Productivity, Quality and Exporting Behavior under Minimum Quality Requirements

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Abstract

We develop a model of industry equilibrium with heterogeneous firms that explicitly incorporates quality and productivity in one framework. In our model, productivity reduces marginal costs, whereas quality shifts out demand and increases marginal and fixed costs. We propose that to export firms need to cross a threshold quality level. We examine exporting behavior of manufacturing establishments in Chile, Colombia and India and find that our model's predictions are consistent with a number of regularities in the data relating exporting status to size, capital intensity, skill intensity and output prices.

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1 Introduction

The field of international trade is witnessing a radical change in paradigm about what determines export performance. In contrast to the exclusive focus placed on variation in export behavior across sectors since the work of Ricardo, a growing new literature focuses on the variation in export behavior across firms within sectors. Among the most important theoretical results of this literature [e.g. Melitz (2003)] is the prediction that there are systematic differences between firms in productivity, size, and export status, even when the firms operate in the same sector. This prediction matches overwhelming empirical evidence showing that more productive firms are generally larger and more active in export markets [Clerides, Lach and Tybout (1998) and Bernard and Jensen (1999)]. Almost unanimously, this literature points to differences in productivity as the sole source of heterogeneity in firms' export behavior.

Despite the literature's emphasis on productivity differences, an increasingly held view is that firms' ability to produce quality is also key for explaining export success [Rauch (2006)]. Quality and productivity are intimately related. While higher productivity is typically understood to be the ability to produce the same quantity at a lower cost, it could alternatively be thought of as the ability to produce higher quality at the same cost.[1] The latter view is modeled in Verhoogen (2004), where differences in firms' the ability to produce quality is the only source of heterogeneity. In that model, as in models with standard productivity differences, more "productive" firms (those with greater ability to produce high quality) are larger, and all firms larger than a threshold size enter the export market.

Quality and productivity, however, need not be perfectly correlated. Firms producing high quality goods might have low productivity if their costs are sufficiently high while firms producing low quality goods might have high productivity if their costs are sufficiently low. Despite the absence of a one-to-one correspondence between quality and productivity, models that highlight either standard productivity or ability to produce quality as alternative sources of firm heterogeneity generate similar predictions for the relationship between (broadly-defined) productivity, size, and export status. A looming question then is whether the simultaneous presence of these two sources of heterogeneity generates qualitatively different predictions. We show in the paper that the answer to this question depends on the trading environment that is assumed. In particular, we analyze

[1] This argument is made, for example, by Melitz (2000).

trading environments without and with minimum quality requirements for exports. The first is a benchmark case. In the second case, we find theoretical predictions that, though broadly consistent with previous theoretical results, characterize more closely a number of empirical regularities that are present in the data.

The paper builds a model with two sources of heterogeneity. The first source of heterogeneity is standard; it is the ability to produce output with low marginal costs. Following the literature, we term such ability "productivity" (φ). The second source of heterogeneity is the ability to produce high quality at low cost, which we term "caliber" (ξ). High quality in the model benefits the firm by shifting out the demand for the firm's output. High quality also increases marginal costs of production and requires higher fixed costs. High caliber allows firms to produce high quality paying a relatively lower fixed cost.[2] Even though the caliber of a firm is the primary determinant of its quality choice, productivity is also important as it reduces the impact of quality on marginal costs. Therefore, both caliber and productivity increase the level of quality that is optimally chosen.

First, we solve for industry equilibrium in a closed economy. The model has two sources of heterogeneity, productivity (φ) and caliber (ξ). In the closed economy, the two can be lumped together in a single "combined productivity" parameter (η), a scalar function of the underlying productivity and caliber factors ($\eta = \eta(\varphi, \xi)$). The equilibrium and all key variables of interest (such as firm revenues and profits) can then be characterized in terms of this single parameter - although firms with different combinations of φ and ξ that result in the same η choose different quality levels. Furthermore, in the closed economy the model allows for a representation that is isomorphic to the standard (Melitz 2003) model of trade with heterogeneous firms. To survive in equilibrium, firms need to possess combined productivity above a certain cutoff level η^*.

Next, we examine the open economy. We start by considering a case in which only two obstacles constrain firms' export activity: fixed costs of exporting (f_x) and "iceberg" transport costs (τ). As was the case in the closed economy, here too the model with two sources of heterogeneity can be collapsed into a model with only one source of heterogeneity – isomorphic to Melitz' – making this case a transparent benchmark for evaluating the different implications of caliber (the ability

[2] This approach to modeling quality production captures the trade-offs in Yeaple (2005) and Bustos (2005), where the adoption of high technology involves incurring a fixed cost to lower marginal costs. Under certain assumptions on demand, the downward shift in marginal costs is isomorphic to an outward shift in the demand curve perceived by the firm.

to produce high quality) and productivity (lower marginal costs). However, this isomorphism disappears once we include more realistic features of the relationship between quality production and export behavior. In particular, we analyze the case where firms need to satisfy minimum quality requirements in order to export. Here the model with two sources of heterogeneity generates a different equilibrium with several distinct implications for the relationship between size, productivity, quality and export status.

The assumption of a minimum quality export requirement, although a major simplification, is based on a wealth of anecdotal evidence documenting firms' need to upgrade quality to enter export markets and on empirical evidence showing that exporters produce higher quality than domestic firms [Brooks (2006) and Verhoogen (2004)]. While the empirical literature emphasizes the demand for higher quality products of rich countries, several alternative explanations can motivate this assumption. First, as conjectured by Alchian and Allen (1964) and showed by Hummels and Skiba (2004), transportation costs are proportionally lower for high quality goods. The assumption of a minimum quality for export reduces this fact to the existence of a quality level below which transport costs are prohibitive. Second, low quality might lead to haggling and negotiations over defective items, which are costlier to undertake in international transactions. Firms might refrain from trading low quality goods if they anticipate a sufficiently high probability of returns. Third, some export markets directly impose minimum quality standards. Fourth, in the presence of incomplete contracts and given costs of international monitoring, high quality standards (e.g. ISO 9000) might be a way to prevent cheating on the contract, as those standards commit the firm to established procedures. It is not the purpose of the paper to identify the relative importance of these different explanations. Rather, the aim is to analyze how the predictions of standard firm-heterogeneity models are modified in a context in which minimum quality requirements are present.

Once a minimum quality constraint for exports is imposed, productivity and caliber become distinct characteristics of a firm that cannot perfectly substitute for one another. Conditional on the same value of combined productivity η (and hence size), firms with lower caliber (and hence higher productivity) are inclined to choose lower quality levels. Those firms are forced to choose between upgrading their quality to meet the requirements of the export market or instead focus on the domestic market. Therefore, firms that would have been of equal size (i.e. revenue) in the closed economy (or were so at a pre-liberalization stage) might differ in size and export status in the open economy, a prediction that departs from that in standard theoretical models where size in the closed economy is a perfect predictor of export status.[3]

Similarly, the model demonstrates that, again in contrast to the predictions of standard theoretical models, size in the open economy does not perfectly predict export status either. A firm that is large in the domestic market but does not export might have sales revenue equal to another firm that sells smaller volumes in the domestic market but is able to access foreign markets. The former is a firm with high φ and low ξ. The latter is a firm with low φ and high ξ. In the firm-level datasets for Chile, Colombia, and India that we examine, we observe that exporting behavior is not perfectly explained by firm size. This is clearly shown in Figure 1. Although the fraction of exporters is higher for larger size percentiles, there are significant number of exporters in almost all size percentiles and a significant number of non-exporters even among the largest firms.

The non-sufficiency of size for explaining export status is the central piece of our theoretical results. Conditional on size, we find that exporters sell products of higher quality. This prediction is substantially different from the prediction that exporters sell products of higher quality *unconditionally.* In the latter case, size is sufficient for explaining export status; other information (e.g. on quality levels) would be redundant. In contrast, our model predicts that conditional on size, the probability of exporting increases with quality. In addition, to the extent that higher quality products are more expensive and require a more intensive use of capital and skilled-labor, the model also predicts that, conditional on size, the probability of exporting increases with price, the capital-labor ratio and the skilled-labor share of the labor force. Those are the predictions that we take to the data.

We use firm-level data for manufacturing in three developing countries: India, Chile and Colombia. For Chile and Colombia, we have data from census surveys of all manufacturing plants that employ more than 10 workers. These datasets include information on output, inputs and exports. For India, we have a unique survey dataset covering all manufacturing plants for the year 1998. In addition to data on inputs, output and exports also available for Chile and Colombia, the India dataset includes information on price per unit of output for each of the product lines produced by

[3]In the extremes, the results of our model are standard. If the productivity (φ) and caliber (ξ) parameter realizations are both low, then the firm either exits or serves only the domestic market. If both parameters are high, then they "naturally " choose a quality level above the threshold and serve both domestic and foreign markets.

a plant.

Our analysis of the data shows that, consistent with the predictions of our model, exporters are more capital intensive, more skilled-labor intensive and charge higher prices even after controlling for size, a reflection of the fact that they produce higher quality goods. These results imply that quality has significant explanatory power, in addition to size, for explaining export status. The findings are remarkably consistent across countries.

The rest of the paper is organized as follows. Section 2 describes our theoretical model. Section 3 describes the data. Section 4 presents our empirical results. Section 5 concludes.

2 Productivity and quality in a two-factor heterogenous-firm model

This section develops a two-factor heterogenous-firm model of industry equilibrium. In Section 2.1, we characterize the equilibrium in a closed economy. In Section 2.2.1, we examine the case of an open economy with no quality constrains on exports. In both of these cases, we show that the model can be collapsed to a model with only one source of heterogeneity. Finally, in Section 2.2.2, we consider the case in which exports require the attainment of minimum quality levels.

2.1 The Closed Economy

The model is developed in partial equilibrium. We assume a monopolistic competition framework with constant-elasticity-of-substitution (CES) demand. The demand system here is augmented to account for product quality variation across varieties (as in Hallak and Schott 2005):

$$D_j = \frac{p_j^{-\sigma} \lambda_j^{\sigma-1}}{(P')^{1-\sigma}} E \tag{1}$$

where j indexes products, and p_j and λ_j are, respectively, the price and quality of product j. We assume that each firm produces only one product; therefore, j also indexes firms. Finally, E is the (exogenously given) level of expenditure and

$$P' = \left[\int_j p_j^{1-\sigma} \lambda_j^{\sigma-1} dj \right]^{\frac{1}{1-\sigma}}$$

is a cost-of-utility price index. For notational simplicity, we define $P = (P')^{1-\sigma}$. [4]

Product quality is modelled here as a demand shifter. It captures all attributes of a product – other than price – that consumers value. This demand system solves a consumer maximization problem with a Dixit-Stiglitz utility function defined in terms of quality-adjusted units of consumption, $\widetilde{q}_j = q_j \lambda_j$, and quality adjusted prices $\widetilde{p}_j = \frac{p_j}{\lambda_j}$. Thus, firm revenues, $r_j = p_j q_j = \widetilde{p}_j \widetilde{q}_j$, can be expressed as

$$r_j = \frac{\widetilde{p}_j^{\,1-\sigma}}{P} E. \tag{2}$$

There are two sources of firm heterogeneity. Following standard models (Melitz 2003, Bernard et al. 2003), a first source of heterogeneity is "productivity" (φ). Productivity indexes firms' ability to produce output with low marginal costs. In addition, we introduce a second source of heterogeneity, which we denote "caliber" (ξ). Caliber indexes firms' ability to develop a high quality product paying a low fixed cost. We follow Shaked and Sutton (1983) in assuming that attaining higher quality levels requires paying higher fixed costs.[5]

Marginal costs are assumed to be constant in the scale of production. They are also increasing in the quality (λ) of the product and decreasing in the productivity (φ) of the firm. Marginal costs are given by

$$c(\lambda, \varphi) = \frac{c}{\varphi} \lambda^{\beta} \tag{3}$$

where c is a constant parameter. Fixed costs are increasing in the quality (λ) of the product and decreasing in the caliber (ξ) of the firm. They are given by

$$F(\lambda, \xi) = \frac{f}{\xi} \lambda^{\alpha} + F \tag{4}$$

where f is a constant parameter and F is a fixed cost of plant operation.

[4] It is important to keep in mind for the remainder of the paper that, since $\sigma > 1$, P is inversely related to the price index. Therefore, higher P implies lower (average) prices.

[5] Verhoogen (2004) also considers heterogeneity in the ability to produce higher quality, but this heterogeneity only affects variable costs. As a result, this source of heterogeneity plays essentially the same role as typical productivity heterogeneity (except for the fact that quality has a differential impact on demand according to importer per-capita income).

2.1.1 Firm's optimal choice of price and quality

Firms choose price and quality to maximize profits, which are given by

$$\Pi\left(\varphi,\xi\right)=D(p-c(\lambda))-F(\lambda)=p^{-\sigma}\lambda^{\sigma-1}\frac{E}{P}\left(p-\frac{c}{\varphi}\lambda^{\beta}\right)-\frac{f}{\xi}\lambda^{\alpha}-F.$$

The first order condition with respect to price yields the standard CES result of a constant mark-up over marginal cost:

$$p=\frac{\sigma}{\sigma-1}c(\lambda)=\frac{\sigma}{\sigma-1}\frac{c}{\varphi}\lambda^{\beta}. \tag{5}$$

Using this result and the first order condition with respect to quality yields:

$$\lambda(\varphi,\xi)=\left[\frac{1-\beta}{\alpha}\frac{\xi}{f}\left(\frac{\sigma-1}{\sigma}\right)^{\sigma}\left(\frac{\varphi}{c}\right)^{\sigma-1}\frac{E}{P}\right]^{\frac{1}{\alpha'}} \tag{6}$$

where $\alpha'=\alpha-(1-\beta)(\sigma-1)$. To ensure that the first order conditions identify a maximum, we need to impose two restrictions on parameter values. First, we assume that $0<\beta<1$, so that marginal costs are increasing in quality but not excessively fast. Second, we assume that $\alpha'>0$, so that fixed costs grow fast enough with quality. Equation (6) indicates that both caliber (ξ) and productivity (φ) have a positive effect on quality choice; caliber and productivity reduce, respectively, the fixed costs and marginal costs of producing quality.

