Productivity, quality and exporting behavior under minimum quality constraints

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Productivity, Quality and Exporting Behavior Under Minimum Quality Requirements*

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Abstract

We develop a model of international trade with two sources of firm heterogeneity: "productivity" and "caliber". Productivity is modeled as is standard in the literature. Caliber is the ability to produce quality using few fixed inputs. While there is no quality restriction to sell domestically, exporting requires the attainment of minimum quality levels. Compared to single-attribute models of firm heterogeneity emphasizing either productivity or the ability to produce quality, our model provides a more nuanced characterization of firms' export behavior. In particular, it explains the empirical fact that firm size is not monotonically related with export status; there are small firms that export while there are large firms that only operate in the domestic market. The model also delivers novel testable predictions. Conditional on size, exporters sell products of higher quality and at higher prices, they pay higher wages and use capital more intensively. We test these predictions using data on manufacturing establishments in India, the U.S., Chile, and Colombia. The empirical findings confirm the theoretical predictions.

JEL codes: F10, F12, F14,

Keywords: Productivity, quality, exports, firm heterogeneity

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1 Introduction

Developing countries that have experienced rapid economic growth in the last decades have also shown impressive export performances (World Bank 1987, 1991, 1993, 2000). The development experiences of these countries suggest the potential importance of export growth for helping countries attain high income levels. There are various possible channels; for example, export growth might allow firms to take advantage of unexploited economies of scale (Krueger 1998, Demiroglu 2008). Export growth could also generate productivity gains from factor reallocations, reduce macroeconomic volatility with a more diverse exposure to shocks, and increase the absorption of foreign technologies due to more intense interactions with the outside world (Das et al. 2007). Since export growth is potentially an important driver of economic growth, understanding what makes firms successful in the global marketplace is critical. Furthermore, governments increasingly view export development as an important objective that justifies policies aimed at fostering it.[1] Thus, understanding the determinants of firms' export success can also contribute to enhancing the effectiveness of these policies.

While work in international trade has traditionally focused on determinants of comparative advantage at the sector level to explain patterns of trade across countries, a growing new literature emphasizes the role played by firm heterogeneity even within narrowly defined sectors. The shifting focus from sectors to firms reflects the understanding that, in addition to explaining countries' export development, the identification of the determinants of firms' export behavior is also critical for answering the field's core question of what determines trade patterns across countries.

In this growing heterogeneous-firm literature, a single attribute is usually the sole determinant of firms' ability to conduct business successfully, both domestically and abroad. This attribute is often modeled as productivity (e.g. Bernard et al. 2003, Melitz 2003, Chaney 2008, Arkolakis 2008), or alternatively as the ability to produce quality (Baldwin and Harrigan 2007, Johnson 2008, Verhoogen 2008, Kugler and Verhoogen 2008). Whether the single attribute is productivity or the ability to produce quality, the models share the property that the endowment of this attribute perfectly predicts firms' revenue (henceforth our measure of firm size) and export status. This property then implies a threshold firm size above which all firms export (and below which none do).

[1]For example, the number of export promotion agencies in the world has tripled in the last two decades (Lederman et al. 2007). Two international organizations, the WTO and UNCTAD, have also set up a joint agency (the International Trade Center) to help firms succeed in world markets.

Although these models parsimoniously explain the salient fact that exporters tend to be large (Clerides et al. 1998, Bernard and Jensen 1999) this prediction, common to single-attribute models, is contradicted in the data by a large number of "anomalous" firms. Notable among them are "born globals" – small and recently established firms with a strong export orientation (Oviatt and McDougall 1994 and Rialp et al. 2005), and "local dynamos" – large firms that are successful in their domestic markets but do not sell abroad (Boston Consulting Group 2008). More generally, the models leave much of the observed relationship between firm size and export status unexplained. As a preview of the data we will describe later in more detail, Figure 1 plots, for each of the four countries in our sample, the fraction of exporters in each size percentile (size is adjusted by industry mean). Violating the theoretical prediction, there are many exporters in the lowest size percentiles as well as a substantial fraction of firms with no export activity even among the highest percentiles of the size distribution.

In this paper, we develop a theoretical model that can explain these graphs. In addition to firm heterogeneity in "productivity" (modeled as is typically done in the literature), we introduce a second source of heterogeneity, "caliber", which is the ability to produce quality using few fixed inputs. We describe and analyze the equilibrium in a trade environment with minimum quality requirements for export. In the presence of these requirements, firms with high productivity and low caliber are large in size but they refrain from exporting because they find achieving the minimum export quality excessively onerous. In turn, firms with low productivity and high caliber are active in the export market despite being small. More generally, the model implies that export success might depend critically on firm capabilities that are not essential for domestic success.

Although our multi-attribute model explains the non-monotonic relationship between firm size and export status documented in Figure 1, our assessment of its empirical relevance for characterizing firms' exporting behavior is based on testing the set of additional predictions that it generates. These predictions are, as a whole, distinct from those generated by potential alternative explanations for the relationship between firm size and export status.[2] In particular, our model predicts that, *conditional on firm size*, exporters produce higher quality and sell at higher prices. Also, to the extent that production of quality goods requires more intensive use of skilled labor and capital, exporters will pay higher wages and be more capital intensive. We test and find strong support for these predictions using establishment-level data from India, the United States, Chile,

[2] We later discuss alternative sources of heterogeneity that could also explain the patterns observed in Figure 1 (but not all the remaining predictions of the model).

and Colombia.

The paper develops a partial-equilibrium heterogeneous-firm model with endogenous product quality. Product quality shifts out product demand but increases marginal costs of production and fixed costs of product development. The model embeds two sources of heterogeneity. Productivity (φ) is the ability to produce output using few variable inputs. Caliber (ξ) is the ability to produce quality with low fixed outlays. Even though caliber is the primary determinant of quality choice, productivity also affects this choice by reducing the impact of quality on marginal costs. Therefore, both caliber and productivity increase the firm's optimal choice of quality.

First, we solve for the industry equilibrium in a closed economy and in a benchmark case of an open economy with no quality requirements for export. In both cases, productivity (φ) and caliber (ξ) can be combined into a single "ability" parameter η ($\eta = \eta(\varphi, \xi)$), such that key variables of interest can be expressed in terms of this parameter. For example, regardless of the particular combinations of φ and ξ, firms with the same value of η have identical revenue, profits, and export status (though they choose different quality levels and charge different prices). Furthermore, the model allows for a representation that is isomorphic to Melitz's (2003) model. To survive in equilibrium, firms need an ability level above a certain threshold $\underline{\eta}$, while there is also a cut-off ability level $\underline{\eta}_u$ that determines firms' participation in the export market. The isomorphism with Melitz' model is appealing as it makes the case with no export quality requirements a transparent benchmark.

Next we analyze the full model, where we assume that to export firms are required to meet certain minimum quality requirements.[3] Although simplistic, this assumption captures a wealth of evidence suggesting that export success is associated with firms' ability to satisfy foreign quality requirements.[4] While different reasons, discussed later, can be invoked to justify the existence of these export quality requirements, our aim in this paper is not to identify their particular source

[3]This assumption is similar to Rauch (2007), who builds a model with two quality levels in which only the high quality good is internationally tradable.

[4]The international management literature widely acknowledges quality as a key requisite to access foreign markets (e.g. Guler et al. 2002, Gosen et al. 2005). In particular, several studies based on specifically-designed firm-level surveys both in developed and developing countries (e.g. Weston 1995, Erel and Ghosh 1997, Mersha 1997, Anderson et al. 1999, Corbett 2005) document satisfying the demands of international buyers as a critical motivation for obtaining quality management certification (ISO 9000). Using census or large-sample datasets, studies in international trade find that quality strongly influences firms' ability to export (Brooks 2006, Verhoogen 2008, Iacovone and Javorcik 2007). Finally, international organizations emphasize the attainment of quality standards as a crucial requirement for export competitiveness (International Trade Center 1999, 2001, 2005, World Bank 1999).

but rather to examine how they affect firms' export behavior.

