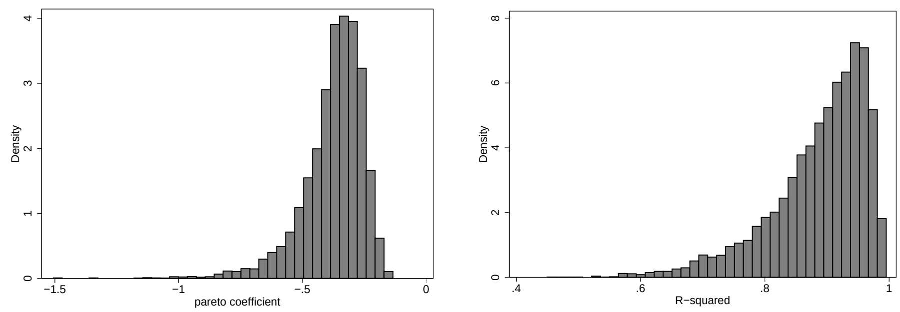

Figure 3: Coefficients and fit of firm-level log rank-size regressions.

4.2 Independent variables

Our theoretical model predicts that the toughness of competition in a destination is determined by that destination's size, and by its geography (proximity to other big countries). We control for country size using GDP expressed in a common currency at market exchange rates. We now seek a control for the geography of a destination that does not rely on country-level data for that destination. We use the *supply potential* concept introduced by Redding and Venables (2004) as such a control. Intuitively, the supply potential is the aggregate predicted exports to a destination based on a bilateral trade gravity equation (in logs) with both exporter and importer fixed effects and the standard bi-lateral measures of trade barriers/enhancers. We then construct the predicted aggregate exports to each destination without using the importer fixed effects (and thus uncorrelated with the importer fixed effect by construction). We call this measure a destination's *foreign supply potential*. Its construction is closely related to that of a country's market potential (which seeks to capture a measure of predicted import demand for a country).[26] The construction of the supply potential measures is discussed in greater detail in Redding and Venables (2004); we use the foreign supply measure for the year 2003 from Mayer (2008) who extends the analysis to many more countries and more years of data.[27] We also use a set of controls for bilateral trade barriers (τ in the model) between France and the destination country: distance, contiguity, colonial links, common-language, and dummies for membership of Regional Trading Agreements, GATT/WTO,

[26] Redding and Venables (2004) show that this construction for supply potential (and the similar one for market potential) is also consistent with its theoretical counterpart in a Dixit-Stiglitz-Krugman model. They construct those measures for a cross-section of 100 countries in 1994. Mayer (2008) uses the same methodology to cover more countries and a longer time period.

[27] As is the case with market potential, a country's supplier potential is strongly correlated with that country's GDP: big trading economies tend to be located near one-another. The supply potential data is available online at `http://www.cepii.fr/anglaisgraph/bdd/marketpotentials.htm`

and a common currency area (the eurozone in this case).[28]

4.3 Results

Before reporting the regression results of the skewness measures on the destination country measures, we first show some scatter plots for the global ratio against both destination country GDP and our measure of foreign supply potential. These are displayed in figures 4 and 5. For each destination, we use the mean global ratio across exporting firms. Since the firm-level measure is very noisy, the precision of the mean increases with the number of available firm data points (for each destination). We first show the scatter plots using all available destinations, with symbol weights proportional to the number of available firm observations, and then again dropping any destination with fewer than 250 exporting firms.[29] Those scatter plots show a very strong positive correlation between the export share ratios and the measures of toughness of competition in the destination. Absent any variation in the toughness of competition across destinations – such as in a world with monopolistic competition and C.E.S. preferences where markups are exogenously fixed – the variation in the relative export shares should be white noise. The data show that variations in competition (at least as proxied by country size and supplier potential) is strong enough to induce large variations in the firms' relative export sales across destinations. Scatter plots for the local ratio and Theil index look surprisingly similar.