Substituting the result for λ into the solution for price in equation (5) results in:

$$p(\varphi,\xi)=\left(\frac{\sigma}{\sigma-1}\right)^{\frac{\alpha-\beta-(\sigma-1)}{\alpha'}}\left(\frac{c}{\varphi}\right)^{\frac{\alpha-(\sigma-1)}{\alpha'}}\left[\frac{1-\beta}{\alpha}\frac{\xi}{f}\frac{E}{P}\right]^{\frac{\beta}{\alpha'}}. \tag{7}$$

Equation (7) shows that high caliber firms sell their products at a higher price, as they produce higher quality. The effect of productivity on price, however, is ambiguous, depending on the sign of the term $\alpha-(\sigma-1)$. On the one hand, higher productivity induces lower prices conditional on quality, as in all standard models. On the other hand, higher productivity induces higher quality, which in turn increases production costs and prices. Whether one or the other effect dominates depends on parameter values. It is interesting to note that, as opposed to models with only one source of heterogeneity, productivity and prices here do not display a monotonic relationship. Since prices depend on the values of two parameters, the correlation between productivity and prices observed in the data will depend on the correlation between the productivity and caliber draws.

2.1.2 The cut-off function

We can substitute the solutions for quality and price in equations (6) and (7), respectively, into the expression for revenues (2) to obtain:

$$r(\varphi, \xi) = \left(\frac{\sigma - 1}{\sigma}\right)^{\frac{(\alpha\sigma - \alpha')}{\alpha'}} \left(\frac{E}{P}\right)^{\frac{\alpha}{\alpha'}} \left(\frac{\varphi}{c}\right)^{\frac{\alpha(\sigma-1)}{\alpha'}} \left[\frac{1-\beta}{\alpha}\frac{\xi}{f}\right]^{\frac{\alpha-\alpha'}{\alpha'}}. \tag{8}$$

Revenues increase with both productivity (φ) and caliber (ξ). As with price, the relationship between revenues and any one of these variables alone is not necessarily monotonic. A convenient way of summarizing information about the two heterogeneity draws is to define a firm's "combined" productivity η as

$$\eta(\varphi, \xi) = \left[\varphi^{\frac{\alpha}{\alpha'}} \xi^{\frac{1-\beta}{\alpha'}}\right]^{\sigma-1}.$$

Revenues can then be expressed as a function of η:

$$r(\varphi, \xi) = \eta(\varphi, \xi) \left(\frac{\sigma - 1}{\sigma}\right)^{\frac{-(\alpha\sigma - \alpha')}{\alpha'}} \left(\frac{E}{P}\right)^{\frac{\alpha}{\alpha'}} \left(\frac{1}{c}\right)^{\frac{\alpha(\sigma-1)}{\alpha'}} \left[\frac{1-\beta}{\alpha f}\right]^{\frac{\alpha-\alpha'}{\alpha'}}. \tag{9}$$

Relative revenues (size) between any two firms i and j is given by the ratio of their combined productivities: $\frac{r_i}{r_j} = \frac{\eta_i}{\eta_j}$. From standard results of CES demand, we know that operative profits equal $\frac{r}{\sigma}$. Therefore, $\Pi(\varphi, \xi) = \frac{1}{\sigma} r(\varphi, \xi) - F(\xi, \lambda)$. Using this expression and the expression for revenues in equation (8) we obtain firm profits:

$$\Pi(\varphi, \xi) = J \left(\frac{\varphi}{c}\right)^{\frac{\alpha(\sigma-1)}{\alpha'}} \left(\frac{\xi}{f}\right)^{\frac{\alpha-\alpha'}{\alpha'}} \left(\frac{E}{P}\right)^{\frac{\alpha}{\alpha'}} - F \tag{10}$$

where $J = \left(\frac{\sigma-1}{\sigma}\right)^{\frac{\alpha\sigma}{\alpha'}} \left(\frac{1-\beta}{\alpha}\right)^{\frac{\alpha}{\alpha'}} \left(\frac{\alpha'}{\alpha-\alpha'}\right)$.

Profits, as revenues, increase with productivity and caliber and can also be written as a function of η:

$$\Pi(\varphi, \xi) = \eta(\varphi, \xi) J \left(\frac{1}{c}\right)^{\frac{\alpha(\sigma-1)}{\alpha'}} \left(\frac{1}{f}\right)^{\frac{\alpha-\alpha'}{\alpha'}} \left(\frac{E}{P}\right)^{\frac{\alpha}{\alpha'}} - F. \tag{11}$$

Since combined productivity η is a summary statistic for both revenues and profits, it follows that in a graph on φ–ξ space, iso-revenue curves coincide with iso-profit curves.

Firms remain in the market only if they can make non-negative profits, given their productivity and caliber draws. Since profits depend on these two sources of heterogeneity, this condition results in a cut-off function, $\underline{\xi}(\varphi)$; for each productivity level, there is a minimum caliber that allows a firm to make non-negative profits. The cut-off function is easy to derive by equating (10) to zero:

$$\begin{aligned} \Pi(\varphi,\xi) &= 0 \implies \\ \underline{\xi}\left(\varphi\right) &= f\left(\frac{F}{J}\right)^{\frac{\alpha'}{\alpha-\alpha'}}\left(\frac{\varphi}{c}\right)^{\frac{-\alpha}{1-\beta}}\left(\frac{E}{P}\right)^{\frac{-\alpha}{\alpha-\alpha'}}. \end{aligned} \tag{12}$$

The most important feature of (12) is that $\underline{\xi}(\varphi)$ is a negative function of φ. Therefore, more productive firms can afford to be of lower caliber (and vice versa). This negative relationship is easy to understand as an implication of the fact that combined productivity η is a summary statistic for the effect of the two heterogeneity factors on profits. In fact, given this property, the model can be collapsed into a one-factor model, isomorphic to Melitz', where a single productivity draw determines entry-exit decisions: firms stay iff η is above a cut-off value $\underline{\eta}$, determined by equating (11) to zero.

The solutions for price, quality, revenues, profits, and cut-off function all depend on P, which is an endogenous variable. To complete the characterization of the equilibrium, we need to determine P using the free-entry condition.

2.1.3 The price index and the free-entry condition

Before entering, firms do not know their productivity or caliber. They have to pay a fixed entry cost of $f_e > 0$ to learn them. Once they pay this cost, they draw φ and ξ from a bivariate probability distribution with density $v\left(\varphi,\xi\right)$. Denote the probability of surviving by P_{in}. This probability is given by

$$P_{in} = \int_0^\infty \int_{\underline{\xi}(\varphi)}^\infty v\left(\varphi,\xi\right) d\xi d\varphi \tag{13}$$

The joint distribution of φ and ξ conditional on surviving can then be characterized by the density function

$$h(\phi,\xi) = \begin{cases} \dfrac{1}{P_{in}} v(\varphi,\xi) & \text{if } \ \xi > \underline{\xi}(\varphi) \\ \\ 0 & \text{otherwise} \end{cases} \tag{14}$$

Denoting by M the mass of surviving firms, we can now rewrite P as the aggregation across productivity and (surviving) caliber levels instead of across firms:

$$P=\int\limits_{j} p_j^{1-\sigma}\lambda_j^{\sigma-1}dj = M\int\limits_{\varphi}\int\limits_{\underline{\xi}(\varphi)} r\left(\varphi,\xi\right)\left(\frac{E}{P}\right)^{-1}h\left(\varphi,\xi\right)d\xi d\varphi.$$

Using (8) to substitute for revenues, and solving for P, we obtain:

$$\begin{aligned} P &= M^{\frac{\alpha'}{\alpha}}\left(\frac{\sigma-1}{\sigma}\right)^{\frac{\alpha\sigma-\alpha'}{\alpha}}\left(\frac{1-\beta}{\alpha}\frac{E}{f}\right)^{\frac{\alpha-\alpha'}{\alpha}}\left(\frac{1}{c}\right)^{\sigma-1}\left[\int\limits_{\varphi}\int\limits_{\underline{\xi}(\varphi)}\varphi^{\frac{(\sigma-1)\alpha}{\alpha'}}\xi^{\frac{\alpha-\alpha'}{\alpha'}}h\left(\varphi,\xi\right)d\xi d\varphi\right]^{\frac{\alpha'}{\alpha}} \\ &= M^{\frac{\alpha'}{\alpha}}\left(\frac{\sigma-1}{\sigma}\right)^{\frac{\alpha\sigma-\alpha'}{\alpha}}\left(\frac{1-\beta}{\alpha}\frac{E}{f}\right)^{\frac{\alpha-\alpha'}{\alpha}}\left(\frac{1}{c}\right)^{\sigma-1}\left(\widetilde{\eta}\right)^{\frac{\alpha'}{\alpha}} \end{aligned} \tag{15}$$

where

$$\widetilde{\eta}\equiv\int\limits_{\varphi}\int\limits_{\underline{\xi}(\varphi)}\eta(\varphi,\xi)h\left(\varphi,\xi\right)d\xi d\varphi \tag{16}$$

is the (weighted) average combined productivity of surviving firms.

There is free entry into the market. Firms choose to pay the fixed cost f_e and learn their productivity and caliber only if the expected profits are greater or equal than the entry cost. Expected profits $\overline{\Pi}$ are given by

$$\overline{\Pi}=\int\limits_{\varphi}\int\limits_{\xi}\Pi\left(\varphi,\xi\right)v\left(\varphi,\xi\right)d\xi d\varphi = P_{in}\int\limits_{\varphi}\int\limits_{\underline{\xi}(\varphi)}\Pi\left(\varphi,\xi\right)h\left(\varphi,\xi\right)d\xi d\varphi \tag{17}$$

where the last equality uses equation (14) and the fact that firms with $\xi<\underline{\xi}\left(\varphi\right)$ earn zero profits. The free-entry condition imposes $\overline{\Pi}=f_e$. Using (10), (15), and (17), we obtain:

$$M=\left(\frac{P_{in}E}{f_e+P_{in}F}\right)\left(\frac{\alpha'}{\alpha\sigma}\right). \tag{18}$$

The free-entry condition determines the mass of entrants as an increasing function of P_{in}. The intuition is simple. Since expected profits have to equal the exogenously given f_e, the easier it is to survive (higher P_{in}) the larger will be the mass of entrants, so that the competition effect of entry exactly cancels out with the higher survival rate.

Finally, we can substitute (18) into (15), divide both sides by P and elevate them to the power of $\frac{\alpha}{\alpha'}$ to obtain

$$1=\left(\frac{\widehat{\eta}/P^{\frac{\alpha}{\alpha'}}}{f_e+P_{in}F}\right)B^{\frac{\alpha}{\alpha'}} \tag{19}$$

where $B = J^{\frac{\alpha'}{\alpha}} E \left(\frac{1}{f}\right)^{\frac{\alpha-\alpha'}{\alpha}} \left(\frac{1}{c}\right)^{\sigma-1}$ and

$$\widehat{\eta} \equiv P_{in}\widetilde{\eta} = \int\limits_{\varphi} \int\limits_{\underline{\xi}(\varphi)} \eta(\varphi,\xi) v\left(\varphi,\xi\right) d\xi d\varphi. \tag{20}$$

The cut-off condition (12) and the free-entry condition (19) form a system in P and $\underline{\xi}\left(\varphi\right)$. We cannot solve this system in closed form unless we assume a particular shape of the bivariate distribution. However, we can prove that there exists a solution and that it is unique.

Proposition 1. In the closed economy, an equilibrium exists and it is unique.

Proof. See Appendix.

2.2 The Open Economy

This section analyzes the open-economy equilibrium. First, we follow standard firm-heterogeneity models by assuming that exporting requires paying iceberg transport cost τ and fixed exporting cost f_x. Then, we introduce a minimum quality requirement for export and characterize the cross-section of firms in equilibrium. We also consider how differences in the distributions of productivity and caliber across countries affect the benefits of opening up an economy to trade.[6]

2.2.1 Unconstrained export quality

For a firm that exports, we define total demand D^w as the sum of domestic and foreign demand:[7]

$$D^w = D + D^* = p^{-\sigma}\lambda^{\sigma-1}\left[\frac{E}{P} + \tau^{-\sigma}\frac{E^*}{P^*}\right].$$

The maximization problem of an exporting firm is analogous to the problem of a firm in the closed economy except for the fact that $\frac{E}{P} + \tau^{-\sigma}\frac{E^*}{P^*}$ is their relevant market size. For a firm that exports, optimal quality is then given by

$$\lambda_u(\varphi,\xi) = \left[\frac{1-\beta}{\alpha}\frac{\xi}{f}\left(\frac{\sigma-1}{\sigma}\right)^{\sigma}\left(\frac{\varphi}{c}\right)^{\sigma-1}\left(\frac{E}{P} + \tau^{-\sigma}\frac{E^*}{P^*}\right)\right]^{\frac{1}{\alpha'}} \tag{21}$$

[6]We do not include this part in the paper because it is not completed yet.

[7]Foreign variables are denoted with an asterisk.

while profits are given by

$$\Pi_{x.u}(\varphi,\xi) = J\left(\frac{\varphi}{c}\right)^{\frac{\alpha(\sigma-1)}{\alpha'}}\left(\frac{\xi}{f}\right)^{\frac{\alpha-\alpha'}{\alpha'}}\left(\frac{E}{P}+\tau^{-\sigma}\frac{E^*}{P^*}\right)^{\frac{\alpha}{\alpha'}} - F - f_x \tag{22}$$

$$= \eta(\varphi,\xi)J\left(\frac{1}{c}\right)^{\frac{\alpha(\sigma-1)}{\alpha'}}\left(\frac{1}{f}\right)^{\frac{\alpha-\alpha'}{\alpha'}}\left(\frac{E}{P}+\tau^{-\sigma}\frac{E^*}{P^*}\right)^{\frac{\alpha}{\alpha'}} - F - f_x \tag{23}$$

where the subindex "$x.u$" refers to an exporting firm in the unconstrained equilibrium. A firm that chooses not to export but remains active in the domestic market has profits given by equation (10). For expositional clarity, we now denote those profits by Π_d. Finally, denote by $\Delta_u(\varphi,\xi)$ the difference in profits between exporting and not exporting. Using (11) and (22), we obtain

$$\begin{aligned}\Delta_u(\varphi,\xi) &= \Pi_{x.u}(\varphi,\xi) - \Pi_d(\varphi,\xi) \\ &= \eta(\varphi,\xi)JA\left(\frac{1}{c}\right)^{\frac{\alpha(\sigma-1)}{\alpha'}}\left(\frac{1}{f}\right)^{\frac{\alpha-\alpha'}{\alpha'}} - f_x\end{aligned} \tag{24}$$

where $A = \left[\left(\frac{E}{P}+\tau^{-\sigma}\frac{E^*}{P^*}\right)^{\frac{\alpha}{\alpha'}} - \left(\frac{E}{P}\right)^{\frac{\alpha}{\alpha'}}\right]$. Firms choose to export if $\Pi_{x.u}(\varphi,\xi) > \Pi_d(\varphi,\xi)$, i.e. if $\Delta_u(\varphi,\xi) \geq 0$ (indifferent firms are assumed to export). The function $\Delta_u(\varphi,\xi)$ is increasing in η, which in turn is increasing in both of its arguments, φ and ξ. This implies that a firm will export if its caliber is above a threshold value

$$\underline{\xi}_{x.u}(\varphi) = \frac{f_x}{JA}^{\frac{\alpha'}{\alpha-\alpha'}} f\left(\frac{\varphi}{c}\right)^{-\frac{\alpha(\sigma-1)}{\alpha-\alpha'}}, \tag{25}$$

determined by setting $\Delta_u(\varphi,\xi) = 0$ and solving for ξ.