In the presence of minimum export quality requirements, our model delivers predictions that depart strongly from those of single-attribute models. First, while in the closed economy firms with identical η have equal revenue and export status, in the open economy revenue and export status could differ even among firms with the same η. In particular, conditional on η, firms with high caliber (and low productivity) find the quality constraint not binding while firms with low caliber (and high productivity) might decide to remain exclusively oriented to the domestic market to avoid a costly investment in quality upgrading. Therefore, firms of equal size (i.e. revenue) in the closed economy could differ in size and export status after trade is liberalized. Single-attribute models, in contrast, predict that firm size in the closed economy is a perfect predictor of export status once the economy opens up to trade.

Second, in contrast to single-attribute models, in our model firm size is not sufficient information to infer export status. In particular, a domestic firm that does not export might be of the same size as another firm with a smaller volume of domestic sales but positive exports (the former firm would have high φ and low ξ while the latter would have low φ and high ξ). Thus, variation in export behavior within a given size percentile of the size distribution, as shown in Figure 1, can be explained by the existence of these two types of firms.

Third, *conditional on firm size*, the model predicts systematic differences between exporters and non-exporters. In particular, exporters sell products of higher quality and at higher prices. This prediction departs from those of standard models of firm heterogeneity, which predict higher productivity and hence *lower* prices for exporters. It is also substantially different from results of recently proposed single-attribute models with product quality (Baldwin and Harrigan 2007, Johnson 2007, Kugler and Verhoogen 2008), which predict that exporters sell products of higher quality and at higher prices *unconditionally.* In those models, since firm size is monotonically related to quality, prices, and export status, there is no variation in the other variables left to explain *once size is conditioned upon.*

In our model, because the export status of a firm provides relevant information about its quality and price even after conditioning on size, in a regression framework with price as the dependent variable, an indicator variable for export status as the independent variable, and controls for firm size, the coefficient on the export dummy should be positive. In addition, to the extent that higher quality products require more intensive use of skilled labor and capital, the coefficient on the export dummy in a similar specification with average wage or capital intensity as the dependent variables should also be positive. These are the predictions that we take to the data.[5]

We employ firm-level data for manufacturing in four countries: India, the United States, Chile, and Colombia. For India, we have a unique dataset covering all manufacturing plants for the year 1998. In addition to data on inputs, output and exports, this dataset includes product level information on revenue and quantities sold from which we derive prices per unit of output by product. For the U.S., we use data from the Census of Manufactures 1997 which, like the Indian dataset, has information on inputs, output, exports, and product level information on revenue and quantities sold to derive per-unit prices by product. For Chile and Colombia, we have panel data from census surveys of all manufacturing plants that employ more than 10 workers. Even though these datasets include information on inputs, output and export but not product-level information, we use them to obtain complementary evidence for some of our ancillary predictions.

Our analysis of the data shows that, consistent with the predictions of our model, exporters charge higher prices, pay higher wages and are more and capital intensive, even after size is controlled for. We find that the results are mostly consistent across countries and robust to using a number of alternative specifications. We undertake a number of tests to address potential concern about measurement error in revenue, as well as to rule out potential alternative explanations of our results.

The goal of this paper is to propose a more nuanced characterization of the determinants of firms' export behavior. Thus, our empirical analysis focuses on providing evidence of its relevance. This characterization, however, has important implications beyond what we explore here. For example, while single-attribute models predict that the largest firms will be the ones to enter foreign markets in response to trade liberalization, our model predicts that many of those large firms will be unwilling to pay the required quality-upgrading costs, thus lowering the predicted magnitude of export responses to trade liberalization. Similarly, the complex relationship between firm size and export status stressed in our model should also affect intensive-margin versus extensive-margin export responses to changes in trade costs (e.g. Arkolakis 2008, Chaney 2008, Ruhl 2008) as export volumes of new entrants in the export markets are allowed to be larger than those required to cover fixed exporting costs. More generally, we hope our model can be used as an alternative benchmark to evaluate the effects of exchange rate fluctuations, international price movements, trade liberalization, and other economic events or policies.

[5] Interestingly, some empirical papers estimate similar specifications but do not provide theoretical foundations to justify their use (Bernard and Jensen 1999, Fajnzylber and Fernandes 2006, Kugler and Verhoogen 2008).

Several recent papers have proposed international trade models with more than one source of heterogeneity that can explain the lack of a one-to-one correspondence between firm size and export status displayed in Figure 1. Alessandria and Choi (2007), Das et al. (2007) and Ruhl (2008) build dynamic models with sunk costs of entry into the export market that deliver a cross section of firms heterogeneous in productivity and export history. In addition, Ruhl (2008) allows for heterogeneity in sunk export costs while Das et al. (2007) allow for heterogeneity in both sunk and fixed exporting costs. A more closely related paper is Nguyen (2007), which also explains, among other facts, the existence of small exporters and large domestic firms by modeling heterogeneity in both the domestic and foreign appeal for a firm's products. In section 5.2.1, we discuss why none of these models can explain all the facts we document.[6]

The rest of the paper is organized as follows. Section 2 describes our theoretical model. Section 3 describes the data. Section 4 presents our baseline results. Section 5 performs several robustness checks. Section 6 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, we examine the case of a benchmark open economy with no quality constrains on exports. In Section 2.3 , we introduce minimum quality requirements for exports and analyze the open-economy equilibrium when those requirements are present. In Section 2.4, we analyze the factor requirements of quality production.

2.1 The closed economy

2.1.1 Demand

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 2008):

$$q_j = p_j^{-\sigma} \lambda_j^{\sigma-1} \frac{E}{P}, \qquad \sigma > 1, \tag{1}$$

[6]Bernard, Redding, and Schott (2006) allows for heterogeneous firm-specific "ability" and product-specific "expertises" but still predicts a monotonic relationship between firm size and export status. Sutton (2007) allows for "productivity" and "quality" but his analysis of the open economy equilibrium does not allow for firm heterogeneity in those attributes.

where j indexes product varieties while p_j and λ_j are, respectively, the price and quality of variety j. Since we assume that each firm produces only one variety, j also indexes firms. E is the (exogenously given) level of expenditure and the "price aggregator" P is defined as $P \equiv \int_j p_j^{1-\sigma} \lambda_j^{\sigma-1} dj$. Since $\sigma > 1$, the price aggregator P is inversely related to product prices; thus higher (lower) prices imply a lower (higher) value of P. P can be thought of as an index of the toughness of competition in the market. A higher P then implies a tougher competitive market.[7]

Product quality is modeled 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:

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

Equation (2) indicates that larger firms are those that charge lower quality-adjusted prices.

2.1.2 Production

The model allows for two sources of firm heterogeneity. Following standard models (Melitz 2003, Bernard et al. 2003), the first source of heterogeneity is "productivity", φ, which reduces variable production costs. Productivity enters the marginal cost function in the following form:

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

where c is a constant parameter. In equation (3), marginal costs are assumed to be independent of scale and increasing in product quality (λ). Conditional on quality, firms with higher productivity (φ) pay lower variable costs.

In addition to productivity, there is a second source of heterogeneity, which we denote "caliber" (ξ). Caliber indexes firms' ability to develop high quality products paying low fixed costs. Fixed costs are represented by the following function:

$$F(\lambda, \xi) = F_0 + \frac{f}{\xi} \lambda^{\alpha} \tag{4}$$

where F_0 is a fixed cost of plant operation and f is a constant parameter.[8] Attaining higher quality

[7] Note that $P^{1-\sigma}$ is the cost-of-utility index for a CES utility function.