We now turn to our regression analysis using the three skewness measures. Each observation summarizes the skewness of export sales for a given firm to a given destination. Since we seek to uncover variation in that skewness for a given firm, we include firm fixed effects throughout. We use destination specific controls for both competition (GDP and supplier potential, both in logs) and for the bilateral trade and customization costs when exporting from France (we discuss how we specify those in the paragraph below). There are undoubtedly other unobserved characteristics of countries that affect competition in that destination and would be captured in the error term (as well as other country characteristics that could affect the skewness of export sales via a channel other than competition). Such unobserved country characteristics are common to firms exporting to that destination and hence generate a correlated error-term structure, potentially biasing the standard error of our variables of interest downwards. The standard clustering procedure does not apply very well here for two reasons: i) the level of clustering is not nested within the level of fixed

[28] All those variables are available at `http://www.cepii.fr/anglaisgraph/bdd/distances.htm`

[29] Increasing that cutoff level for the number of exporters slightly increases the fit and slope of the regression line through the scatter plot.

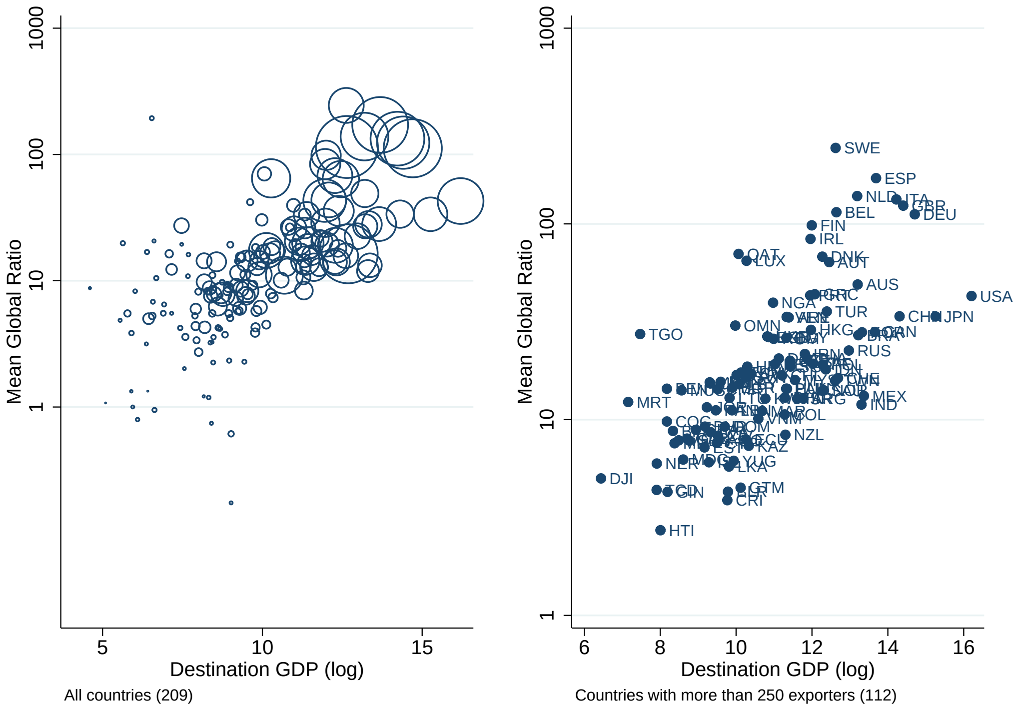

Figure 4: Mean Global Ratio and Destination Country GDP in 2003

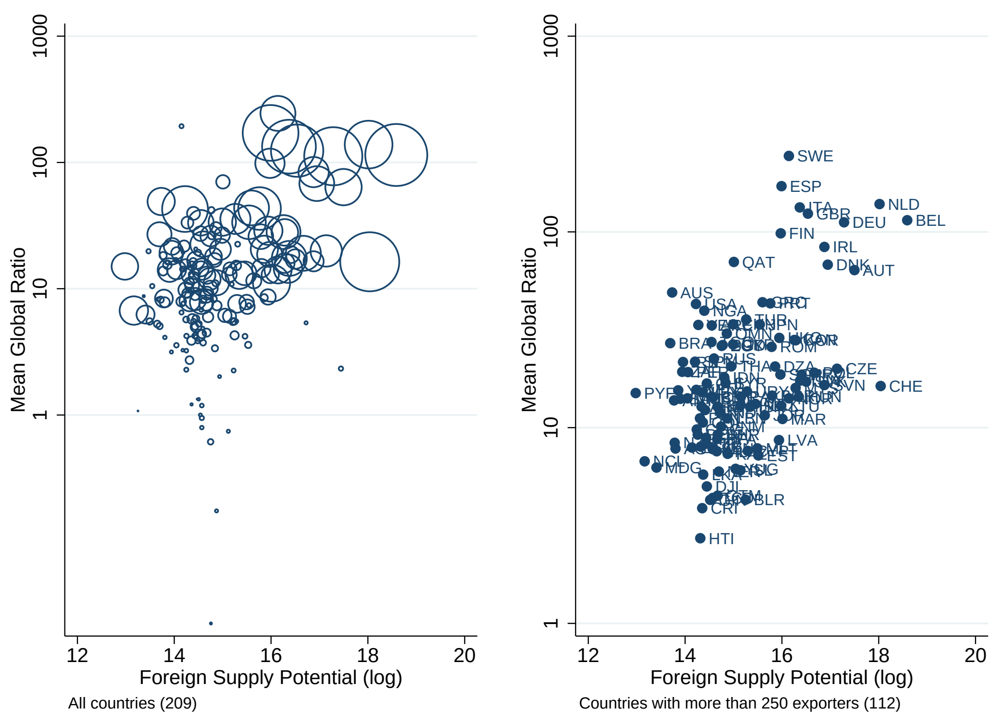

Figure 5: Mean Global Ratio and Destination Supply Potential in 2003

effects, ii) the number of clusters is quite small with respect to the size of each cluster. Harrigan and Deng (2008) experience a similar problem and use the solution proposed by Wooldridge (2006), which recommends to run country-specific random effects on firm-demeaned data, with a robust covariance matrix estimation. This procedure allows to account for firm fixed effects, as well as country-level correlation patterns in the error term. We follow this estimation strategy here.[30]