As in Melitz (2003), there are two possible scenarios. Either all surviving firms export or there is a subset of them who do not enter the foreign market. Whether one or the other scenario prevails can be determined by evaluating the profits that cut-off firms – those located on the curve $\underline{\xi}(\varphi)$ – would make if they exported. If cut-off firms make negative profits by entering foreign markets ($\Pi_{x.u}(\varphi, \underline{\xi}(\varphi) < 0$), they will prefer to be active only domestically. Therefore, a non-empty subset of non-exporting survivors will exist iff

$$f_x > \frac{FA}{\left(\frac{E}{P}\right)^{\frac{\alpha}{\alpha'}}}, \tag{26}$$

which we assume holds for the remainder of the paper. This assumption then implies that $\underline{\xi}_{x.u}(\varphi) > \underline{\xi}(\varphi)$.

Combined productivity η is a summary statistic for profits and revenues, both for exporters and for non-exporters. Thus, firms with the same η have identical profits and revenues regardless of their particular realizations of φ and ξ. This property has several implications, which are shared by most trade models of firm heterogeneity. First, firm size perfectly explains export status. In particular, there is a cut-off size such that all firms larger (smaller) than the cut-off size are exporters (non-exporters). Second, since η summarizes all relevant information determining relative size (revenue) both before and after trade, the ranking of firms by size is invariant to trade regime. In addition, the relative size of any two exporters or any two non-exporters is not affected by trade liberalization; only the relative size between exporters and non-exporters changes.

Since both exporter and non-exporter profits depend only on η, the function $\Delta_u(\varphi, \xi)$ also depends on the value of this variable alone. This implies that the value of η that defines the function $\underline{\xi}_{x.u}(\varphi)$ is also an iso-profit curve.[8] Even though exporters with the same combined productivity η have equal size and profits, the quality that they produce is not identical. Equating $\Pi_{x.u}(\varphi, \xi)$ to any constant, solving for $\xi^c(\varphi)$ (superscript c denotes the level of the iso-profit curve) and substituting into equation (21), we obtain:

$$\lambda_u(\varphi, \xi^c(\varphi)) = B\left(\frac{\varphi}{c}\right)^{-\frac{\sigma-1}{\alpha-\alpha'}} \tag{27}$$

where B is a function of constant parameters. Equation (27) shows that, along any iso-profit curve (including $\underline{\xi}_{x.u}(\varphi)$), quality is decreasing in φ.[9]

In the equilibrium with no export quality requirements, the composition of η in terms of φ and ξ is relevant as a determinant of prices and quality choice. However, it is only η that matters as a determinant of firm size, profits and export status; the two heterogeneity factors' influence on those outcomes operates only through η. As a result, this benchmark model of the open economy can also be collapsed into a model isomorphic to Melitz'. Figure 2 shows the equilibrium configuration of firms. Firms with productivity values below the cut-off function $\underline{\xi}(\varphi)$ (those with η below the cut-off combined productivity $\underline{\eta}$) exit the market. Firms with productivity values between this function and the export cut-off function $\underline{\xi}_{x.u}(\varphi)$ (those with η between the two relevant cut-off values) sell in the domestic market but do not export. Finally, firms with productivity draws above

[8] It is easy to show that firms located on this curve earn strictly positive profits: substitute (25) into (22) to find that $\Pi_{x.u}(\varphi, \underline{\xi}_{x.u}(\varphi)) > 0$.

[9] The property that quality is decreasing with φ along an iso-profit curve is also true for non-exporters, both in the open-economy and in the closed-economy case.

$\underline{\xi}_{x.u}(\varphi)$ are active in the export market.

2.2.2 Constrained export quality

Firm-level evidence in developing countries suggests that exporters produce higher quality products than non-exporters (e.g. Brooks 2006 and Verhoogen 2004). The standard explanation for this regularity is that the largest export markets are countries with high income levels, which demand higher quality. However, a number of other factors, in addition to income differences between domestic and foreign markets, can explain the regularity. First, as conjectured by Alchian and Allen (1964), transportation costs could be lower for higher quality goods. Second, low quality could lead to haggling and negotiations over defective items, which are costlier to undertake in international transactions. Third, some export markets might impose minimum quality standards. Fourth, in the presence of incomplete contracts and given the costs of international monitoring, high quality standards (e.g. ISO 9000) might be a way to prevent cheating on the contract. For some or all of these reasons, quality for export may be higher than quality for the domestic markets. If these factors – instead of income differences – are important, the finding that quality for export is higher than quality for the domestic market would be true not only for developing countries but also for developed countries, even when they export to developing countries.

In our model, we capture the idea that quality for export is higher than quality for the domestic market in a simple manner by assuming that a firm has to attain a minimum quality $\underline{\lambda}$ to be able to export. Therefore, compared to the unconstrained export quality equilibrium, the requirement of a minimum quality forces firms who would otherwise export with quality $\lambda_u < \underline{\lambda}$ to choose between upgrading their quality (relative to their unconstrained choice) or otherwise not participating in the export market. As a result, the unconstrained export cut-off function $\underline{\xi}_{x.u}(\varphi)$ derived in the previous section is no longer relevant.

We now characterize the export cut-off function in the constrained environment, which we denote by $\underline{\xi}_x(\varphi)$. First, we focus on firms located along $\underline{\xi}_{x.u}(\varphi)$, those that in the unconstrained environment are indifferent between exporting and not exporting. Since unconstrained quality is decreasing in φ along $\underline{\xi}_{x.u}(\varphi)$, there exists a threshold productivity value φ^*_λ such that $\lambda_u(\varphi, \underline{\xi}_{x.u}(\varphi)) \geq \underline{\lambda}$ for $\forall \varphi \leq \varphi^*_\lambda$. For those values of φ, firms that would export in the unconstrained environment will also export in the constrained environment, as their unconstrained optimal choice of quality is above the minimum export requirement. Thus $\underline{\xi}_{x.u}(\varphi) = \underline{\xi}_x(\varphi)$ for $\varphi \leq \varphi^*_\lambda$. Using (21) and (25), we can solve $\lambda_u(\varphi, \underline{\xi}_{x.u}(\varphi)) = \underline{\lambda}$ for φ^*_λ to find:

$$\varphi^*_\lambda = c\underline{\lambda}^{-\frac{\alpha-\alpha'}{(\sigma-1)}} \left[\frac{1-\beta}{\alpha}\left(\frac{E}{P} + \tau^{-\sigma}\frac{E^*}{P^*}\right)\right]^{\frac{\alpha-\alpha'}{(\sigma-1)\alpha'}} \left(\frac{f_x}{AJ}\right)^{\frac{1}{(\sigma-1)}} \left(\frac{\sigma-1}{\sigma}\right)^{\frac{\sigma(\alpha-\alpha')}{(\sigma-1)\alpha'}}. \tag{28}$$

In contrast, the quality choice of firms with $\varphi > \varphi^*_\lambda$ in the unconstrained environment is below the minimum threshold ($\lambda_u(\varphi, \underline{\xi}_{x.u}(\varphi)) < \underline{\lambda}$). In order to export, these firms need to upgrade their quality. Since they were indifferent between exporting and not exporting in the unconstrained environment, while exporting now requires deviating from their optimal choice, these firms will strictly prefer not to export. Therefore, we can establish that $\underline{\xi}_x(\varphi) > \underline{\xi}_{x.u}(\varphi)$ for all firms with $\varphi > \varphi^*_\lambda$.

Among exporters with $\varphi > \varphi^*_\lambda$, not all of them are forced to upgrade their unconstrained choice of quality. In fact, firms with sufficiently high ξ will spontaneously choose quality levels above $\underline{\lambda}$. Denote by $\underline{\xi}_{x\underline{\lambda}}(\varphi)$ the threshold function above which firms spontaneously choose quality higher than $\underline{\lambda}$. This function is an "unconstrained" iso-quality curve; i.e. it represents the locus of points on the (φ, ξ) plane on which firms choose the same quality level ($\underline{\lambda}$). We can obtain this function by equating (21) to $\underline{\lambda}$ and solving for ξ, which results in

$$\underline{\xi}_{x\underline{\lambda}}(\varphi) = \underline{\lambda}^{\alpha'} f \frac{\alpha}{1-\beta}\left(\frac{\sigma-1}{\sigma}\right)^{-\sigma}\left(\frac{\varphi}{c}\right)^{-(\sigma-1)}\left(\frac{E}{P} + \tau^{-\sigma}\frac{E^*}{P^*}\right)^{-1}. \tag{29}$$

Using the fact that $\underline{\lambda} > \lambda\left(\varphi, \underline{\xi}_{x.u}(\varphi)\right)$ when $\varphi > \varphi^*_\lambda$ in equation (29), it is easy to show that $\underline{\xi}_{x\underline{\lambda}}(\varphi) > \underline{\xi}_{x.u}(\varphi)$ when $\varphi > \varphi^*_\lambda$ (note also that $\underline{\xi}_{x.u}(\varphi^*_\lambda) = \underline{\xi}_{x\underline{\lambda}}(\varphi^*_\lambda)$).

Define the difference in profits between exporting and not exporting in the constrained environment as $\Delta(\varphi, \xi) = \Pi_x(\varphi, \xi) - \Pi_d(\varphi, \xi)$. Then the locus of firms that are indifferent between exporting and not exporting, $\underline{\xi}_x(\varphi)$, is defined implicitly by the equation $\Delta(\phi, \underline{\xi}_x(\varphi)) = 0$. For firms with $\varphi > \varphi^*_\lambda$ and $\xi(\varphi) > \underline{\xi}_{x\underline{\lambda}}(\varphi^*_\lambda)$, $\Delta_u = \Delta$, as $\Pi_{x.u}(\varphi, \xi) = \Pi_x(\varphi, \xi)$. Since we found in equation (24) that Δ_u is an increasing function of both φ and ξ, $\Delta(\varphi, \underline{\xi}_{x\underline{\lambda}}(\varphi)) = \Delta_u(\varphi, \underline{\xi}_{x\underline{\lambda}}(\varphi)) > \Delta_u(\varphi, \underline{\xi}_{x.u}(\varphi)) = 0$. This implies that firms along $\underline{\xi}_{x\underline{\lambda}}(\varphi)$ strictly prefer to be exporters. Hence, firms that are indifferent between exporting and not exporting must have $\xi(\varphi) < \underline{\xi}_{x\underline{\lambda}}(\varphi)$. Combining this result with the result of the previous paragraph, we have that $\underline{\xi}_{x.u}(\varphi) < \underline{\xi}_x(\varphi) < \underline{\xi}_{x\underline{\lambda}}(\varphi)$.

The export cut-off function $\underline{\xi}_x(\varphi)$ cannot be solved in closed form. To characterize this function in implicit form we first need to derive the profit function for firms that upgrade their quality to export ($\Pi_{x\underline{\lambda}}$). These firms are forced to match the minimum export quality. Therefore, their price, demand, revenue and profits are, respectively,

$$\begin{aligned}
p &= \frac{\sigma}{\sigma-1}\frac{c}{\varphi}\underline{\lambda}^{\beta} \\
D &= p^{-\sigma}\underline{\lambda}^{\sigma-1}\left(\frac{E}{P}+\tau^{-\sigma}\frac{E^*}{P^*}\right) \\
r &= \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}\left(\frac{c}{\varphi}\right)^{1-\sigma}\underline{\lambda}^{\alpha-\alpha\prime}\left(\frac{E}{P}+\tau^{-\sigma}\frac{E^*}{P^*}\right) \\
\Pi_{x\underline{\lambda}} &= \frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}\left(\frac{c}{\varphi}\right)^{1-\sigma}\underline{\lambda}^{\alpha-\alpha\prime}\left(\frac{E}{P}+\tau^{-\sigma}\frac{E^*}{P^*}\right)-\frac{f}{\xi}\underline{\lambda}^{\alpha}-f_x-F
\end{aligned}$$

Accordingly, the difference in profits between exporting and not exporting is given by:

$$\begin{aligned}
\Delta &= \Pi_{x\underline{\lambda}}-\Pi_d=\frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}\left(\frac{c}{\varphi}\right)^{1-\sigma}\underline{\lambda}^{\alpha-\alpha\prime}\left(\frac{E}{P}+\tau^{-\sigma}\frac{E^*}{P^*}\right)-\frac{f}{\xi}\underline{\lambda}^{\alpha}-f_x \\
&\quad -J\left(\frac{\varphi}{c}\right)^{\frac{\alpha(\sigma-1)}{\alpha'}}\left(\frac{\xi}{f}\right)^{\frac{\alpha-\alpha'}{\alpha'}}\left(\frac{E}{P}\right)^{\frac{\alpha}{\alpha'}}
\end{aligned}$$

It can be shown that $\frac{\partial\Delta}{\partial\varphi}>0$ and that $\frac{\partial\Delta}{\partial\xi}>0$. Therefore, applying the implicit function theorem to $\Delta(\varphi,\xi)=0$, we find that $\frac{\Delta\underline{\xi}_x(\varphi)}{d\varphi}<0$.

The characterization of the equilibrium can be seen in Figure 3. The export cutoff function in the constrained regime $\underline{\xi}_x(\varphi)$ coincides with the export cutoff function in the unconstrained regime $\underline{\xi}_{x.u}(\varphi)$ for all values of $\varphi\leq\varphi^*_{\lambda}$. For $\varphi>\varphi^*_{\lambda}$, $\underline{\xi}_{x.u}(\varphi)$ plays a role only as a reference locus. Thus, it is represented by a dotted line. Another reference locus (also represented by a dotted line) is the threshold iso-quality curve $\underline{\xi}_{x\underline{\lambda}}(\varphi)$. As shown previously, the relevant export cut-off function $\underline{\xi}_x(\varphi)$ (represented by a solid line) lies between those two curves. Firms in region I do not survive. Firms in region II only sell in the domestic market. Firms in region III also sell only in the domestic market but they would be exporters in the absence of the minimum quality requirement. Firms in region IV export by producing the minimum export quality $\underline{\lambda}$, which is above their optimal choice in the unconstrained environment. Firms in region V export without being forced to change their optimal quality choice.