[8] In section 2.4 we derive c and f as a function of factor prices and other parameters of the model.

requires paying higher fixed costs.[9] Conditional on attaining a given level of quality, those costs are lower for high-caliber firms.

2.1.3 Firm's optimal choice of price and quality

Firms choose price and quality to maximize post-entry profits, Π, the difference between operative profits, Π_0, and fixed costs. The first order condition with respect to price yields the standard constant mark-up result of CES demand: $p_d = \frac{\sigma}{\sigma-1}\frac{c}{\varphi}\lambda_d^{\beta}$.[10] Using this result, the first order condition with respect to quality yields:

$$\lambda_d(\varphi,\xi) = \left[\frac{1-\beta}{\alpha}\left(\frac{\sigma-1}{\sigma}\right)^{\sigma}\left(\frac{\varphi}{c}\right)^{\sigma-1}\frac{\xi}{f}\frac{E}{P}\right]^{\frac{1}{\alpha'}} \tag{5}$$

where $\alpha' \equiv \alpha - (1-\beta)(\sigma-1)$. To ensure that the first order conditions identify a maximum we assume that $0 < \beta < 1$, so that marginal costs are increasing in quality but not excessively fast, and we assume that $\alpha' > 0$, so that fixed costs grow sufficiently fast with quality. Both productivity (φ) and caliber (ξ) have a positive impact on quality choice since they reduce, respectively, the marginal costs and fixed costs of quality production.

Using equation (5) to solve for the optimal price, we obtain

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

Conditional on φ, high caliber firms sell their products more expensively because they produce higher quality and hence have higher marginal costs. The effect of productivity on price conditional on ξ, however, is ambiguous. On the one hand, productivity lowers marginal costs and thus prices. On the other hand, it induces the choice of higher quality levels, which in turn raises marginal costs and prices. Whether one or the other effect dominates depends on the sign of $\alpha - (\sigma - 1)$. Equation (6) shows that prices depend on the value of two parameters. Therefore, in contrast to the predictions of quality-based models with a single heterogeneity factor (Baldwin and Harrigan 2007, Johnson 2008, Kugler and Verhoogen 2008), prices here are not monotonically related to productivity, size, or export status.

[9] This approach to modeling quality production is based on Sutton (1991). It also captures the trade-offs that are present in Yeaple (2005) and Bustos (2005), where the adoption of a superior technology requires firms to incur a fixed cost. In those models, investing in high technology shifts down the marginal cost. In a world with no export quality requirements and under specific demand assumptions, this type of investment is isomorphic to one that shifts out the demand curve.

[10] Subindex d is used to indicate "domestic" firms, those that only operate in the domestic market (all firms are domestic in this section).

2.1.4 The cut-off function

Substituting the solutions for quality and price into equation (2), we obtain firm revenue:

$$r_d(\varphi, \xi) = H\left(\frac{\varphi}{c}\right)^{\frac{\alpha(\sigma-1)}{\alpha'}}\left(\frac{\xi}{f}\right)^{\frac{\alpha-\alpha'}{\alpha'}}\left(\frac{E}{P}\right)^{\frac{\alpha}{\alpha'}}, \tag{7}$$

$H \equiv \left(\frac{\sigma-1}{\sigma}\right)^{\frac{(\alpha\sigma-\alpha')}{\alpha'}}\left(\frac{1-\beta}{\alpha}\right)^{\frac{\alpha-\alpha'}{\alpha'}}$, as an increasing function of productivity (φ) and caliber (ξ).

From standard results of CES demand we know that operative profits equal $\frac{r}{\sigma}$. Therefore, $\Pi_d = \frac{1}{\sigma}r_d - F_d$. Using equations (4), (5), and (7), firm profits are:

$$\Pi_d(\varphi, \xi) = J\left(\frac{\varphi}{c}\right)^{\frac{\alpha(\sigma-1)}{\alpha'}}\left(\frac{\xi}{f}\right)^{\frac{\alpha-\alpha'}{\alpha'}}\left(\frac{E}{P}\right)^{\frac{\alpha}{\alpha'}} - F_0 \tag{8}$$

where $J \equiv \left(\frac{\sigma-1}{\sigma}\right)^{\frac{\alpha\sigma}{\alpha'}}\left(\frac{1-\beta}{\alpha}\right)^{\frac{\alpha}{\alpha'}}\left(\frac{\alpha'}{\alpha-\alpha'}\right)$. Profits are also increasing in productivity and caliber.

Firms remain in the market only if they can make non-negative profits ($\Pi_d \geq 0$). Since profits depend on two variables, φ and ξ, this survival condition results in a cut-off *function* rather than in a cut-off *value:*

$$\underline{\xi}(\varphi) = f\left(\frac{F_0}{J}\right)^{\frac{\alpha'}{\alpha-\alpha'}}\left(\frac{\varphi}{c}\right)^{\frac{-\alpha}{1-\beta}}\left(\frac{E}{P}\right)^{\frac{-\alpha}{\alpha-\alpha'}}. \tag{9}$$

For each productivity level φ, there is a minimum caliber such that firms above this minimum earn non-negative profits. The cut-off function $\underline{\xi}(\varphi)$ is decreasing in φ, highlighting a trade-off for survival between φ and ξ: more productive firms can afford to be of lower caliber while high caliber firms can afford to be less productive. The function $\underline{\xi}(\varphi)$ is displayed in Figure 2. Each firm, characterized by a pair of draws (φ, ξ), can be represented in the figure by a single point. Firms above $\underline{\xi}(\varphi)$ survive while those below this curve exit the market.

A convenient way of summarizing information about firms' productivity and caliber is to define their "ability" η as[11]

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

The model has the property that both revenue and profits can be expressed as functions of η alone:[12]

$$r_d(\eta) = \eta H\left(\frac{E}{P}\right)^{\frac{\alpha}{\alpha'}}, \qquad \Pi_d(\eta) = \eta J\left(\frac{E}{P}\right)^{\frac{\alpha}{\alpha'}} - F_0. \tag{10}$$

The main implication of this property is that η is a summary statistic for φ and ξ in both functions, which depend on these heterogeneity factors only through η. Thus firms with the same η – such as

[11] We include the parameters c and f in the definition of η only for notation compactness.

[12] Equation (2) implies this is also true for pure prices. Firms with higher (lower) η charge lower (higer) pure prices.

those along $\underline{\xi}(\varphi)$ – obtain equal revenue and equal profits regardless of their particular combinations of η and ξ. In Figure 2, this property implies that iso-ability curves are also iso-revenue curves and iso-profit curves. Due to this property, the model can be collapsed into a one-dimensional model iso-morphic to Melitz (2003). In particular, as in the latter model we can think of η as a single productivity draw that determines entry-exit decisions: firms survive *iff* η is above a cut-off value $\underline{\eta}$, determined so that $\Pi_d(\underline{\eta}) = 0$.[13] This cut-off value satisfies $\underline{\eta} = \eta(\varphi, \underline{\xi}(\varphi))$.

2.1.5 Free-entry and industry equilibrium

Before entering the industry, firms do not know their productivity or caliber. To learn them, they have to pay a fixed entry cost $f_e > 0$. Once they pay this cost, they draw φ and ξ from a bivariate probability distribution with density $v(\varphi, \xi) > 0$ on the support $[0, \overline{\varphi}] \times [0, \overline{\xi}]$.