Our first set of results investigate the question of the trade and customization costs specification. The gravity literature has identified a very large set of covariates that are likely to influence both trade and customization costs, which we use here. We investigate the sensitivity of our estimates to the trade and customization costs specification in Table 2. The first three columns take global sales' ratios as a dependent variable. The last three consider local ratios. Columns (1) and (4) omit all trade costs, columns (2) and (5) include all classical gravity covariates, while columns (3) and (6) include a global freeness of trade index between France and the destination country under consideration. This index attributes weights to all trade costs components of the preceding column, those weights being drawn from the same bilateral trade equation used to derive the foreign supply potential variable. It is immediately clear that while market size influence's on sales' ratios is very stable and of the expected positive sign, the foreign supply potential coefficient is sensitive to the trade costs specification. While comparable to the GDP coefficient in columns (1) and (4), the estimate of supply potential falls drastically, and most of the time to insignificance, when trade costs are taken into account. When looking at correlations between those variables, it is easy to understand why. France is a very centrally located country in terms of worldwide economic geography.[31] Therefore, for a given destination country, ease of access from France and supply potential (which captures how centrally located the destination country is) are very strongly, and positively, correlated. For instance, log supply potential and log freeness of trade have a correlation coefficient of almost 78%. Note also that log freeness of trade and log distance have a pairwise correlation of 94%. Therefore distance from France and trade costs in general are so correlated for supply potential of the destination country that estimating those together yields very imprecise estimates. Note that those correlations would be much lower for an exporting country such as the United States or China, and it would be very interesting to see if supply potential resists better in

[30] Results available upon request are qualitatively similar using a set of different estimation procedures for our benchmark regression: firm-level fixed effects with/without country clustering, demeaned data run with simple OLS or with country random effects as in the benchmark. Results point to the fact that not taking into account country-level correlation when calculating standard errors yields a large underestimate of standard errors for both GDP and foreign supply potential, but only challenges significance for the latter variable.