The requirement of a minimum export quality breaks the sufficiency of η to explain size rankings and export status, both of which now depend on the particular combinations of φ and ξ. This implies that the monotonic relationship between size and export status is also broken. As opposed to the predictions of models with only one source of heterogeneity, the export status of firms with the same size might be different. In particular, we now prove that:

Proposition 1. *Conditional on size (total revenue), expected quality is higher for exporters.*

Proof: We provide a graphical proof of this proposition using Figure 4. Figure 4 reproduces Figure 3, but adds two iso-revenue curves. The iso-revenue curve R1 represents a set of curves that lie fully in Region II. Since there are no exporters on those curves, the proposition holds trivially for the revenue levels that they represent. A second set of iso-revenue curves is characterized by R2. R2 crosses Region V (point A is representative of that segment) until it intersects with region IV at point B. At that point, it goes straight down across region IV until reaches point C.[10] To understand why firms with different ξ have identical revenue along the last segment, we can note that, since those firms all produce the minimum export quality ($\underline{\lambda}$) and have the same productivity (φ), there marginal cost is identical and so they charge the same price. Therefore, with equal price and quality, their revenue is also identical (despite the fact that they pay different fixed costs to produce $\underline{\lambda}$ due to their different caliber ξ).

At point C, there is a discontinuity in the revenue curve. This point marks the threshold between firms who choose to upgrade their quality to meet the export requirement and those who decide to focus in the domestic market. Formally, the existence of a discontinuity can be shown by considering a point $(\varphi_C^{IV}, \xi_C^{IV})$ arbitrarily close to point C belonging to Region IV, and a second point $(\varphi_C^{III}, \xi_C^{III})$ arbitrarily close to point C belonging to Region III. It is easy to find that:

$$\begin{aligned} r_C^{III} &= (\lambda_C^{III})^{\alpha-\alpha'} \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} \left(\frac{c}{\varphi_C^{III}}\right)^{1-\sigma} \left(\frac{E}{P}\right) \\ < \quad r_C^{IV} &= (\underline{\lambda})^{\alpha-\alpha'} \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} \left(\frac{c}{\varphi_C^{IV}}\right)^{1-\sigma} \left(\frac{E'}{P'}\right) \end{aligned}$$

since $\lambda_C^{III} < \underline{\lambda}$ and $\frac{E}{P} < \frac{E'}{P'} = \frac{E}{P} + \tau^{-\sigma}\frac{E^*}{P^*}$. Finally, iso-revenue curve R2 continues in region III starting in point D and continuing through point E indefinitely to the right.

Let $D(\varphi, \xi)$ be an indicator function for export status, so that $D(\varphi, \xi) = 1$ when a firm exports and $D(\varphi, \xi) = 0$ otherwise. From our discussion of iso-revenue curve R2, we can establish that

[10] Those two segments are characterized, respectively, by the equations $\xi(R2, \varphi) = \left(\frac{R2^{\frac{\alpha'}{\alpha-\alpha'}}}{\varphi^{\frac{\alpha(\sigma-1)}{(\alpha-\alpha')}}}\right)\frac{1}{H}$ and $\varphi(R2) = \left(\frac{R2^{\frac{1}{\sigma-1}}}{\underline{\lambda}^{\frac{\alpha-\alpha'}{\sigma-1}}}\right)\frac{1}{H'}$, where H and H' are constant functions of the parameters, $H = \left(\frac{\sigma-1}{\sigma}\right)^{\frac{\alpha\sigma-\alpha'}{\alpha-\alpha'}} \left(\frac{E'}{P'}\right)^{\frac{\alpha}{\alpha-\alpha'}} \left(\frac{1}{c}\right)^{\frac{\alpha}{1-\beta}} \left(\frac{1-\beta}{\alpha f}\right)$, $H' = \left(\frac{\sigma-1}{\sigma}\right)\left(\frac{1}{c}\right)\left(\frac{E'}{P'}\right)^{\frac{1}{\sigma-1}}$, and $\frac{E'}{P'} = \frac{E}{P} + \tau^{-\sigma}\frac{E^*}{P^*}$. Note that the second equation does not depend on ξ.

$\forall(\varphi, \xi)$ on R2 such that $D = 1$, the *minimum* quality level is $\underline{\lambda}$. In contrast, $\forall(\varphi, \xi)$ on R2 such that $D = 0$, the *maximum* quality level is (infinitesimally) less than $\underline{\lambda}$. Generalizing this result to the set of iso-revenue curves represented by R2, we obtain that:

$$E[\lambda|D = 1, r = \bar{R}] \geq \underline{\lambda} > E[\lambda|D = 0, r = \bar{R}]$$

Thus, size is not the sole predictor of export status. Conditional on size, expected quality is higher for exporters. QED

$\square$

Since quality is unobserved, we are unable to test this prediction. However, a corollary of Proposition 2 establishes a similar prediction in terms of observable variables. Given the above result, we can show that the following corollary holds:

Corollary 1. *Conditional on size, expected price is higher for exporters.*

Proof: Using Proposition 2 and equations 6, 7 and 8, we derive the price charged by a non-exporting firm:

$$p = \left(\frac{E}{P}\right)^{\frac{1}{\sigma-1}} \left(\frac{\lambda}{r^{\frac{1}{\sigma-1}}}\right).$$

Therefore,

$$E[p|D = 0, r = \bar{R}] = \left(\frac{E}{P}\right)^{\frac{1}{\sigma-1}} \left(\frac{1}{\bar{R}^{\frac{1}{\sigma-1}}}\right) E[\lambda|D = 0, r = \bar{R}].$$

Similarly, for an exporter we have:

$$E[p|D = 1, r = \bar{R}] = \left(\frac{E'}{P'}\right)^{\frac{1}{\sigma-1}} \left(\frac{1}{\bar{R}^{\frac{1}{\sigma-1}}}\right) E[\lambda|D = 1, r = \bar{R}].$$

Then, Proposition 1 and the fact that $\dfrac{E}{P} < \dfrac{E'}{P'} = \dfrac{E}{P} + \tau^{-\sigma}\dfrac{E^*}{P^*}$ imply that:

$$E[p|D = 1, r = \bar{R}] > E[p|D = 0, r = \bar{R}].$$

The intuition for this result is very simple. Compare the segments to the left and to the right of point C along R2. Firms to the left of point C produce higher quality and have lower productivity, both of which are factors that induce them to charge a higher price. QED

□

Thus, in a world where firms need to exceed a minimum quality threshold to become exporters, firms that have the same size (gross revenues) may differ in their export status. As a result, the relationship between size and export status is smoother than a step function, a prediction that is consistent with the data, as shown in Figure 1. Conditional on size, firms that have relatively higher caliber (ξ) choose higher levels of quality and become exporters, while firms that have relatively high productivity (φ) stay as purely domestic firms. The same revenue level is achieved differently in both cases. Exporters produce fewer quantities but charge higher prices, whereas purely domestic firms produce larger quantities which they sell at lower prices.

In the empirical section below (Section 4), we test the predictions of Proposition 2 and Corollary 1 using plant-level data (described in Section 3) for the Indian manufacturing sector. This dataset includes information on unit quantities and value of sales, which allows us to measure the per-unit price for all the products produced by each plant. These price data can be used to directly test corollary 1, by forming sample analogs of $E[p|D, r]$ (see discussion in Section 4).

The data does not include measures of quality directly consistent with λ in our model. In the model, quality affects marginal costs and fixed costs of operations. If these quality related costs could be identified in the data, they could form proxies for quality, allowing us to test Proposition 2 indirectly. In the Indian dataset, there is information that allows us to form such proxies for quality. One available variable is a dummy that tracks whether the firm has ISO 9000 certification. Since ISO 9000 is a quality certification, this dummy can be regarded as a good proxy for quality (λ). In addition, there are five additional dummy variables that track whether the establishment uses computer and robotics technologies. Since it is reasonable that at least part of the investments in computers and robotics may be related to helping the firm to improve the quality of their products, these dummy variables can also serve as proxies for λ.

In the next section, we model the fixed and variable costs of producing quality in greater detail. This allows us to relate the production of quality to capital and skill intensity.[11]

[11] Our model also makes subtle predictions related to reallocation of resources following trade liberalization. Specifically, our model suggests that the ranking of firm sizes is reshuffled with trade liberalization. For example, consider an iso-revenue curve (i.e. an iso-η curve) in autarky that crosses regions V, IV, and III in Figure 3. Following trade liberalization with constrained quality, firms on the part of the iso-revenue curve that lies in Region V (relatively

2.3 Capital and skill intensity

Since this is a partial equilibrium model, we did not need to fully specify the source of the higher costs required for the production of quality. We do this here by following an approach similar to Verhoogen (2004).

Define the average wage paid by the firm as w:

$$w = \frac{\sum_k w_k L_k}{\sum_k L_k}$$

where k denotes types of workers by their ability and w_k the market wage for that ability. Similarly, define the average rental rate paid by the firm as r:

$$r = \frac{\sum_k r_k K_k}{\sum_k K_k}$$

where k here denotes different vintages of capital. To produce quality λ, it is required that $w = \underline{w}\lambda^\gamma$ and $r = \underline{r}\lambda^\gamma$, i.e. quality requires on average more skilled labor and more recent (hence more productive) vintages of capital. In the data, we will observe that firms that produce higher quality hire more skilled workers (the higher skill intensity might only be manifested as a higher average wage [Bustos (2005)]). Also, since firm level data does not distinguish between vintages of capital, those firms will appear as more capital intensive.

We assume that producing higher quality also affects the quantity used of each factor input as variable and fixed costs. To produce quality λ, a firm with productivity φ has to use $\frac{c'}{\varphi}\lambda^\delta$ units of capital and of labor in a Leontief fashion to produce one unit of output. Therefore:

$$c(\lambda) = \frac{c'}{\varphi}\lambda^\delta \left[w + r\right] = \frac{c'}{\varphi}\lambda^\delta \left[\underline{w}\lambda^\gamma + \underline{r}\lambda^\gamma\right] = \frac{c'\left(\underline{w} + \underline{r}\right)}{\varphi}\lambda^{\delta+\gamma} = \frac{c}{\varphi}\lambda^\beta$$

where $\beta = \delta + \gamma$ and $c = c'\left(\underline{w} + \underline{r}\right)$.

Similarly, to produce quality λ, a firm with ability ξ has to use $\frac{f'}{\xi}\lambda^\mu$ units of capital and of labor in a Leontief fashion as a fixed cost. These quality-related fixed costs can be thought of as expenses

high caliber firms) would choose to export and hence would increase in size considerably. However, firms on the part of the iso-revenue curve that lies in region III would instead choose to focus on the domestic market and probably contract as a result of the increased foreign competition. Firms on the part of the iso-revenue curve that lies in region IV would upgrade their quality and serve the export markets. Thus their size (total revenue) would go up due to both the upgrading of their quality and to their access to export markets. In sum, trade liberalization would lead to the reallocation of resources towards higher caliber firms.

associated with maintaining records, doing inspections, or training workers in identifying quality issues. In addition, the firm incurs other fixed costs F (such as annual maintenance expenses or headquarters expenses) unrelated to quality. Therefore:

$$\begin{aligned} F(\lambda) &= \frac{f'}{\xi}\lambda^{\mu}\left[w+r\right]+F=\frac{f'}{\xi}\lambda^{\mu}\left[\underline{w}\lambda^{\gamma}+\underline{r}\lambda^{\gamma}\right]+F \\ &= \frac{f'\left(\underline{w}+\underline{r}\right)}{\xi}\lambda^{\mu+\gamma}+F=\frac{f}{\xi}\lambda^{a} \end{aligned}$$

where $\alpha = \mu + \gamma$ and $f = f'\left(\underline{w} + \underline{r}\right)$.

Given these assumptions regarding the production of quality, we can show the following additional corollaries to Proposition 2.

Corollary 2. *Conditional on size, mean capital intensity (measured as the capital to labor ratio) is higher for exporting firms.*

Proof TO DO.

Corollary 3. *Conditional on size, mean skill intensity (measured as the average wage rate) is higher for exporting firms.*

Proof This follows directly from our assumptions in section 2.3 and Proposition 2 above. From section 2.3, the observed average wage $w = \underline{w}\lambda^{\gamma}$. Therefore following from Proposition 2:

$$\begin{aligned} E[w|D=1,r=\bar{R}] &= \underline{w}E[\lambda^{\gamma}|D=1,r=\bar{R}]\underline{\lambda} \\ > \underline{w}E[\lambda^{\gamma}|D=0,r=\bar{R}] &= E[w|D=0,r=\bar{R}] \end{aligned}$$

□

We use plant-level data on the manufacturing sector in Chile, Colombia and India to test corollaries 2 and 3 (see discussion in Section 3 for details). Data on capital to labor ratio and the average wage rate is available in the datasets for all three countries, so corollaries 2 and 3 are testable using all three datasets. In addition to the average wage, there are three other measures of skill intensity observable in the data – the skilled (non-production) share of wages, the wage rate for skilled (non-production) workers and wage rate for unskilled (production) workers.

3 Data

For our empirical analysis, we use data from manufacturing sector surveys for India, Chile and Colombia.

For India, we use unit-level data from the Annual Survey of Industries for the year 1997-98. The Annual Survey of Industries (ASI) is a survey undertaken by the Central Statistical Organization (CSO), a department in the Ministry of Statistics and Programme Implementation. The ASI covers all industrial units (called "Factories") registered under the Factories Act employing more than 20 persons.[12] The ASI frame is classified into two sectors: the "census sector" and the "sample sector". Factories employing more than 100 workers constitute the census sector. Factories in the sample sector are stratified and randomly sampled, while all those in the census sector are surveyed. The sample weights (multipliers) for all the establishments are provided in the dataset. In our analysis, we use these multipliers to adjust for the sampling weights. We focus on 1997-98 because the ASI data for this year includes information on exports and on output quantities and values. The Indian data is classified according to the National Industrial classification 1987 revision (NIC-87). Each establishment is provided a 4 digit NIC code, which is a finer classification than the ISIC 4 digit code. In fact, the NIC 3 digit code is based on the ISIC 4 digit classification. There are about 450 distinct 4 digit NIC industries in the data.

For Chile, the data we use is drawn from the annual Chilean Manufacturing Census (Encuesta Nacional Industrial Anual) conducted by the Chilean government statistical office (Instituto Nacional de Estadistica). The survey covers all manufacturing plants in Chile with more than 10 employees and has been conducted annually since 1979. We use data for the years 1991-96, for which data on exporting is available. Chilean industries are classified using the ISIC 4 digit classification. Data for Colombia comes from the Colombian manufacturing census for the years 1981 to 1991. The census covers all plants with 10 or more employees and includes data on exports for each establishment. Like Chile, Colombia's industries are classified using the ISIC 4 digit classification.