There is free entry into the industry. Therefore, firms pay f_e and learn their productivity and caliber only if the expected post-entry profits, $\overline{\Pi}$, are greater or equal than the entry cost. Since ex-ante all firms are equal, the free entry condition imposes that

$$\overline{\Pi}(P) = \int_0^{\overline{\varphi}} \int_{\underline{\xi}(\varphi,P)}^{\overline{\xi}} \Pi_d(\varphi, \xi, P)\, v(\varphi, \xi)\, d\xi d\varphi = f_e. \tag{11}$$

Equilibrium in the industry involves finding a P that solves equation (11) (in this section we explicitly include P as argument of Π_d and $\underline{\xi}$ to emphasize its role). Finding a closed-form solution for P in equation (11) would require assuming a particular shape of the bivariate distribution $v(\varphi, \xi)$. Instead, we prefer to keep the analysis general and prove that a solution for P in equation (11) exists and is unique.

Proposition 1. *In the closed economy, an equilibrium in the industry exists and is unique*

Proof. Since $\Pi_d(\varphi, \xi, P)$ and $\underline{\xi}(\varphi, P)$ are continuous and differentiable in P, $\overline{\Pi}(P)$ is also continuous and differentiable in P. Because $\overline{\Pi}(P)$ is continuous, to demonstrate existence we only need to show that this function takes the value f_e at least once. Substituting equations (8) and (9) into (11) it is easy to see that $\lim_{P\to 0} \overline{\Pi}(P) = \infty$ and $\lim_{P\to\infty} \overline{\Pi}(P) = 0$. This implies that there exists at least one value of P such that $\overline{\Pi}(P) = f_e$.

[13] This property stems from the fact that the two components of the profit function, $\Pi_0(\lambda)$ and $F(\lambda)$, are particular cases of the polynomial form $a\lambda^b$. Thus, their ratio is proportional to the ratio of their derivatives. As a result, fixed costs are optimally chosen to be proportional to operative profits, which implies that they are also proportional to revenue and post-entry profits.

Since $\forall(\varphi,\xi)$, $\frac{d\Pi_d(\varphi,\xi,P)}{dP} < 0$, application of Leibniz's rule implies that $\frac{d\overline{\Pi}(P)}{dP} < 0$, i.e. $\overline{\Pi}(P)$ is a strictly decreasing function of P. Therefore, $\overline{\Pi}(P)$ takes the value f_e only once. *QED*

Once P is determined, we can solve for the equilibrium prices, quality levels, revenues, profits, and cut-off values, all of which depend on P. In addition, the probability of surviving, P_{in}, the productivity and caliber joint density conditional on surviving, $h(\varphi,\xi)$, and the mass of surviving entrants, M, are also determined. The probability of surviving is given by

$$P_{in} = \int_0^{\overline{\varphi}} \int_{\underline{\xi}(\varphi,P)}^{\overline{\xi}} v(\varphi,\xi)\, d\xi d\varphi \tag{12}$$

where a higher value of the cut-off function $\underline{\xi}(\varphi,P)$ implies a lower probability of successful entry. The productivity and caliber joint density functions conditional on surviving is simply $h(\varphi,\xi) = \frac{1}{P_{in}} v(\varphi,\xi)$. Finally, P can be expressed as the aggregation across productivity and (surviving) caliber levels instead of across firms. Making appropriate substitutions we obtain

$$P = \int_j p_j^{1-\sigma} \lambda_j^{\sigma-1} dj = M^{\frac{\alpha'}{\alpha}} HE^{\frac{\alpha-\alpha'}{\alpha}} (\widetilde{\eta})^{\frac{\alpha'}{\alpha}} \tag{13}$$

where $\widetilde{\eta} \equiv \int_0^{\overline{\varphi}} \int_{\underline{\xi}(\varphi,P)}^{\overline{\xi}} \eta(\varphi,\xi) h(\varphi,\xi)\, d\xi d\varphi$ is the (weighted) average ability of surviving firms. Solving for M in equation (13) yields $M = HE^{\frac{\alpha'-\alpha}{\alpha'}} P^{\frac{\alpha}{\alpha'}} \widetilde{\eta}^{-1}$. Since the right-hand-side of this equation is increasing in P, in equilibrium tougher competition in the market is associated with a larger number of entrants.

2.2 The open economy with unconstrained export quality

Before describing the full model, we examine the open-economy equilibrium in a two-country world economy in which export quality is unconstrained. The analysis of this section provides a benchmark for the results of the constrained case we evaluate later. Rather than analyzing differences across countries in firm characteristics or the effects of trade liberalization, we focus on the characterization of the equilibrium cross-section of firms in a given country. We find that, as in the closed economy, in this "unconstrained" open economy the model can also be collapsed into a model with only one source of heterogeneity à la Melitz (2003).

The structure of the industry in the foreign country is analogous to that of the home country. However, the parameters F_0^*, c^*, f^*, f_e^*, and E^*, denoted with asterisks for the foreign country, are allowed to be different. The joint density function from which firms draw their productivity and caliber is $\upsilon^*(\varphi, \xi) > 0$, defined on the support $[0, \overline{\varphi}] \times [0, \overline{\xi}]$, while the (endogenously determined) price aggregator is P^*. We analyze the equilibrium cross-section of firms in the home country. The qualitative characteristics of the equilibrium in the foreign country are analogous.

In order to export, firms in the home and foreign countries need to pay fixed exporting costs, f_x and f_x^*, respectively, and iceberg transport costs τ. Firms need to decide whether to become exporters or remain domestic. They choose to export if the marginal profits they would make in the foreign market outweigh the fixed exporting costs. Exporters face CES demand in both the domestic and the foreign markets and thus charge the same (factory gate) price at home and abroad. The maximization problem in this case is analogous to the one described in the previous section, except that here total demand, $q^w \equiv q + q^*$, is the sum of domestic and foreign demand. Total demand is determined by $q^w = p^{-\sigma}\lambda^{\sigma-1}W$, where $W = \frac{E}{P} + \tau^{-\sigma}\frac{E^*}{P^*}$. Then, exporter's optimal quality, revenue, and profits are given by the following expressions:

$$\lambda_u(\varphi, \xi) = \left[\frac{1-\beta}{\alpha}\left(\frac{\sigma-1}{\sigma}\right)^{\sigma}\left(\frac{\varphi}{c}\right)^{\sigma-1}\frac{\xi}{f}W\right]^{\frac{1}{\alpha'}}, \tag{14}$$

$$r_u(\eta) = \eta H W^{\frac{\alpha}{\alpha'}} \tag{15}$$

and

$$\Pi_u(\eta) = \eta J W^{\frac{\alpha}{\alpha'}} - F_0 - f_x. \tag{16}$$

Equations (14), (15), and (16) are analogous to equations (5), (7), and (8), which still determine quality, revenue and profits for firms that do not export (the only difference is that W substitutes for $\frac{E}{P}$). Therefore, for (unconstrained) exporters η is also a summary statistic for φ and ξ in the revenue and profit functions, which implies that, as in the closed economy, iso-ability curves are also iso-revenue curves and iso-profit curves.

Define the difference in benefits between exporting and not exporting as $\Delta_u\Pi \equiv \Pi_u - \Pi_d$. Using (10) and (16), this difference can also be expressed as a function of η:

$$\Delta_u\Pi(\eta) = \eta J A - f_x \tag{17}$$

where $A = \left[W^{\frac{\alpha}{\alpha'}} - \left(\frac{E}{P}\right)^{\frac{\alpha}{\alpha'}}\right] > 0$.