[31] Using our measure of foreign supply potential, France is at rank eight out of 196 countries for which the variable is available in 2003.

such a sample. In the following tables we stick with freeness of trade as our measure of trade costs, which combines the advantages of compactness and consistency with the way supply potential is calculated, that is from a bilateral trade equation.

We now report our main results using the global sales ratio in Table 3, the local ratio in Table 4, and the overall skewness measures in Table 5. The first column uses first to second product ratio. The second column uses the ratio of the best to third best product. The next two columns return to the initial ratio (best to second best), and progressively select country destinations with income levels above a threshold. Column 3 excludes all countries below the median income level, while column 4 only selects destinations in the top 20% of the cross-country income distribution.[32] The results using the skewness statistics (standard deviation of log sales, Herfindahl, Theil) are reported in Table 5, with columns 4-5 representing the same selection by destination country income as in the previous two tables (reported for the Theil only). Since the measures of skewness in this table can be mechanically affected by the number of observations used to compute it (especially when this number of products exported by a firm to a destination is very small), we also control directly for that number in the regressions using an unreported cubic polynomial.

All three tables strongly confirm the important and significant impact of destination country size on the within-firm measure of export skewness: a French firm sells relatively more of its best performing products to bigger country destinations. This effect is also economically significant. Using the first column's estimate of Table 3, a doubling of GDP raises the sales' ratio by $(2^{(0.093)} - 1) \times 100 = 6.63\%$. The effect is roughly the same using the alternative (local) definition of the ratio. If the Czech Republic's GDP were equal to German GDP (an increase from the 79th to 99th percentile in the world's GDP distribution in 2003), then French firms would respond by increasing the relative shipment of their best global product (relative to their second best global product) by 36% (from an observed mean ratio of 20 in 2003 to 25.6).

The effect of geography, via supply potential, is overall not very significant in explaining relative exports sales based on their destination-specific ranking. This variable has an expected and significant effect in columns 1-2 in Table 4 for the local ratio. The effect on the skewness measures are also significant in similar specifications (columns 2-4). Lastly, the effect of supply potential does not have a significant impact on the global ranking. This may be due in part to higher level of noise in this measure. However, as shown in Table 2, the main issue with this variable is the

[32] Since French firms ship disproportionately more goods to countries with higher incomes, the number of observations drops very slowly with the number of excluded country destinations.

Table 2: Global ratio of core product ($m = 0$) to m' product sales' regressions

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.	Ratio of core to second product sales' regressions					
	Global ratio			Local ratio		
ln GDP	0.092***	0.083***	0.093***	0.073***	0.057***	0.078***
	(0.013)	(0.012)	(0.011)	(0.008)	(0.005)	(0.008)
ln supply potential	0.067***	-0.017	-0.000	0.080***	0.018	0.044***
	(0.016)	(0.024)	(0.019)	(0.016)	(0.016)	(0.015)
ln distance		-0.063			-0.046*	
		(0.043)			(0.023)	
contiguity		0.013			-0.108	
		(0.051)			(0.081)	
colonial link		-0.060			-0.041	
		(0.051)			(0.043)	
common language		0.023			-0.048	
		(0.050)			(0.038)	
RTA		0.066			0.004	
		(0.059)			(0.033)	
common currency		0.182***			0.336***	
		(0.047)			(0.037)	
both in GATT		0.006			-0.033	
		(0.046)			(0.026)	
ln freeness of trade			0.059***			0.026***
			(0.014)			(0.010)
Observations	56096	56096	56096	96892	96892	96892
Within R^2	0.004	0.006	0.005	0.007	0.011	0.007