[12]This limit is lower (10 employees) for plants that use electric power for production. Even though plants with employment below this lower limit are not required to register, a significant number of plants report less than 10 employees. This happens apparently because some plants below the mandated limit voluntarily choose to register or because some plants that initially registered when they had more than 10 employees continue to stay registered even after employment levels fall below the cutoff.

Panel 1, Panel 2 and Panel 3 of Table 1 present summary statistics for India, Chile and Colombia respectively. All statistics are adjusted to account for sampling weights. The adjustment for sampling weights is important only for India, as the datasets for Chile and Colombia are census datasets. That is, for Chile and Colombia, each establishment is sampled with certainty so that multipliers (inverse of the sampling weights) are equal to one for all observations.

For India, there is more information collected from the establishments, which allows us to form additional proxies for quality. Data on quantity and sales value allow us to estimate the per-unit prices for each product line for each firm. The price variable is defined at the product category level, so that there are multiple price observations for each firm. Since all other data, especially data on exports (value of exports), is available only at the establishment level, in our analysis we check robustness to different assumptions about which product lines may be exported (see discussion in Section 4 below).

The Indian dataset also includes information on whether the establishment has obtained ISO 9000 certification. We use an indicator variable for ISO 9000 as a proxy for quality to test Proposition 2 in Section 2.2.2. Also, the dataset includes five dummy variables that reflect adoption of computer usage. One dummy indicates whether computers are used in the establishment. A second dummy is an indicator for the use of robotics in the plant. A third dummy variable indicates the presence of a computer network. A fourth dummy variable indicates whether there is access to internet at the plant. Finally, a fifth dummy variable indicates whether the establishment provided responses to the survey on a floppy – this dummy could indicate a more active use of computers among plants that do have computers on the premises. These variables are relevant to our model in two ways. One, investment in computers could reflect the higher fixed costs incurred in raising quality. Two, as discussed in section 2.3, we expect higher quality firms to invest in more sophisticated equipment (such as computers). The mean values for these variables indicate that only 3% of the establishments has obtained ISO 9000 certification. While 32% of the establishments used computers in some form, usage of robotics and presence of a computer network are really low (2%). Also, only 4% of the establishments has access to the internet (6% responded to the survey on a floppy).

All other variables that are common across the three datasets are defined in a consistent manner. The export dummy variable is defined to equal one for all establishments reporting positive value of total exports. The capital variable for Chile is constructed using the perpetual inventory method. For India and Colombia, capital is taken as the reported total fixed assets.[13] For all three datasets, the labor variable used in constructing the log capital to labor ratio is total employment. To minimize the influence of extreme outliers, the capital to labor ratio is winsorized by 0.5% on both tails of the distribution.

The average wage rate is obtained by dividing total wages by total employment for each establishment. The skilled share of the wage bill is the ratio of total wages to non-production workers divided by the total wage bill of the establishment (which is the sum of total wages to non-production and production workers). The skilled wage rate is obtained by dividing the total wages to non-production workers by the number of non-production workers. Similarly, the unskilled wage rate is defined as the total wages to production workers divided by the number of production workers. Total sales is the total revenues for each establishment.

The mean value for the export dummy shows that exporting is more common in Chile, where about 20% of establishments export. It is less common in India (13%) and in Colombia (12%). Since the currency units vary across countries, all the variables are not comparable across the three countries. The skilled share of the wage bill is remarkably similar across the three countries – 0.35 for India and Chile and 0.34 for Colombia. The mean employment level is higher in India (4.88 log points) and similar across Chile and Colombia (3.72 and 3.45 log points respectively).

4 Empirical Results

In this section, we test the predictions of our model (specifically Proposition 2 and Corollaries 1, 2 and 3). The constrained quality model predicts that the expected value of quality and other variables related to quality (price, capital intensity and skill intensity) are higher for exporters relative to non-exporters, *conditional on size*. We test these predictions by forming sample analogs of the conditional expectations. First, we follow a parametric approach by estimating a linear regression model. Alternatively, we estimate using a non-parametric locally weighted smoothed (lowess) regression of each dependent variable on size separately for exporters and non-exporters.

[13]In all our analysis, we use industry-year fixed effects. Coupled with the fact that the capital variable is logged in all the regressions, we expect our results to be invariant to using an industry level deflator to normalize the capital variable.

In the linear regression approach, the predictions of our model imply a positive coefficient on an exporter dummy in a regression of the different dependent variables (price, skill intensity, capital intensity and proxies for quality) on size (and industry-year controls). Based on the results of section 2, we use the following baseline regression specification:

$$\log Y_{it} = \alpha \log X_{it} + \beta D^{e}_{it} + \delta_{jt} + \epsilon_{it} \tag{30}$$

where i indexes firms, t indexes years and j indexes industries. D^e_{it} is a dummy that equals 1 if firm i is an exporter in year t and X_{it} is firm size. The predicted differences between exporters and non-exporters in our theory should apply to differences *within* industries. Thus, in all our specifications, we include industry-year fixed effects (δ_{jt}). To conform with the theoretical model, in our baseline specifications we use revenues as the proxy for size. In alternative specifications, drawing on some studies in the literature (e.g. Bernard and Jensen 1999), we check the robustness of our results to using total employment as the size proxy.

Under the non-parametric approach, we condition on size using a locally weighted smoothed regression (lowess). The lowess graph provides a non-parametric picture of $E[Y|D, r]$, allowing for a much richer dependence between export status (D) and the variable of interest (Y) across different size percentiles. We use the default bandwidth of 0.8 in our analysis (which implies that 80% of the data are used in smoothing each point).[14]

First, we use data from the Indian manufacturing sector for 1997-98 to examine the relation between per unit price and export status. As predicted by Corollary 1 in section 2.2.2, per-unit prices should be higher for exporters relative to non-exporters within an industry, reflecting the higher quality of exporters. As discussed in section 3, the price per unit is obtained by dividing value of production by quantities per product line. There are multiple product lines for most establishments. Also, units used to measure quantity differs from product to product. For example

[14] Technically, the lowess smoother forms a locally weighted smoothed prediction for the dependent variable in the following manner. Let y_i and x_i be two variables, and order the data so that $x_i \leq x_{i+1}$ for i =1,..., N-1. For each y_i, a smoothed value y_i^s is calculated. The subset used in the calculation of y_i^s is indexed by $i_{=} max(1, i-k)$ through $i_+ = min(i+k, N)$, where k= Int[(N.bandwidth - 0.5)/2]. The weights for each of the observations between $j = i,..., i_+$ are the tricube (default):

$$w_j = \left\{ 1 - \left(\frac{|x_j - x_i|}{\Delta} \right)^3 \right\}$$

where $\Delta = 1.0001 max(x_{i_+} - x_i, x_i - x_{i_-})$. The smoothed value y_i^s is the (weighted) regression prediction at x_i.

some products are measured in kilograms, others in liters – there are 25 different units used. Data on exports, however, are not disaggregated by product line. For our baseline analysis, we assume that an establishment exports all of its product lines. We control for industry fixed effects at two different levels of aggregation. The results are presented in Table 1. In the first row of Table 1 we report the coefficient on the exporter dummy controlling for 4-digit industry-unit code fixed effects. In the second row, we report results using a more aggregated fixed effect (3-digit industry-unit code). Column one is the specification in equation (30) run without any controls for size. Column 2 includes log revenues, column 3 includes log revenue and the square of log revenue. Column 4 includes log total employment as the size proxy, and column 5 is the same as column 4 except with the square of log employment as an additional control. In all specifications, we find that price per unit is significantly higher for exporting firms. In column 2, controlling for log revenue, prices are on average 20% higher for exporting firms. The effects are stronger when we control for size using employment (columns 4 and 5) than when we use revenue (columns 2 and 3).

We undertake two robustness checks of our baseline results. First, we redo our analysis retaining only the largest product line for each establishment, thus checking for robustness to the possibility that establishments are more likely to export only their main line of products. Two, we exclude observations where the units are undefined. There are about 10,000 observations where the name of the unit used is unspecified; hence the measured prices on these products could be noisy.[15] We find that our qualitative conclusions are largely unaffected by these robustness checks.

Figure 5 illustrates a locally weighted smoothed (lowess) regression of per unit price on size, separately for domestic and export firms. This provides a more detailed view of the relationship between price and size, as we allow the relationship to vary across size percentiles. We find a large difference between prices for domestic firms and exporters. Across all percentiles of the size distribution, exporters have a higher price per unit, consistent with the predictions of our model (and the results in Table 2).

Next, we look at differences in capital intensity (measured as the log of the capital to labor ratio) between exporters and non-exporters within industries, conditioning on size. The industries are defined at 4 digit NIC level for India and at 4 digit ISIC level for Chile and Colombia. The

[15] In the baseline specification, we assume that all product lines with unspecified units within a 4 digit industry have the same units, so that their prices are comparable.

results are presented in Table 3. We find that capital intensity is significantly higher for exporters, conditioning on both revenue and employment proxies for size. In column 2 (conditioning on log revenue), capital to labor ratio is about 43% higher for exporters in India, while it is 28.3% and 13.6% higher in Chile and Colombia respectively. As in the case for prices, effects are stronger when we control for size using employment (In columns 4 and 5). These results are confirmed by the lowess regressions illustrated in Figure 6. These figures show that across all size percentiles, exporters have a higher capital to labor ratio compared to non-exporters (purely domestic firms).

In Table 4, we examine different measures of the skill intensity of exporters relative to non-exporters within industries (defined the same way as for Table 3). The first measure we look at it the average wage rate. As predicted by our model (see corollary 3 in section 2.3), we find that the average wage rate is higher for exporters compared to non-exporters even conditioning on size – alternatively revenues or employment – in India and Chile. The results are not significant in regressions conditioning on revenues for Colombia; however, it continues to be significant when size is controlled for using employment.

An alternative measure of skill intensity is the skilled share of wage bill. In Table 4, we find that this measure of skill intensity is significantly higher for exporters, across all three countries and across all specifications. Conditioning on log of total revenues (column 2), the skilled share of the wage bill is 2.6% higher for exporters in India relative to non-exporters. This premium is 1.9% in Chile and 2.3% in Colombia.

We also examine the wage rate for skilled and unskilled workers separately. As for the average wage rate, we find a premium for exporters in both skilled and unskilled wage rates across all specifications for India. The premium is larger for skilled (non-production) workers than production workers. For Chile, we find a significant premium for skilled workers across all specifications. There is also a wage premium for unskilled workers except when we condition on revenues. Again, the estimated premium for exporters is larger for skilled workers in all specifications. For Colombia, we find the results similar to that for the average wage rate. The wage premia for skilled and unskilled workers are not significant once we condition on size using total revenues. However, the effects are significant when we condition on employment. Again, the magnitude of the estimated wage premia are larger for skilled workers compared to unskilled workers.

As in all previous cases (with price and capital intensity), results are stronger for all the skill intensity variables, when we control for size using employment rather than revenues.

Figures 7a and 7b provide a more detailed picture of the differences in skill premia between exporters and non-exporters, conditional on size. The graphs here confirm the findings in Table 4. In Figure 7a, we find that across all size percentiles, the average wage rate is higher for exporters (the difference is smallest for Colombia). The premium is starker when we measure skill intensity using the skilled share of the wage bill (Figure 7b).

In Table 5, we look at other proxies for quality that we can form using information in the ASI 1998 dataset for India. In the first row of Table 5, we look at a dummy variable for ISO 9000 certification. We find that, within 4 digit NIC industries, exporters are more likely to obtain ISO 9000 quality certification, and this holds even when we control for linear and non-linear measures of size.

The rest of the Table 5 reports results for the 5 dummy variables indicating adoption of computer technology (see section 3 for a description of these variables). For all 5 of the variables, we find that exporters are more likely to adopt computer technology. The effects are all significant at the 1% level, even in specifications controlling for size. Conditioning on revenue (column 2), we find that a 17.5% greater probability of an exporter having computers on the facility (row 2), a 5% greater propensity to use robotics (row 3), a 4.7% greater propensity to have a computer network (row 4), and a 12% greater likelihood of having internet access (row 5). Also, there is an 8% greater likelihood of exporters responding to the survey on floppies. In all specifications, we include 4 digit NIC code industry dummies.

Finally, in Table 6, we reproduce results for the US from Table 2 of Bernard and Jensen (1999). Using data on manufacturing plants from the Longitudinal Research Database of the United States Bureau of Census, Bernard and Jensen show that exporters have a premia on a number of different measures. The results reproduced here show that both capital intensity and skill intensity (measured using wage rates) is higher for exporters. All the reported effects are significant at 1% level. Also, the specification 2 for each of the years includes a control for size (measured a log total employment). Thus, even for the US, the findings are consistent with those for the three developing countries – exporters exhibit a significantly higher levels of capital and skill intensity relative to non-exporters, even when we control for size. The results for the U.S. suggest that the reason exporters produce higher quality than non-exporters cannot only be due to the fact that they export to countries that consume higher quality, as this is unlikely to be the case of U.S. firms selling in foreign markets.

Given all the results, we conclude that on a large number of reasonable proxies for quality, exporters exhibit a premium relative to non exporters. These effects are highly robust to the inclusion of linear and non-linear controls for size. Even when we control non-parametrically for size, we find that exporters are generally likely to have higher quality levels compared to non-exporters. This evidence is consistent with the predictions of our model, and suggest that the modification to the standard single-factor heterogenous firm models provide a better fit to the data.

5 Conclusion and future work

To be completed.

Appendix 1: Proof of existence and uniqueness

Proof of Proposition 1. The first thing to note is that the function $\underline{\xi}(\varphi)$ is increasing in P. Note that this function enters (19) through $\widehat{\eta}$, as it is the lower limit of the second integral in (20). In (19), the left-hand-side (LHS) is constant while the right-hand-side (RHS) can be expressed as a function of P. When $P \to 0$, then $\underline{\xi}(\varphi) \to 0 \quad \forall\varphi$, which implies that $P_{in} \to 1$. Also, in that case, $\widehat{\eta}$ takes some finite positive value.[16] As a result, the RHS $\to \infty$. In contrast, when $P \to \infty$, then $\underline{\xi}(\varphi) \to \infty \quad \forall\varphi$, which implies that $P_{in} \to 0$. Since $\widehat{\eta} \to 0$, the RHS $\to 0$. Therefore, to prove existence and uniqueness, we only need to show that the RHS of (19) is decreasing in P.