Firms choose to export if $\Delta_u\Pi(\eta) \geq 0$. Setting $\Delta_u\Pi(\eta) = 0$ and solving for η, we obtain an export cut-off value, $\underline{\eta}_u$, such that only firms with ability above this value export. Since η is increasing in both φ and ξ, the cut-off value $\underline{\eta}_u$ also determines a cut-off function

$$\underline{\xi}_u(\varphi) = \frac{f_x}{JA}^{\frac{\alpha'}{\alpha-\alpha'}} f \left(\frac{\varphi}{c}\right)^{-\frac{\alpha(\sigma-1)}{\alpha-\alpha'}}, \tag{18}$$

which satisfies $\underline{\eta}_u = \eta(\varphi, \underline{\xi}_u(\varphi))$. Since η is constant along $\underline{\xi}_u(\varphi)$, this cut-off function is also an iso-revenue curve and an iso-profit curve.

As in Melitz (2003), there are two possible scenarios: either all surviving firms export or only a subset of them do it. The latter case prevails if firms located on the curve $\underline{\xi}(\varphi)$ make negative profits in the export market ($\Pi_u(\varphi, \underline{\xi}(\varphi)) < 0$). Hence, the existence of (purely) domestic firms is ensured with $f_x > (F_0 A) / \frac{E}{P}^{\frac{\alpha}{\alpha'}}$, which we assume holds for the remainder of the paper. This assumption then implies that $\underline{\xi}_u(\varphi) > \underline{\xi}(\varphi)$.

Figure 3 shows the equilibrium configuration of firms in the open economy with unconstrained export quality. Firms with caliber below $\underline{\xi}(\varphi)$ (those with ability below the cut-off value $\underline{\eta}$) exit the market. Firms with caliber between this function and the export cut-off function $\underline{\xi}_u(\varphi)$ (those with ability between $\underline{\eta}$ and $\underline{\eta}_u$) are active in the domestic market but do not export. Finally, firms with caliber draws above $\underline{\xi}_u(\varphi)$ (those with ability above $\underline{\eta}_u$) sell domestically and also export.

Since there is a one-to-one correspondence between η, revenue, and $\Delta_u\Pi$, firm size (revenue) is a perfect predictor of export status. In particular, there is a cut-off size, $r_d(\underline{\eta}_u)$, such that every firm below that size does not export while there is another cut-off size, $r_u(\underline{\eta}_u)$, such that every firm above it exports.[14] The predictions of the unconstrained model for the relationship between size and export status are therefore stark. Figure 4 shows the fraction of exporting firms as a function of size. As illustrated in the figure, this is a discontinuous step function. No firm with sales below the cut-off value $r_u(\underline{\eta}_u)$ exports while all firms with sales above that value do it. This implication is shared with all single-attribute models of firm heterogeneity.[15]

Finally, we note that even though revenue and profits are equal among all firms on the same iso-ability curve η, the quality of their products is not equal. Consider the case of an exporter located on iso-ability and iso-revenue curve $\xi^k(\varphi)$, defined so that $r_u(\varphi, \xi^k(\varphi)) = k$. Solving this equation for ξ and substituting the result into equation (14), we obtain:

$$\lambda_u(\varphi, \xi^k(\varphi)) = B\left(\frac{\varphi}{c}\right)^{-\frac{\sigma-1}{\alpha-\alpha'}} \tag{19}$$

where B is a function of constant parameters. Equation (19) shows that quality decreases along an iso-revenue curve in $\varphi \times \xi$ space.[16]

[14] No firm has revenues in the interval $\left(r_d(\varphi, \underline{\xi}_u(\varphi)), r_u(\varphi, \underline{\xi}_u(\varphi))\right)$.

[15] Another implication, which we do not pursue further in this paper, is that since η summarizes all relevant information determining relative size both before and after trade liberalization, the size ranking of firms should be invariant to the trade regime.

[16] For non-exporters, quality is also decreasing in φ along any iso-revenue curve, both in the open economy and in

2.3 The open economy with constrained export quality

A substantial amount of evidence suggests that success in foreign markets is associated with firms' ability to attain high levels of product quality. Brooks (2006) finds that Colombian firms in sectors with lower quality gaps relative to G-7 countries – measured by the unit-value difference of their exports to the U.S. – tend to export a larger fraction of their output. Verhoogen (2008) finds that Mexican firms invest in quality upgrading in response to export opportunities created by the Peso devaluation. Iacovone and Javorcik (2007), also working with Mexican firm-level data, find that firms increase their average prices two years before they start exporting, which suggests a process of quality upgrading in preparation to export. Alvarez and Lopez (2005) find similar results focusing on investment outlays, presumably targeted at quality upgrading. More direct evidence of the existence of export quality requirements is provided by studies in international management. Based on firm-level surveys both in developed and developing countries, those studies document firms' need to upgrade quality as a crucial requirement to export [e.g. Weston 1995 (U.S.), Erel and Ghosh 1997 (Turkey), Mersha 1997 (Africa), Anderson et al. 1999 (Canada and U.S.), Corbett 2005 (9 mostly-developed countries)]. Policy-oriented research also emphasizes the existence of quality requirements for exports as part of a broader concern about the impact of standards on market access (World Bank 1999, WTO 2005, Maskus et al. 2005, Chen et al. 2006).

The potential motives for the existence of export quality requirements are various. First, higher income countries tend to consume higher-quality goods (Hallak 2006, 2007) and therefore are likely to set higher minimum quality standards. Then, firms that on average ship their products to higher income countries should find quality standards to be more stringent. Even if per capita income in the export destination market is similar to that in the source country, firms may find export quality requirements more stringent than domestic ones if quality standards are higher in the former than in the latter countries.[17] Second, transportation costs are proportionally higher for low-quality goods (Alchian and Allen 1964, Hummels and Skiba 2004). Therefore, they can become prohibitive below some minimum threshold. Third, export quality requirements might be present in the form of requirements of management quality certification (e.g. ISO 9000), which are more intensively demanded in international transactions. Since international transactions are often conducted under severe information asymmetry problems, management quality certification

the closed economy.

[17]We will argue later that the much earlier implementation of ISO 9000 in the European Union than in the United States might explain our findings for the latter country.

can alleviate those problems due to its quality-signaling, common-language, and conflict-setting properties (Guler et al. 2002, Hudson and Jones 2003, Terlaak and Kind 2006, Clougherty and Grajek 2008).

In our model, we capture the idea that entering the export market imposes more stringent quality requirements by simply assuming that firms need to attain a minimum quality level to export. Since in this paper we do not intend to uncover the particular source of these requirements but rather assess their implications for the export behavior of firms, we favor a modeling choice that, although stylized, is robust to alternative determinants of the quality constraints. Furthermore, the predictions of the model stem more generally from the weaker condition that quality requirements for export are more stringent than those prevailing in the domestic market.

In this section, we examine the open-economy equilibrium in a two-country world economy with minimum quality requirements for export. The minimum is introduced as follows. In order to export, firms need to attain at least quality level $\underline{\lambda}$. The minimum is allowed to be different across countries. Thus, it is $\underline{\lambda}^*$ for firms in the foreign country that want to export to the home country. In every other respect, the "constrained" environment we analyze here is identical to the unconstrained environment we analyzed in the previous section.

2.3.1 Characterization of the equilibrium

The main implication of the minimum export quality requirement is to force firms that would otherwise export with quality $\lambda_u < \underline{\lambda}$ to choose between upgrading their quality (relative to their unconstrained choice) or not participating in the export market. In this section, we characterize the equilibrium in the constrained environment. As in the unconstrained case, we focus on the cross-sectional configuration of firm characteristics within a country, represented in Figure 5.