Note: All columns use Wooldridge (2006) procedure: country-specific random effects on firm-demeaned data, with a robust covariance matrix estimation. Standard errors in parentheses. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3: Global ratio of core product ($m = 0$) to m' product sales' regressions

	(1)	(2)	(3)	(4)	(5)
ln GDP	0.093***	0.158***	0.087***	0.061***	0.079***
	(0.011)	(0.029)	(0.012)	(0.015)	(0.012)
ln supply potential	-0.000	0.044	-0.013	-0.031*	-0.020
	(0.019)	(0.049)	(0.019)	(0.018)	(0.021)
ln freeness of trade	0.059***	0.066*	0.065***	0.068***	0.062***
	(0.014)	(0.035)	(0.015)	(0.018)	(0.013)
ln GDP per cap					0.044**
					(0.019)
$m' =$	1	2	1	1	1
Destination GDP/cap	all	all	top 50%	top 20%	all
Observations	56096	5689	50626	40967	56096
Within R^2	0.005	0.019	0.004	0.002	0.005

Note: All columns use Wooldridge (2006) procedure: country-specific random effects on firm-demeaned data, with a robust covariance matrix estimation. Standard errors in parentheses. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Local ratio of core product ($m = 0$) to m' product sales' regressions

	(1)	(2)	(3)	(4)	(5)
ln GDP	0.078***	0.099***	0.073***	0.041**	0.065***
	(0.008)	(0.013)	(0.012)	(0.020)	(0.011)
ln supply potential	0.044***	0.052*	0.027	-0.004	0.024
	(0.015)	(0.029)	(0.020)	(0.018)	(0.016)
ln freeness of trade	0.026***	0.012	0.032**	0.044***	0.029***
	(0.010)	(0.020)	(0.016)	(0.015)	(0.010)
ln GDP per cap					0.034**
					(0.014)
$m' =$	1	2	1	1	1
Destination GDP/cap	all	all	top 50%	top 20%	all
Observations	96891	49557	84721	64666	96891
Within R^2	0.007	0.009	0.005	0.002	0.007

Note: All columns use Wooldridge (2006) procedure: country-specific random effects on firm-demeaned data, with a robust covariance matrix estimation. Standard errors in parentheses. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Theil index regressions

	(1)	(2)	(3)	(4)	(5)	(6)
ln GDP	0.140***	0.019***	0.046***	0.047***	0.035***	0.039***
	(0.011)	(0.001)	(0.002)	(0.003)	(0.006)	(0.003)
ln supply potential	0.031	0.008***	0.014***	0.009*	0.003	0.004
	(0.024)	(0.002)	(0.004)	(0.005)	(0.008)	(0.004)
ln freeness of trade	0.092***	0.008***	0.022***	0.024***	0.022**	0.023***
	(0.019)	(0.002)	(0.004)	(0.006)	(0.009)	(0.005)
ln GDP per cap						0.017***
						(0.006)
Dep. Var.	s.d. ln x	herf	theil	theil	theil	theil
Destination GDP/cap	all	all	all	top 50%	top 20%	all
Observations	82096	82096	82096	73035	57082	82096
Within R^2	0.110	0.164	0.359	0.357	0.342	0.360

Note: Firm-level fixed effects for all columns. Standard errors in parentheses. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All columns include a cubic polynomial of the number of products exported by the firm to the country

very high correlation with standard measures of trade costs for the particular case of our exporting country where distance from France and supply potential (related to economic centrality) happen to be very strongly negatively correlated.[33]

The last column in all three regression tables adds GDP per capita as an additional regressor. We do this to control for differences in preferences across countries (outside the scope of our theoretical model) tied to product quality and consumer income. In particular, we want to allow consumer income to bias consumption towards higher quality varieties. If within-firm product quality is negatively related to its distance from the core product, then this would induce a positive correlation between consumer income and the within-firm skewness of expenditure shares. Our empirical results strongly support this hypothesis.[34] Nevertheless, we still find a very strong effect of competition, now captured by the independent contribution of country population (the coefficient for log GDP, when controlling for log GDP per capita), on the skewness of within-firm export sales. Measuring the independent contribution of geography now becomes even more problematic as the same forces that generate a link between geography and increased competition are also most likely

[33] When running all regressions of Tables 3, 4, and 5 without trade freeness, supply potential is systematically positive and significant at the one percent level.