The derivative of the RHS of (19) with respect to P is:

$$\begin{aligned}
& \frac{B^{\frac{\alpha}{\alpha'}}}{(f_e + P_{in}F)^2}\left[\frac{\partial\left(\widehat{\eta}/P^{\frac{\alpha}{\alpha'}}\right)}{\partial P}(f_e + P_{in}F) - \frac{\partial P_{in}}{\partial P}F\frac{\widehat{\eta}}{P^{\frac{\alpha'}{\alpha}}}\right] \\
= \quad & \frac{B^{\frac{\alpha}{\alpha'}}}{(f_e + P_{in}F)^2}\left[\frac{1}{P^{\frac{\alpha}{\alpha'}}}\left[\frac{\partial\widehat{\eta}}{\partial P} - \frac{\alpha}{\alpha'}\frac{\widehat{\eta}}{P}\right](f_e + P_{in}F) - \frac{\partial P_{in}}{\partial P}\frac{F\widehat{\eta}}{P^{\frac{\alpha}{\alpha'}}}\right].
\end{aligned}$$

The sign of this derivative depends on the sign of

$$-\frac{\alpha}{\alpha'}\frac{\widehat{\eta}}{P}(f_e + P_{in}F) + \frac{\partial\widehat{\eta}}{\partial P}(f_e + P_{in}F) - \frac{\partial P_{in}}{\partial P}F\widehat{\eta}.$$

We will now show that the last two terms of this expression cancel out with one another, leaving only the first term, which is negative, to determine the sign of the derivative.

Using equations (17) and (10) together with $\widehat{\eta} \equiv P_{in}\widetilde{\eta}$, we find:

$$f_e + P_{in}F = J\left(\frac{1}{c}\right)^{\frac{(\sigma-1)\alpha}{\alpha'}}\left(\frac{1}{f}\right)^{\frac{\alpha-\alpha'}{\alpha'}}\left(\frac{E}{P}\right)^{\frac{\alpha}{\alpha'}}\widehat{\eta} \tag{31}$$

Then, we can calculate

$$\frac{\partial\widehat{\eta}}{\partial P} = -\int_{\varphi}\varphi^{\frac{(\sigma-1)\alpha}{\alpha'}}\underline{\xi}(\varphi)^{\frac{\alpha-\alpha'}{\alpha'}}\frac{\partial\underline{\xi}}{\partial P}k(\varphi)d\varphi \tag{32}$$

and

$$\frac{\partial P_{in}}{\partial P} = -\int_{\varphi}\frac{\partial\underline{\xi}}{\partial P}k(\varphi)d\varphi. \tag{33}$$

[16]We assume that the bivariate distribution has finite relevant moments so that the integral on the RHS of 20 is well defined.

Finally, we can show that

$$
\begin{aligned}
& \frac{\partial \widehat{\eta}}{\partial P}\left(f_e + P_{in}F\right) - \frac{\partial P_{in}}{\partial P}F\widehat{\eta} \\
= \; & \widehat{\eta}\int_{\varphi} \varphi^{\frac{(\sigma-1)\alpha}{\alpha'}} \underline{\xi}\left(\varphi\right)^{\frac{\alpha-\alpha'}{\alpha'}} J\left(\frac{1}{c}\right)^{\frac{(\sigma-1)\alpha}{\alpha'}} \left(\frac{1}{f}\right)^{\frac{\alpha-\alpha'}{\alpha'}} \left(\frac{E}{P}\right)^{\frac{\alpha}{\alpha'}} \frac{\partial \underline{\xi}}{\partial P}k(\varphi)d\varphi \\
& +\widehat{\eta}\int_{\varphi} \frac{\partial \underline{\xi}}{\partial P}Fk(\varphi)d\varphi \\
= \; & \widehat{\eta}\int_{\varphi} \left[\varphi^{\frac{(\sigma-1)\alpha}{\alpha'}} \underline{\xi}\left(\varphi\right)^{\frac{\alpha-\alpha'}{\alpha'}} J\left(\frac{1}{c}\right)^{\frac{(\sigma-1)\alpha}{\alpha'}} \left(\frac{1}{f}\right)^{\frac{\alpha-\alpha'}{\alpha'}} \left(\frac{E}{P}\right)^{\frac{\alpha}{\alpha'}} - F\right] \frac{\partial \underline{\xi}}{\partial P}k(\varphi)d\varphi \\
= \; & 0
\end{aligned}
$$

where the first equality uses (31), (32), and (33), the second equality reorganizes terms, and the last equality uses (12).

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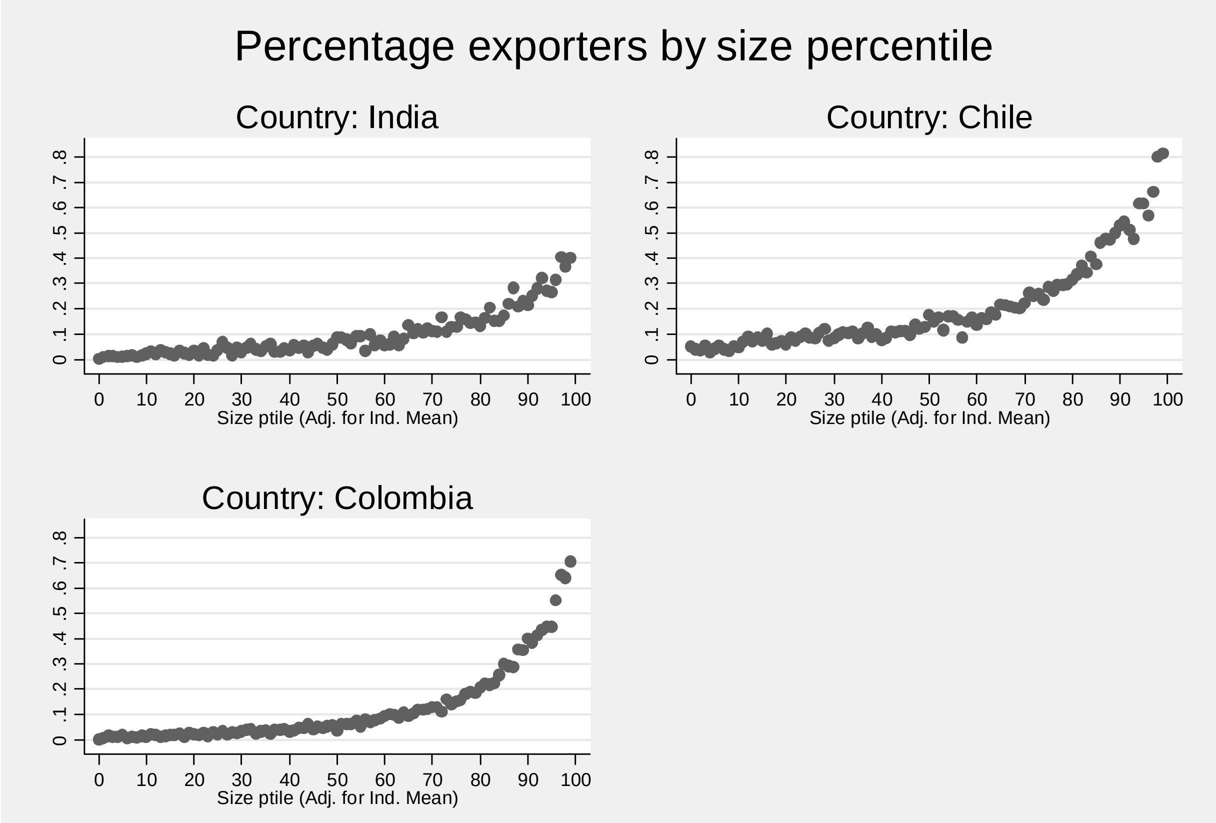
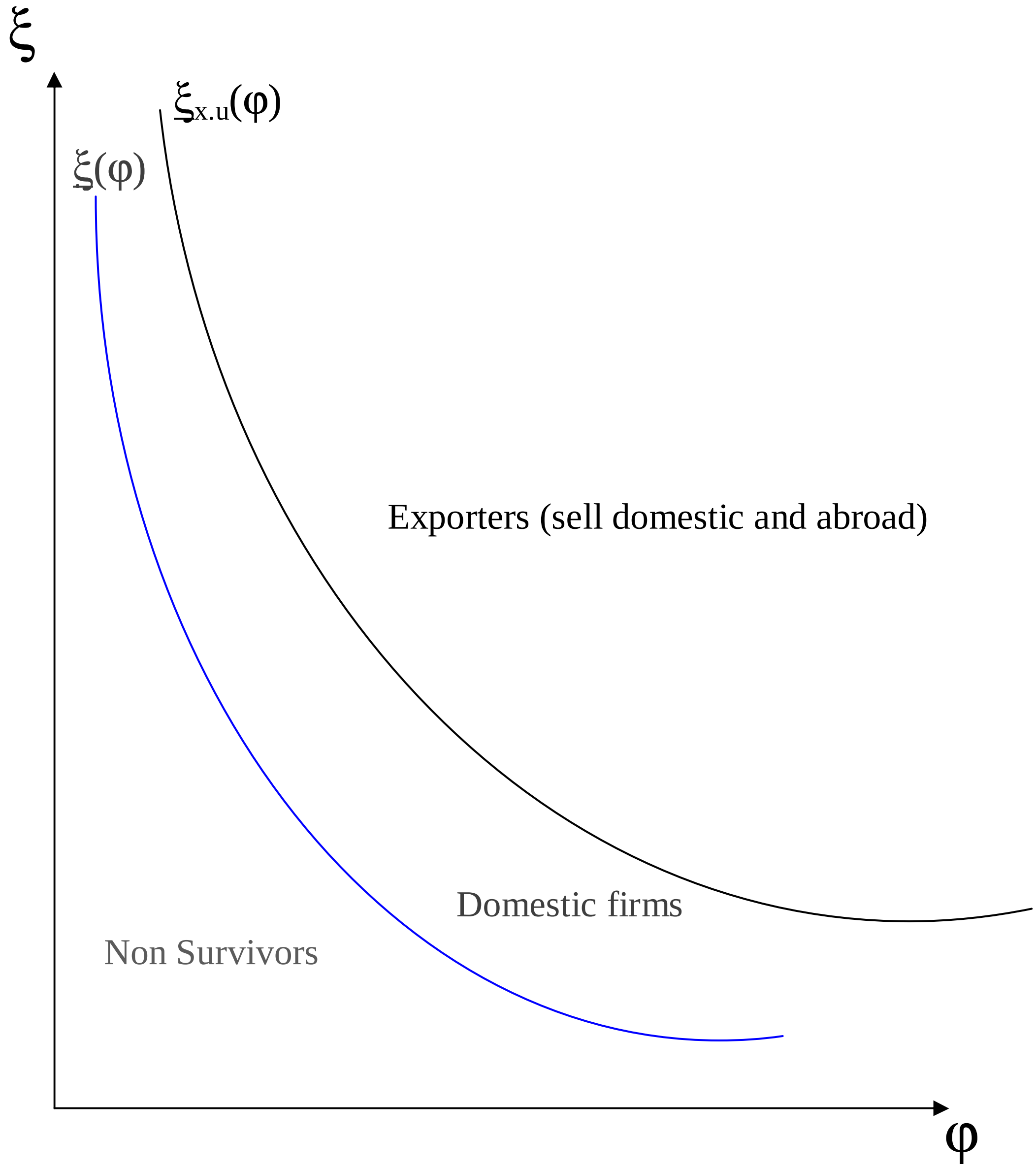
Figure 1: Percentage of firms that are exporters, by size percentile



The Y axis is the fraction of firms that are exporters. Size percentiles are adjusted for industry mean size.

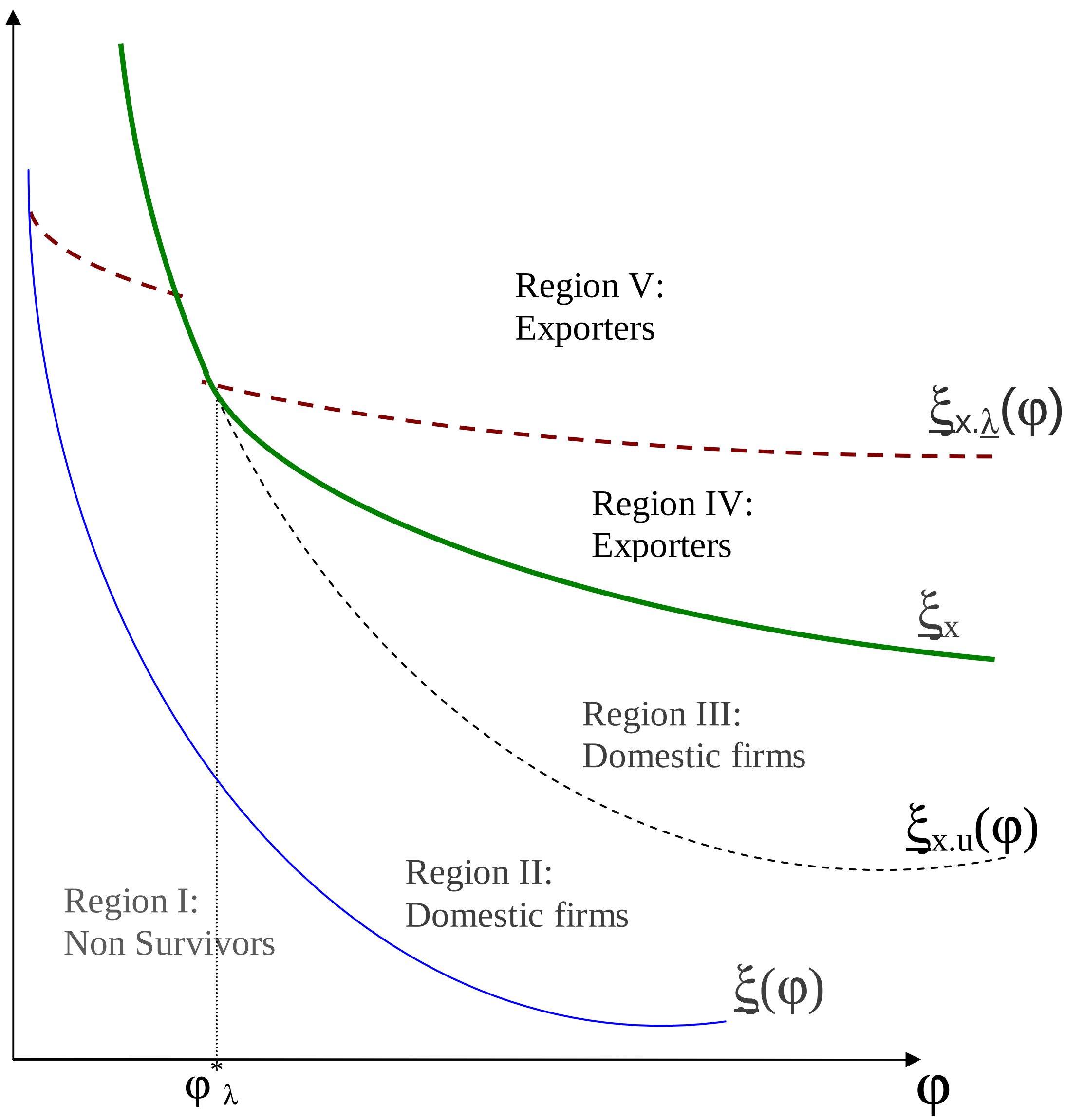
Figure 2: Unconstrained export quality equilibrium