Firms with sufficiently low realizations of φ or ξ do not survive in the market. Those firms are located in region I of the figure, delimited above by the cut-off function $\underline{\xi}(\varphi)$ – still determined by equation (9). In contrast, firms located above $\underline{\xi}(\varphi)$ are either domestic or exporters. These two types of firms are separated in the figure by the export cut-off function, $\underline{\xi}_x(\varphi)$. This function cannot be solved in closed form. To characterize it, we first need to describe the two dashed curves, $\underline{\xi}_u(\varphi)$ and $\underline{\xi}_{\underline{\lambda}}(\varphi)$.

The curve $\underline{\xi}_u(\varphi)$ is the (hypothetical) export cut-off function for a single firm if the export quality restriction were removed only for that firm. By definition, $\underline{\xi}_u(\varphi)$ satisfies $\Delta_u\Pi(\varphi, \underline{\xi}_u(\varphi)) = 0$. Since $\Delta_u\Pi$ is monotonically increasing in ξ, it takes negative values in region II of the figure, where

$\xi < \underline{\xi}_u(\varphi)$. Thus, firms in this region would not export even if unconstrained in their export quality. These firms operate only in the domestic market; they do not export.

In the constrained environment, $\underline{\xi}_u(\varphi)$ is not the relevant export cut-off function. However, it coincides with it in part of its range. Since the unconstrained choice of quality is monotonically decreasing in φ along $\underline{\xi}_u(\varphi)$ (see (19)), there exists a threshold productivity value, $\varphi_{\underline{\lambda}}$, such that to its left unconstrained quality is above $\underline{\lambda}$.[18] Thus, firms located on $\underline{\xi}_u(\varphi)$ with productivity $\varphi \leq \varphi_{\underline{\lambda}}$ "spontaneously" choose quality levels above the minimum requirement. Also, as unconstrained quality choice is increasing in ξ, unconstrained quality is higher than $\underline{\lambda}$ for firms located above $\underline{\xi}_u(\varphi)$ on that range of productivity values. For those firms, the minimum export requirement is not binding. Thus, their export decision is still determined by the sign of $\Delta_u \Pi$. This function equals zero on $\underline{\xi}_u(\varphi)$ and is greater than zero above it. Hence, firms located in region V.a. of the figure prefer to export.

To characterize the export cut-off function $\underline{\xi}_x(\varphi)$ to the right of $\varphi_{\underline{\lambda}}$, we still need to describe the second dashed curve in Figure 5, $\underline{\xi}_{\underline{\lambda}}(\varphi)$. This curve is the locus of firms that spontaneously choose quality level $\underline{\lambda}$. Equating (14) to $\underline{\lambda}$, the expression for this iso-quality curve is[19]

$$\underline{\xi}_{\underline{\lambda}}(\varphi) = \underline{\lambda}^{\alpha'} f \frac{\alpha}{1-\beta} \left(\frac{\sigma-1}{\sigma}\right)^{-\sigma} \left(\frac{\varphi}{c}\right)^{-(\sigma-1)} W^{-1}. \tag{20}$$

Comparing equations (20) and (18), we can check that these two curves coincide at $\varphi_{\underline{\lambda}}$ and $\underline{\xi}_{\underline{\lambda}}(\varphi) > \underline{\xi}_u(\varphi)$ to the right of $\varphi_{\underline{\lambda}}$. Since firms located above $\underline{\xi}_{\underline{\lambda}}(\varphi)$ spontaneously satisfy the export quality requirement, their export decisions are also governed by the sign of $\Delta_u \Pi$. Thus, firms in region V.b, where $\xi \geq \underline{\xi}_{\underline{\lambda}}(\varphi) > \underline{\xi}_u(\varphi)$ also prefer to export.

Firms located between $\underline{\xi}_u(\varphi)$ and $\underline{\xi}_{\underline{\lambda}}(\varphi)$ would find it profitable to sell abroad absent the export quality requirement. However, in the presence of the constraint they are forced to upgrade the quality of their products if they wish to export. These firms need to decide whether to invest additional resources in attaining the minimum export quality or keep their operations domestic. In case they export, their quality is $\underline{\lambda}$. In that case, marginal cost is $\frac{c}{\varphi}\underline{\lambda}^{\beta}$ and price is $p_c(\varphi) = \frac{\sigma}{\sigma-1}\frac{c}{\varphi}\underline{\lambda}^{\beta}$ (subindex c is used to denote "constrained" firms). Revenue and profits are, respectively,

$$\begin{aligned} r_c(\varphi) &= \left(\frac{\sigma-1}{\sigma}\frac{\varphi}{c}\right)^{\sigma-1} \underline{\lambda}^{\alpha-\alpha'} W \\ \Pi_c(\varphi,\xi) &= \frac{1}{\sigma}\left(\frac{\sigma-1}{\sigma}\frac{\varphi}{c}\right)^{\sigma-1} \underline{\lambda}^{\alpha-\alpha'} W - \frac{f}{\xi}\underline{\lambda}^{\alpha} - f_x - F_0. \end{aligned} \tag{21}$$

[18] The expression for $\varphi_{\underline{\lambda}}$ can be obtained using equations (14) and (18) to solve for φ in $\lambda_u(\varphi, \underline{\xi}_u(\varphi)) = \underline{\lambda}$.

[19] The iso-quality curve is discontinuous at $\varphi_{\underline{\lambda}}$. To the left of $\varphi_{\underline{\lambda}}$, its expression is analogous to equation (20), except that $\frac{E}{P}$ substitutes for W.

Since ξ does not affect quality choice for constrained exporters, marginal cost, price, and revenue do not depend on the value of this heterogeneity factor. Profits, however, depend on ξ since firms with higher caliber find it less costly to attain $\underline{\lambda}$. Also, as firms need to deviate from their optimal (unconstrained) choice of quality, it is easy to establish that $\Pi_c(\varphi, \xi) \leq \Pi_u(\varphi, \xi)$.

Define the difference in benefits between exporting and not exporting as $\Delta\Pi_c \equiv \Pi_c(\varphi, \xi) - \Pi_d(\varphi, \xi)$. This difference can be written as

$$\Delta\Pi_c(\varphi, \xi) \equiv \frac{1}{\sigma}\left(\frac{\sigma-1}{\sigma}\frac{\varphi}{c}\right)^{\sigma-1}\underline{\lambda}^{\alpha-\alpha'}W - \frac{f}{\xi}\underline{\lambda}^{\alpha} - f_x - J\left(\frac{\varphi}{c}\right)^{\frac{\alpha(\sigma-1)}{\alpha'}}\left(\frac{\xi}{f}\right)^{\frac{\alpha-\alpha'}{\alpha'}}\left(\frac{E}{P}\right)^{\frac{\alpha}{\alpha'}}.$$

The export cut-off function $\underline{\xi}_x(\varphi)$ is implicitly defined by the equation $\Delta\Pi_c(\varphi, \underline{\xi}_x(\varphi)) = 0$.

Even though we cannot solve for $\underline{\xi}_x(\varphi)$ in closed form, we can characterize its slope and bound its location. First, $\Delta\Pi_c(\varphi, \xi)$ is continuous and strictly increasing in its two arguments. Hence, by application of the implicit function theorem, $\underline{\xi}_x(\varphi)$ is continuous and decreasing in φ. Second, we want to show that the export cut-off function is located between $\underline{\xi}_u(\varphi)$ and $\underline{\xi}_{\underline{\lambda}}(\varphi)$. Note that $\Delta\Pi_c(\varphi, \underline{\xi}_u(\varphi)) < \Delta\Pi_u(\varphi, \underline{\xi}_u(\varphi)) = 0$. Therefore, firms located on $\underline{\xi}_u(\varphi)$ strictly prefer not to export. Also note that, since the export restriction is (just) not binding for firms located on $\underline{\xi}_{\underline{\lambda}}(\varphi)$, $\Delta\Pi_c(\varphi, \underline{\xi}_{\underline{\lambda}}(\varphi)) = \Delta\Pi_u(\varphi, \underline{\xi}_{\underline{\lambda}}(\varphi)) > 0$. Therefore, firms located along $\underline{\xi}_{\underline{\lambda}}(\varphi)$ strictly prefer to export. Combining these two results, the continuity of $\Delta\Pi_c(\varphi, \xi)$, and the fact that this function is strictly increasing in ξ, we can establish that $\forall\varphi > \varphi_{\underline{\lambda}} : \underline{\xi}_u(\varphi) < \underline{\xi}_x(\varphi) < \underline{\xi}_{\underline{\lambda}}(\varphi)$.