[34] Consumer income could also have an independent effect on competition, with ambiguous consequences on that skewness measure.

the same ones that are also reflected in higher GDP per capita.[35]

We now turn to the effects of bilateral trade and customization costs. All three tables show that our trade freeness measure has a strong significant and positive impact on the skewness of the firms' export sales. Interestingly, this can arise in our model through the relative force of two effects that go in opposite direction: an decrease in trade costs (τ) should decrease skewness, while an decrease in customization costs (θ) should increase it. The positive coefficient on our measure of trade freeness suggests that the second effect dominates the first.

5 Conclusion

In this paper, we have developed a model of multi-product firms that highlights how differences in market size and geography affect the within-firm distribution of export sales across destinations. This effect on the firms' product mix choice is driven by variations in the toughness of competition across markets captured by downward shifts in the distribution of markups across products. We test these predictions for a comprehensive set of French exporters, and find that market size and geography indeed have a very strong impact on their product mix choice across world destinations. In particular, French firms skew their export sales towards better performing products in big destination markets, and markets where many exporters from around the world compete (high foreign supply potential markets). We take this as a strong indication that differences in the toughness of competition across export markets generate substantial responses in firm-level markups indirectly revealed by pronounced changes in the skewness of export sales. Trade models based on exogenous markups cannot explain this strong significant link between those destination market characteristics and the within-firm skewness of export sales (after controlling for bilateral trade costs). Theoretically, this within firm change in product mix driven by the trading environment has important repercussions on firm productivity – and can explain the observed link between trade liberalization and productivity improvement within firms.

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[35] Redding and Venables (2004) and Mayer (2008) find strong empirical confirmation for this effect.

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7 Appendix A: Tougher Competition and Firm Productivity

7.1 Closed Economy

Consider a closed economy and a firm with cost $c \in [c_D \omega^M, c_D \omega^{M-1}]$ selling M products. Output per worker is given by (19). Hence we have

$$\frac{d\left(\frac{Q(c)}{C(c)}\right)}{dc_D} < 0 \text{ iff. } c\frac{\omega\left(\omega^M+1\right)}{\omega^M\left(\omega+1\right)} > \frac{c}{M}\frac{\omega\left(\omega^M-1\right)}{\omega^M\left(\omega-1\right)}$$

or, equivalently, iff

$$M > \frac{(1+\omega)\left(1-\omega^M\right)}{\left(1+\omega^M\right)(1-\omega)}$$

which is always the case for $M > 1$ as the LHS and the RHS are identical at $M = 0$ and $M = 1$, and the RHS is increasing and concave in M. This proves that, holding $M > 1$ constant, firm output per worker is larger in a market where competition is tougher.

As to the case of endogenous changes in M, the negative impact of c_D on output per worker is guaranteed by the continuity of $Q(c)/C(c)$ with respect to c_D (both $Q(c)$ and $C(c)$ are continuous in c_D since the firm produces zero units of a variety right before it is dropped when competition gets tougher). To see this, consider large downward changes in the cutoff c_D. The result for given M tells us that productivity for a firm with given c increases on all ranges of c_D where the number of varieties produced does not change. This just leaves a discrete number of c_D's where the firm changes the number of products produced. Since the productivity measure is continuous at those c_D's, and increasing everywhere else, it must be increasing everywhere.