ξ (φ): cutoff between survivors and non survivors

$\xi_{x.u}(\varphi)$: export cutoff in the unconstrained regime

Figure 3: Constrained export quality equilibrium



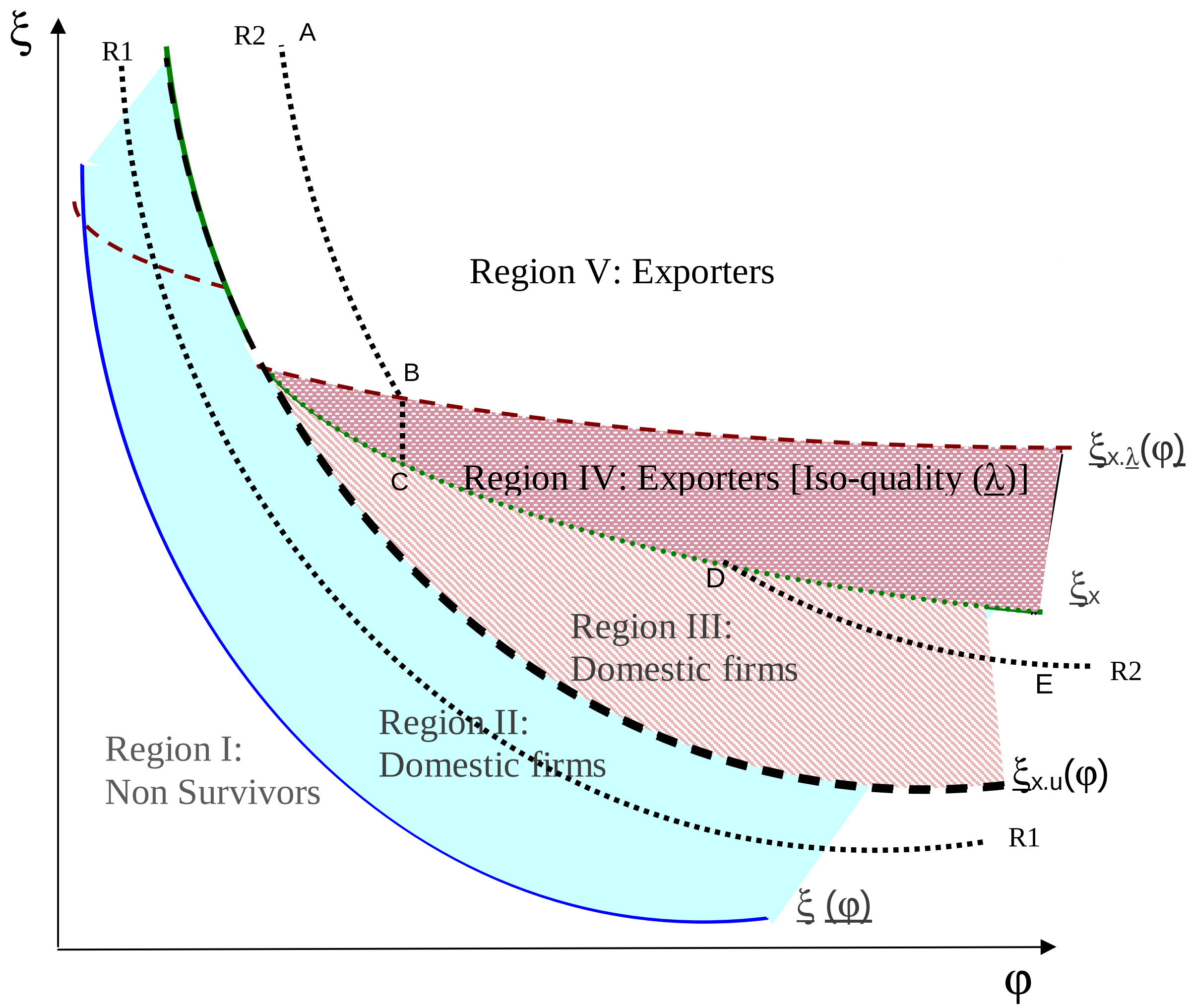
$\underline{\xi}$ (φ): cutoff between survivors and non survivors

$\underline{\xi}_{x.u}(\varphi)$: export cutoff in the unconstrained regime

$\underline{\xi}_{x.\underline{\lambda}}(\varphi)$: the iso-quality curve for threshold quality $\underline{\lambda}$

$\underline{\xi}_x$: the export cutoff in the constrained regime

Figure 4: Iso-revenue and iso-quality curves in the constrained export quality equilibrium



$\underline{\xi}(\varphi)$: cutoff between survivors and non survivors

ξ_x: the export cutoff in the constrained regime

$\xi_{x.u}(\varphi)$: export cutoff in the unconstrained regime

$\xi_{x.\underline{\lambda}}(\varphi)$: the iso-quality curve for threshold quality $\underline{\lambda}$

……….. Iso-revenue

Table 1: Summary Statistics
All summary statistics are adjusted for sampling weights.

Description	N	Mean	SD	P25	Median	P75
Panel 1: India (1998)						
Log per unit price	43,197	7.79	2.87	5.51	8.39	9.86
Export dummy (=1 if exports>0)	28,584	0.09	0.29	0	0	0
Log (capital/labor: winsorized 0.5%)	27,316	10.58	2.06	9.6	10.75	11.83
Log(average wage rate)	27,438	10.02	0.77	9.57	10.05	10.5
Skilled share of wage bill	27,472	0.35	0.24	0.17	0.32	0.5
Log(skilled wage rate)	26,090	10.30	0.89	9.75	10.37	10.93
Log(unskilled wage rate)	26,891	9.91	0.73	9.52	9.94	10.32
Log(total employment)	27,964	4.88	1.24	4.14	4.85	5.68
Log(total sales)	27,159	17.41	2.05	16.05	17.44	18.84
Square of log(total employment)	27,964	25.32	12.25	17.17	23.54	32.23
Square of log(total sales)	27,159	307.24	70.71	257.7	304.24	354.92
ISO 9000 certification dummy	28,584	0.03	0.18	0	0	0
Computer use dummy	28,584	0.32	0.47	0	0	1
Robotics use dummy	28,584	0.02	0.14	0	0	0
Computer network dummy	28,584	0.02	0.13	0	0	0
Internet use dummy	28,584	0.04	0.19	0	0	0
Survey response on floppy dummy	28,584	0.06	0.25	0	0	0
Panel 2: Chile (1991-96)						
Export dummy (=1 if exports>0)	34,990	0.20	0.40	0	0	0
Log (capital/labor: winsorized 0.5%)	33,817	4.76	1.61	3.91	4.74	5.68
Skilled share of wage bill	34,989	0.35	0.24	0.17	0.32	0.5
Log(average wage rate)	34,989	7.27	0.75	6.74	7.26	7.78
Log(skilled wage rate)	32,998	7.58	0.99	6.87	7.64	8.32
Log(unskilled wage rate)	34,220	7.06	0.68	6.59	7.05	7.5
Log(total employment)	34,990	3.72	1.02	2.94	3.5	4.32
Log(total sales)	34,982	12.94	1.63	11.75	12.67	13.92
Square of log(total employment)	34,990	14.91	8.61	8.67	12.23	18.64
Square of log(total sales)	34,982	170.01	44.12	138.04	160.47	193.67
Panel 3: Colombia (1981-91)						
Export dummy (=1 if exports>0)	75,812	0.12	0.33	0	0	0
Log (capital/labor: winsorized 0.5%)	75,069	5.64	1.61	4.62	5.66	6.69
Log(average wage rate)	75,299	6.09	0.92	5.43	6.1	6.75
Skilled share of wage bill	75,300	0.34	0.22	0.18	0.31	0.47
Log(skilled wage rate)	71,472	6.20	1.08	5.47	6.22	6.98
Log(unskilled wage rate)	74,230	6.02	0.85	5.39	6.03	6.66
Log(total employment)	75,770	3.45	1.10	2.64	3.26	4.06
Log(total sales)	75,757	11.20	1.86	9.9	10.98	12.3
Square of log(total employment)	75,770	13.13	8.69	6.96	10.62	16.49
Square of log(total sales)	75,757	128.84	43.77	98.07	120.48	151.32

Table 2: Per unit price (India 1998)

The dependent variable is log per unit price. All reported figures are coefficients on an exporter dummy which equals one for exporting establishments and is zero for non-exporters. The first row reports results from regressions that include 4-digit industry-unit code fixed effects, while the second row includes 3 digit industry-unit code fixed effects. Column (1) includes only the exporter dummy. Column (2) includes log(total sales). Column (3) includes log(total sales) and square of log(total sales). Column (4) includes log(total employment). Column (5) includes log(total employment) and square of log(total employment). The number of observations is about 43000. Standard errors are clustered at industry level. + significant at 10%; * significant at 5%; ** significant at 1%.

Type of fixed effects	(1)	(2)	(3)	(4)	(5)
4-digit industry-unit code fixed effects	0.341	0.192	0.167	0.279	0.248
	[0.052]**	[0.056]**	[0.046]**	[0.058]**	[0.048]**
3-digit industry-unit code fixed effects	0.354	0.200	0.164	0.304	0.262
	[0.056]**	[0.064]**	[0.051]**	[0.066]**	[0.054]**
Log(total sales) included	No	Yes	Yes	No	No
Square of log(total sales) included	No	No	Yes	No	No
Log (total employment) included	No	No	No	Yes	Yes
Square of log(total employment) included	No	No	No	No	Yes

Figure 5: Lowess regression of price on size

The log per unit price and the size variable (log(total sales)) are demeaned of industry effects.

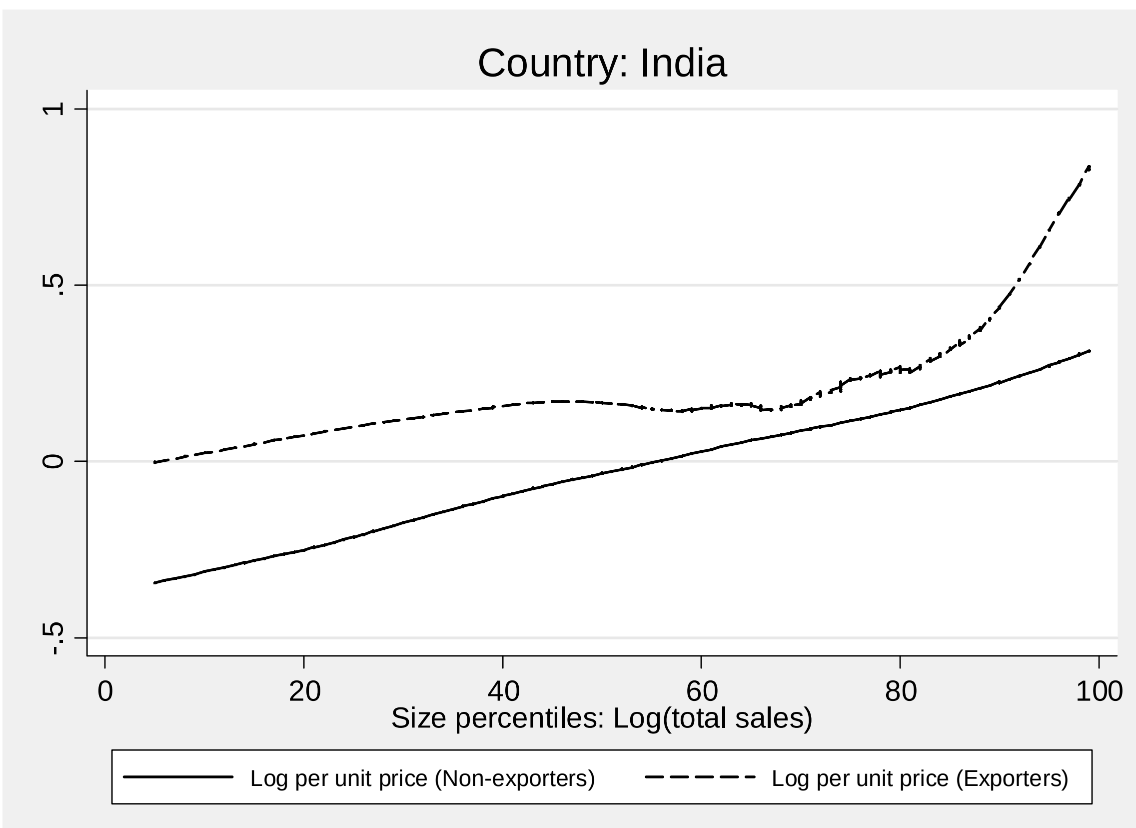


Table 3: Capital labor ratio vs export status

All reported figures are coefficients on an exporter dummy which equals one for exporting establishments and is zero for non-exporters. All regressions included industry-year fixed effects, where the industry definition is 4 digit NIC for India and 4 digit ISIC for Chile and Colombia. Column (1) includes only the exporter dummy. Column (2) includes log(total sales). Column (3) includes log(total sales) and square of log(total sales). Column (4) includes log(total employment). Column (5) includes log(total employment) and square of log(total employment). The number of observations is approximately 27000 for India, 35000 for Chile and 75000 for Colombia. Standard errors are clustered at industry level. + significant at 10%; * significant at 5%; ** significant at 1%.