The export cut-off function $\underline{\xi}_x(\varphi)$ separates the last two regions of Figure 5. Firms located between $\underline{\xi}_u(\varphi)$ and $\underline{\xi}_x(\varphi)$ find that upgrading quality to satisfy the export requirement is too onerous. Those firms, located in region III, remain domestic. In contrast, firms located between $\underline{\xi}_x(\varphi)$ and $\underline{\xi}_{\underline{\lambda}}(\varphi)$, in region IV, upgrade their quality to meet the export requirement. Firms in region IV become constrained exporters.

In the case of the foreign country the analysis is analogous. In Appendix 1 we prove existence and uniqueness of the equilibrium in this world economy.[20]

2.3.2 Firm size and export status

The existence of a minimum export quality requirement breaks the sufficiency of η for predicting firm size (revenue) while it also breaks the sufficiency of size for predicting export status. In Figure 6, we add three representative iso-revenue curves, r_1, r_2, and r_3, to the equilibrium configuration of

[20] A particular case of the proof, with $\underline{\lambda} = \underline{\lambda}^* = 0$, proves equilibrium existence and uniqueness in the unconstrained case.

firms displayed in Figure 5. First, r_1 represents a set of iso-revenue curves fully located in region II. These curves can be derived from equation (10) and contain only domestic firms. Along the curves, the value of η is constant and is also a sufficient statistic for revenue, as in the unconstrained case. Identical characteristics are shared by r_2, which represents a set of iso-revenue curves fully located in region III.

Iso-revenue curve r_3 requires more careful analysis. Its upper-left portion is located in region V. On this part of r_3, firms export and have identical η. Since quality decreases along the curve, at point A quality reaches the minimum level $\underline{\lambda}$. From A, r_3 goes straight down to point B, which is located on $\underline{\xi}_x(\varphi)$. Since firms on this segment all produce quality $\underline{\lambda}$ and have the same productivity φ, their marginal costs, price, and revenue are also equal. At point B there is a discontinuity in r_3, which reappears further to the right — in region III — as shown in the figure. This last portion of the iso-revenue curve contains only domestic firms, which attain revenue level r_3 compensating their lack of exports with more voluminous sales in the domestic market. Note that, as they have a higher η, in an unconstrained environment they would have been larger than firms on the upper-left portion of r_3. The limit case of this set of iso-revenue curves is $\underline{r}_x$, which is the minimum possible revenue for an exporter.

The distinct feature of iso-revenue curve r_3 is the fact that it includes both exporters and non-exporters. Therefore, its level is not sufficient information to predict the export status of firms on the curve. This implies that, in contrast to the unconstrained case and the predictions of single-attribute models of firm heterogeneity, the relationship between firm size and fraction of exporters is not a step function as in Figure 4. Here, the fraction of exporters is strictly between 0 and 1 for a broad range of revenue levels. This prediction is consistent with the evidence presented in Figure 1, which shows the presence of both exporters and non-exporters at most revenue levels.[21] An additional prediction that contrasts with single-attribute models and our unconstrained case, but which we do not test in this paper, is that firm size in the closed economy does not perfectly predict export status in the open economy. While firm size in the closed economy is solely determined by the value of η, in the open economy firms with equal η need not have equal size.

[21] Even though the theory predicts this fraction to be 0 for sufficiently low revenue and 1 for sufficiently high revenue (as long as the upper bounds in the support of $v(\varphi, \xi)$ are sufficiently high), in general the fraction of exporters need not be monotonically increasing in revenue. Monotonicity, however, can be proved for a bivariate uniform distribution for $v(\varphi, \xi)$ (proof available upon request).

2.3.3 Testable predictions

In addition to explaining the simultaneous existence of exporters and non-exporters with equal revenue, the model predicts that, conditional on being located on the same iso-revenue curve, these two type of firms will display systematic differences in quality levels and prices. Consider any exporter on such a curve, characterized by the pair of draws (φ_x, ξ_x). Denote by $\lambda_x(\varphi_x, \xi_x)$ her optimal choice of quality. This exporter might be either constrained or unconstrained in her choice of quality. In the case of an unconstrained exporter, $\lambda_x(\varphi_x, \xi_x) = \lambda_u(\varphi_x, \xi_x)$. In the case of a constrained exporter, $\lambda_x(\varphi_x, \xi_x) = \underline{\lambda}$. Now consider any domestic firm on the same curve with draws (φ_d, ξ_d). In this case, optimal quality is $\lambda_d(\varphi_d, \xi_d)$. The following proposition establishes that, for firms on the same iso-revenue curve, exporters produce higher quality than non-exporters.

Proposition 2. *Conditional on size (total revenue), quality is higher for exporters than for domestic firms:*

$$\forall \overline{r},\ \lambda_x(\varphi_x, \xi_x)|_{r=\overline{r}} > \lambda_d(\varphi_d, \xi_d)|_{r=\overline{r}} \tag{22}$$

In turn, (22) implies the weaker statement:

$$\forall \overline{r},\ E\left[\lambda_x(\varphi_x, \xi_x)|_{r=\overline{r}}\right] > E\left[\lambda_d(\varphi_d, \xi_d)|_{r=\overline{r}}\right]. \tag{23}$$

For $r < \underline{r}_x$, since none of the firms exports this proposition is vacuous.

Proof. See Appendix 2.

This result can be verified by visual inspection of Figure 6. Exporters are either firms located between points A and B, in which case they produce quality $\underline{\lambda}$, or firms located above A, in which case they produce quality above $\underline{\lambda}$. Instead, non-exporters are located to the right of C, and thus produce quality below $\underline{\lambda}$. In particular, exporters are firms with relatively high caliber and low productivity while non-exporters are firms with low caliber but high productivity.

Since quality is unobservable, our empirical investigation relies on corollaries of Proposition 2.[22]

[22]Our model can potentially deliver testable predictions about reallocation of resources following trade liberalization, which we leave for further research. In particular, it suggests that the ranking of firm sizes would be reshuffled with trade liberalization. For example consider an iso-revenue curve in Figure 6 that crosses regions III, IV, and V in an autarky world. Following trade liberalization, firms on the part of the iso-revenue curve lying in Regions IV and V (firms with relatively high caliber) would choose to export and hence increase in size. In contrast, firms on the part of the iso-revenue curve lying in region III would choose to focus on the domestic market and hence decrease their size as a result of import competition. Thus trade liberalization would lead to the reallocation of resources towards high caliber firms.