The unavailaility of data on physical output often leads to the estimation of 'measured' rather than physical productivity. For a firm with cost $c \in [c_D \omega^M, c_D \omega^{M-1}]$ selling M products, measured productivity is defined as

$$\frac{R(c)/\bar{P}}{C(c)} = \frac{1}{2}\frac{k+2}{k+1}\frac{1}{c_D}\frac{M\left(c_D\right)^2 - c^2\omega^2\frac{\omega^{2M}-1}{\omega^{2M}(\omega-1)(\omega+1)}}{c_D c\omega\frac{\omega^M-1}{\omega^M(\omega-1)} - c^2\omega^2\frac{\omega^{2M}-1}{\omega^{2M}(\omega-1)(\omega+1)}}$$

where we have used (17) and (18). Derivation then yields

$$\frac{d\left(\frac{R(c)/\bar{P}}{C(c)}\right)}{dc_D} = -\frac{1}{2}\frac{k+2}{k+1}\frac{1+\omega^M}{1-\omega^M}\frac{M\omega^{2M}\left(1-\omega^2\right)\left(c_D\right)^2 - 2c\omega^{M+1}\left(1+\omega\right)\left(1-\omega^M\right)c_D + c^2\omega^2\left(1-\omega^{2M}\right)}{\left(c_D\right)^2\left[\omega^M\left(\omega+1\right)c_D - c\omega\left(\omega^M+1\right)\right]^2} < 0$$

where the negative sign is granted by the fact that $c \in [c_D\omega^M, c_D\omega^{M-1}]$ implies $M\omega^{2M}\left(1-\omega^2\right)\left(c/\omega^M\right)^2 - 2c\omega^{M+1}\left(1+\omega\right)\left(1-\omega^M\right)\left(c/\omega^M\right) > 0$. This proves that, holding $M > 1$ constant, also measured productivity is larger in a market where competition is tougher. The same applies in the case of endogenous changes in M as $\left[R(c)/\bar{P}\right]/C(c)$ is continuous in c_D.

Note that, in the special case of $M = 1$, we have

$$\frac{R(c)/\bar{P}}{C(c)} = \frac{1}{2}\frac{k+2}{k+1}\left(\frac{1}{c}+\frac{1}{c_D}\right)$$

Hence, whereas tougher competition (lower c_D) has no impact on the physical productivity of a single-product firm, it raises instead its measured productivity. This is due to the fact that measured productivity is also affected by markup changes when the competitive environment changes.

7.2 Open economy

Consider an open economy and a firm with cost c selling M varieties from country l to country h. Output per worker is given by (27). Inspecting (27) reveals that the sign of the impact of c_D on output per worker is determined by its impact on the last ratio on its RHS. This impact is negative whenever

$$c\tau^{lh}\frac{\left(\theta^{lh}\omega\right)\left(\left(\theta^{lh}\omega\right)^M+1\right)}{\left(\theta^{lh}\omega\right)^M\left(\left(\theta^{lh}\omega\right)+1\right)} > \frac{c\tau^{lh}}{M}\frac{\left(\theta^{lh}\omega\right)\left(\left(\theta^{lh}\omega\right)^M-1\right)}{\left(\theta^{lh}\omega\right)^M\left(\left(\theta^{lh}\omega\right)-1\right)}$$

which is again granted by

$$M > \frac{1+\theta^{lh}\omega}{1-\theta^{lh}\omega}\frac{1-\left(\theta^{lh}\omega\right)^M}{1+\left(\theta^{lh}\omega\right)^M}$$

for $M > 1$. Our definition of output per worker excludes output wasted in transit due iceberg frictions in the numerator but not the corresponding employment in the denominator. Note, however, that the impact of c_D on output per worker would be negative even if we excluded also employment wasted in transit at the denominar or included output wasted in transit also at the numerator.

As in the closed economy, the fact that ouput per worker is continuous at a discrete number of c_D^l's, and decreasing in c_D^l everywhere else, it must be increasing in c_D^l everywhere.

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