Dependent Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Panel 1: India (1998)					
Log (capital/labor: winsorized 0.5%)	0.955	0.434	0.322	0.957	0.907
	[0.056]**	[0.064]**	[0.058]**	[0.061]**	[0.062]**
Panel 2: Chile (1991-96)					
Log (capital/labor: winsorized 0.5%)	0.836	0.283	0.266	0.621	0.614
	[0.069]**	[0.068]**	[0.064]**	[0.071]**	[0.071]**
Panel 3: Colombia (1981-91)					
Log (capital/labor: winsorized 0.5%)	0.745	0.136	0.126	0.639	0.536
	[0.051]**	[0.066]*	[0.059]*	[0.084]**	[0.058]**
Log(total sales) included	No	Yes	Yes	No	No
Square of log(total sales) included	No	No	Yes	No	No
Log (total employment) included	No	No	No	Yes	Yes
Square of log(total employment) included	No	No	No	No	Yes

Figure 6: Lowess regression of capital intensity on size

The log(capital/labor) and the size variable (log(total sales)) are demeaned of industry effects

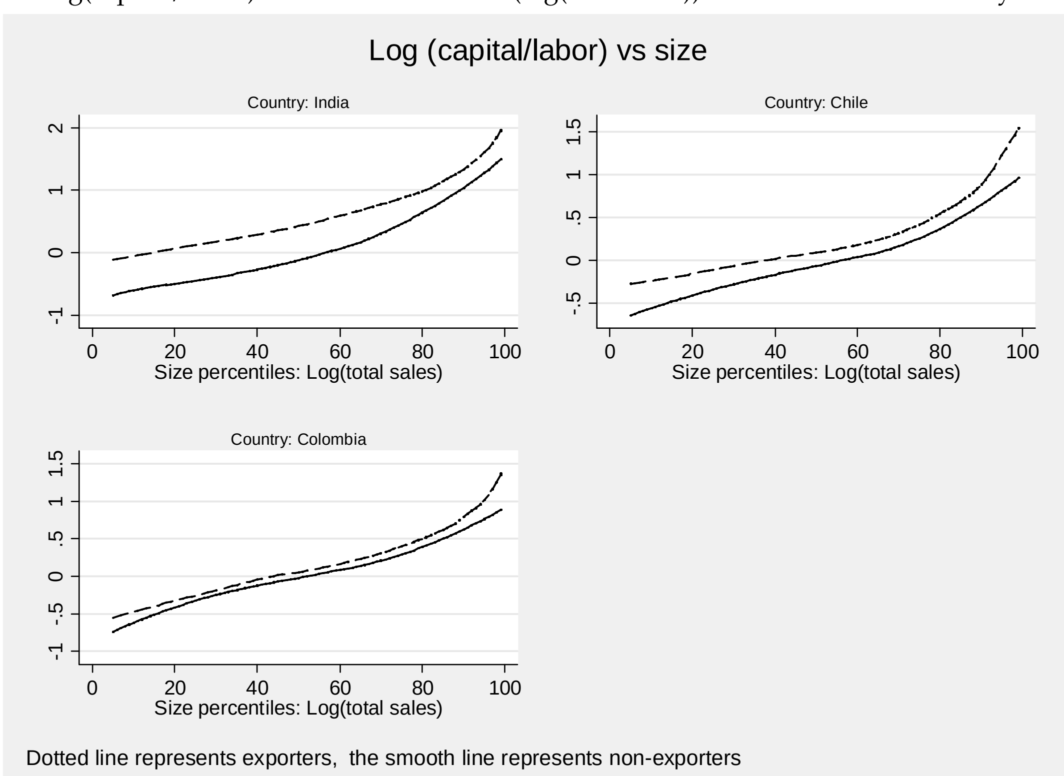


Table 4: Skill Intensity vs export status

All reported figures are coefficients on an exporter dummy which equals one for exporting establishments and is zero for non-exporters. All regressions included industry-year fixed effects, where the industry definition is 4 digit NIC for India and 4 digit ISIC for Chile and Colombia. Column (1) includes only the exporter dummy. Column (2) includes log(total sales). Column (3) includes log(total sales) and square of log(total sales). Column (4) includes log(total employment). Column (5) includes log(total employment) and square of log(total employment). The number of observations is approximately 27000 for India, 35000 for Chile and 75000 for Colombia. Standard errors are clustered at industry level. + significant at 10%; * significant at 5%; ** significant at 1%.

Dependent variable	(1)	(2)	(3)	(4)	(5)
Panel 1: India (1998)					
Log(average wage rate)	0.45	0.129	0.131	0.314	0.316
	[0.024]**	[0.021]**	[0.022]**	[0.019]**	[0.019]**
Skilled share of wage bill	0.055	0.026	0.014	0.071	0.064
	[0.007]**	[0.007]**	[0.007]*	[0.007]**	[0.007]**
Log(skilled wage rate)	0.515	0.16	0.144	0.332	0.327
	[0.026]**	[0.024]**	[0.025]**	[0.021]**	[0.022]**
Log(unskilled wage rate)	0.357	0.109	0.119	0.265	0.264
	[0.025]**	[0.023]**	[0.023]**	[0.020]**	[0.020]**
Panel 2: Chile (1991-96)					
Log(average wage rate)	0.458	0.04	0.05	0.224	0.232
	[0.019]**	[0.021]+	[0.020]*	[0.026]**	[0.026]**
Skilled share of wage bill	0.092	0.019	0.018	0.051	0.05
	[0.009]**	[0.009]*	[0.008]*	[0.008]**	[0.008]**
Log(skilled wage rate)	0.672	0.095	0.124	0.254	0.269
	[0.027]**	[0.023]**	[0.021]**	[0.023]**	[0.022]**
Log(unskilled wage rate)	0.315	0.019	0.025	0.164	0.168
	[0.017]**	[0.019]	[0.018]	[0.023]**	[0.023]**
Panel 3: Colombia (1981-91)					
Log(average wage rate)	0.461	0.016	0.015	0.186	0.174
	[0.040]**	[0.015]	[0.016]	[0.020]**	[0.022]**
Skilled share of wage bill	0.095	0.023	0.026	0.082	0.073
	[0.007]**	[0.006]**	[0.006]**	[0.009]**	[0.007]**
Log(skilled wage rate)	0.657	0.033	0.056	0.213	0.22
	[0.040]**	[0.022]	[0.022]*	[0.027]**	[0.029]**
Log(unskilled wage rate)	0.319	0.001	-0.013	0.117	0.098
	[0.033]**	[0.014]	[0.014]	[0.016]**	[0.016]**
Log(total sales) included	No	Yes	Yes	No	No
Square of log(total sales) included	No	No	Yes	No	No
Log (total employment) included	No	No	No	Yes	Yes
Square of log(total employment) included	No	No	No	No	Yes

Figure 7a: Lowess regression of average wage rate on size

The log average wage rate and the size variable (log(total sales)) are demeaned of industry effects.

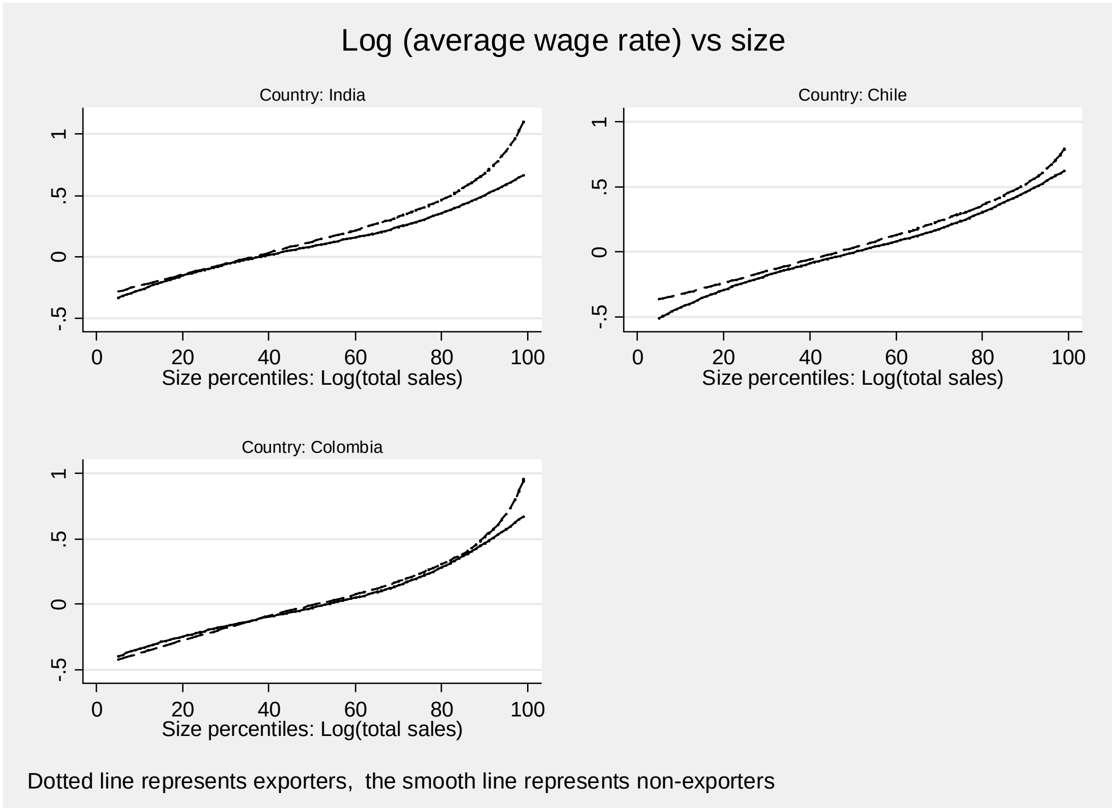


Figure 7b: Lowess regression of skilled share of wage bill on size

The skilled share of wage bill and the size variable (log(total sales)) are demeaned of industry effects.

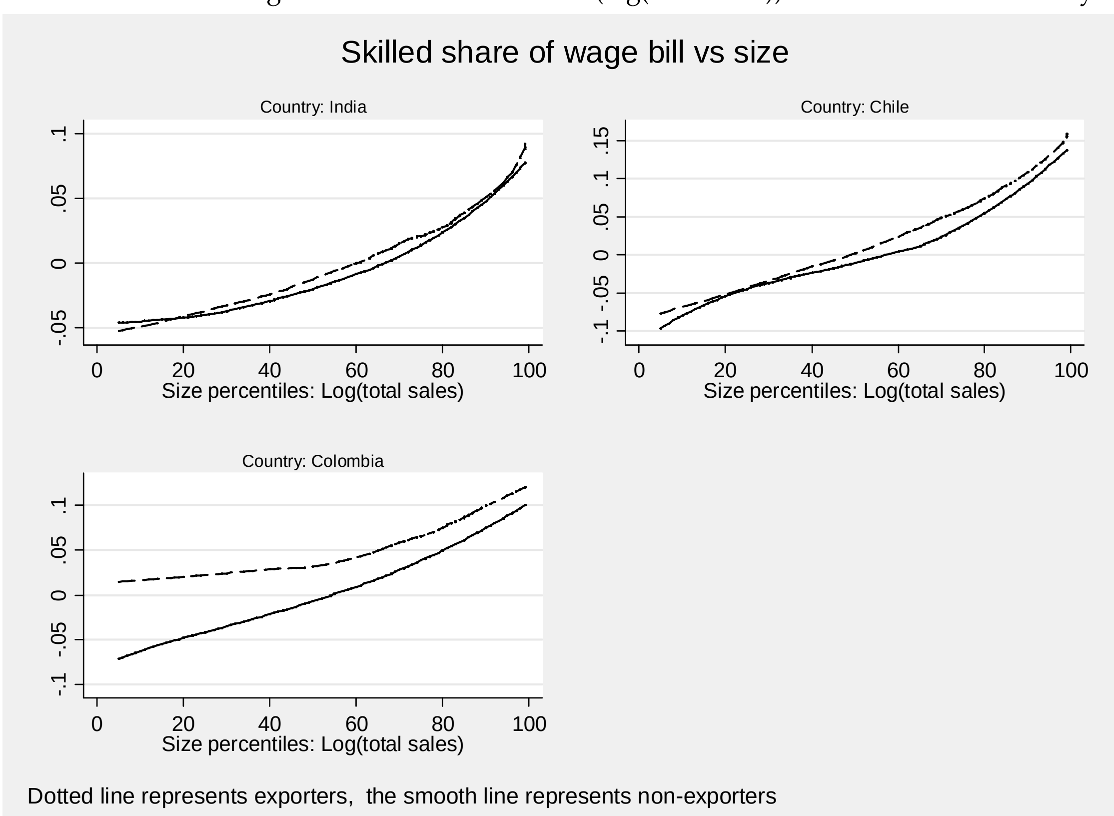


Table 5: Other quality proxies, India (1998)

All reported figures are coefficients on an exporter dummy which equals one for exporting establishments and is zero for non-exporters. All regressions included industry-year fixed effects, where the industry definition is 4 digit NIC. Column (1) includes only the exporter dummy. Column (2) includes log(total sales). Column (3) includes log(total sales) and square of log(total sales). Column (4) includes log(total employment). Column (5) includes log(total employment) and square of log(total employment). The number of observations is approximately 27000. Standard errors are clustered at industry level. + significant at 10%; * significant at 5%; ** significant at 1%.

Dependent variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
ISO 9000 certification dummy	0.147	0.116	0.099	0.125	0.118
	[0.016]**	[0.015]**	[0.014]**	[0.015]**	[0.014]**
Computer use dummy	0.35	0.175	0.144	0.246	0.237
	[0.016]**	[0.018]**	[0.018]**	[0.016]**	[0.016]**
Robotics use dummy	0.065	0.05	0.042	0.056	0.054
	[0.007]**	[0.006]**	[0.006]**	[0.006]**	[0.006]**
Computer network dummy	0.061	0.047	0.038	0.053	0.052
	[0.006]**	[0.006]**	[0.006]**	[0.006]**	[0.006]**
Internet use dummy	0.146	0.12	0.108	0.13	0.127
	[0.010]**	[0.009]**	[0.009]**	[0.009]**	[0.009]**
Survey response on floppy dummy	0.125	0.084	0.068	0.099	0.095
	[0.013]**	[0.013]**	[0.012]**	[0.012]**	[0.012]**
Log(total sales) included	No	Yes	Yes	No	No
Square of log(total sales) included	No	No	Yes	No	No
Log (total employment) included	No	No	No	Yes	Yes
Square of log(total employment) included	No	No	No	No	Yes

Table 6: Capital and skill intensity premium for Exporters, US (from Bernard and Jensen, 1999, Table 2)

This table is based on Table 2 in Bernard and Jensen (1999). All reported figures are coefficients on an exporter dummy which equals one for exporting establishments and is zero for non-exporters. All regressions included industry-year fixed effects, where the industry definition is 4 digit SIC. Column 1 includes only industry and state fixed effects. Column 2 includes log(employment). The number of observations is 56247 in 1984, 199258 in 1987 and 224009 in 1992. All effects are significant at 1% level.

	1984		**1987**		**1992**	
Dependent variable	**(1)**	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**
Log(capital/labor)	0.190	0.175	0.128	0.101	0.119	0.093
Log(average wage rate)	0.179	0.148	0.112	0.093	0.202	0.136
Log(skilled wage rate)	0.188	0.160	0.092	0.072	0.090	0.066
Log(unskilled wage rate)	0.088	0.036	0.099	0.052	0.114	0.046
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Log(employment)	No	Yes	No	Yes	No	Yes