Corollary 1 states that, holding size constant, exporters charge higher prices than non-exporters:

Corollary 1. *Conditional on size, exporters charge higher prices than domestic firms:*

$$\forall \overline{r}, \ p_x(\varphi, \xi)|_{r=\overline{r}} > p_d(\varphi, \xi)|_{r=\overline{r}}. \tag{24}$$

In turn, (24) implies the weaker statement:

$$\forall \overline{r}, \ E\left[p_x(\varphi, \xi)|_{r=\overline{r}}\right] > E\left[p_d(\varphi, \xi)|_{r=\overline{r}}\right]$$

Proof. With CES demand, $r_i = p_i q_i = p_i^{1-\sigma} \lambda_i^{\sigma-1} D_i$, where $D_i = \frac{E}{P}$ if $i = d$ and $D_i = W$ if $i = x = \{u, c\}$. Solving for p_i, we obtain $p_i = r_i^{\frac{1}{1-\sigma}} \lambda_i D_i^{\frac{1}{\sigma-1}}$. On the same iso-revenue curve, $r_x = r_d$. Then, since $W > \frac{E}{P}$ and $\lambda_x > \lambda_d$ (Proposition 2), Corrollary 1 easily follows. *QED*

Proposition 2 is the basis of our empirical investigation while Corollary 1 is the main empirical prediction. These are novel results in the literature. Even though several models of firm heterogeneity with quality differentiation predict that exporters produce higher quality and sell at higher prices than non-exporters (e.g. Baldwin and Harrigan 2007, Johnson 2007, Verhoogen 2008, Kugler and Verhoogen 2008), those models do not deliver these results *holding size constant*. Conditional on size, they predict that all firms have the same export status: either all are exporters or they are non-exporters. Here non-exporters can achieve the same revenue level as exporters by producing higher quantities, which they sell at lower prices because of their higher productivity. However, their lack of caliber makes them unable to reach the quality standards of foreign markets. Despite their high productivity and large size in the domestic market, they remain local.

2.4 Factor input requirements of quality production

The model developed so far assumes that both fixed and variable costs of production increase with the level of quality. Since this is a partial equilibrium model, we have left the source of those costs unmodeled so far. In this section, we model the fixed and variable costs of producing quality in more detail following an approach that partially draws on Verhoogen (2008). This allows us to relate the production of quality to average wages and capital intensity.

Production requires the use of two primary factors, labor and capital. There are H_L types of labor, indexed by $h = 1, ...H$, which earn market-determined wages w_h^L. There are also H_K types of capital, indexed by $h = 1, ..., H_K$, and V vintages of each type of capital, indexed by $v = 0, ..., V-1$. A unit of capital of vintage v lasts $v+1$ remaining periods. All vintages of the same type of capital are perfect substitutes and equally productive. Therefore, they earn identical market-determined rental rate w_h^K. The price of a unit of capital of type h and vintage v is p_{hv} and equals the discounted future sum of rental rates: $p_{hv} = \sum_{t=0}^{v} \frac{w_{ht}^K}{\rho_t}$, where $\rho_t = \Pi_{t'=0}^{t}(1+\rho_{t'})$ and $\rho_{t'}$ is the one period interest rate.

Denote by L_h the units of labor of type h, by $K_h = \sum_{v=0}^{V-1} K_{hv}$ the units of capital of type h hired by the firm, and define $L = \sum_h L_h$ and $K = \sum_h K_h$. Then, the average wage the firm pays is $w^L = \frac{\sum_h w_h^L L_h}{L}$ and the average rental is $w^K = \frac{\sum_h w_h^K K_h}{K}$. Wages and rental rate gaps across types of factor inputs can be thought to reflect differences in relative productivity in an unmodeled "numeraire" industry. In the case of labor, relative productivity is assumed to depend on skills.

To produce quality λ, a firm needs to pay average wage $w^L = \underline{w}^L \lambda^{b_L}$ and average rental rate $w^K = \underline{w}^K \lambda^{b_K}$, $b_L > 0$, $b_K > 0$, where $\underline{w}^L$ and $\underline{w}^K$ are the least expensive types of labor and capital, respectively. This requirement applies to factor inputs associated both with fixed and variable costs. Thus, producing higher quality requires hiring more skilled and higher-paid workers and more expensive types of capital.

The volume (quantity) of output produced does not depend on the type of inputs used in production but only on their quantities. Output is produced using a constant returns to scale Cobb-Douglas production function: $Y = \varphi L^{\alpha_L} K^{\alpha_K}$, where $\alpha_L + \alpha_K = 1$. This production function yields the unit cost function, conditional on quality λ, postulated in equation (3):

$$c(\lambda, \varphi) = \frac{A}{\varphi} \left(w^L\right)^{\alpha_L} \left(w^K\right)^{\alpha_K} = \frac{c}{\varphi} \lambda^{\beta}$$

where $A = \dfrac{1}{\alpha_L^{\alpha_L} \alpha_K^{\alpha_K}}$, $c = A \left(\underline{w}^L\right)^{\alpha_L} \left(\underline{w}^K\right)^{\alpha_K}$, and $\beta = \alpha_L b_L + \alpha_K b_K$.

The fixed cost part of quality production is modeled in a very similar manner. Specifically, we assume that it requires labor and capital combined in a Cobb-Douglas production function with the same exponents: $\lambda = \left[\xi L'^{\alpha_L} K'^{\alpha_K}\right]^{1/\kappa}$.[23] These quality-related fixed costs can be thought of as expenses related to the implementation of quality control systems, worker training, or product development.[24] In addition, the firm incurs other fixed costs F_0 (such as annual maintenance expenses or headquarter expenses) unrelated to quality. Accordingly, fixed costs, conditional on quality λ, are as defined in equation (4):

$$F(\lambda, \xi) = \frac{A}{\xi} \left(w^L\right)^{\alpha_L} \left(w^K\right)^{\alpha_K} \lambda^{\kappa} + F_0 = \frac{f}{\xi} \lambda^{\alpha} + F_0$$

[23] Bernard et al. (2007) also assume that input shares associated with fixed and variable costs are equal.

[24] In this static framework, sunk and fixed costs are equivalent. In a dynamic setting, sunk costs could still be considered fixed costs by converting them into an equivalent stream of per-period fixed costs.

where $f = A\left(\underline{w}^L\right)^{\alpha_L}\left(\underline{w}^K\right)^{\alpha_K}$ and $\alpha = \kappa + \alpha_L b_L + \alpha_K b_K$.[25]

These assumptions, together with the results of Proposition 2, imply a systematic relationship between factor use, quality, and size.

Corollary 2. *Conditional on size, average wages are higher for exporting firms.*

Proof. This corollary follows directly from the assumptions of this section and Proposition 2. In particular, since average wages are a monotonically increasing function of quality, Proposition 2 implies that

$$\forall \bar{r},\ w^L(\lambda_x(\varphi_x, \xi_x))|_{r=\bar{r}} > w^L(\lambda_d(\varphi_d, \xi_d))|_{r=\bar{r}}$$

Corollary 3. *Conditional on size, capital intensity is higher for exporting firms. Capital intensity is measured as the (value of) capital-to-labor ratio, $\frac{VK}{L}$, where $VK = \sum_{h=1}^{H}\sum_{v=1}^{V} p_{hv}K_{hv}$*

Proof. See Appendix 3.

Corollary 2 simply connects Proposition 2 with our assumption about labor requirements of quality production. Exporters need to pay higher average wages because they produce higher quality, which requires a more expensive and higher skilled composition of the labor force. Corollary 3 captures a similar effect. In this case, we note that, since a simple count of "machine units" is meaningless, "physical" capital, as reported in firm-level statistics, cannot be treated analogously to the count of bodies in the case of labor. In terms of our notation, we observe VK, not K. Both Corollaries 2 and 3 can be weakened to be stated in expected values. We take these predictions to the data in this last form.

3 Data

3.1 Data sources

Our empirical analysis utilizes establishment-level manufacturing survey data from the India, US, Chile and Colombia. We discuss the data sources briefly below; more specific discussion of the product level information for India and US, and the steps we took to clean the data for all four datasets is discussed in the Data Appendix.

[25]From the expression for β above, we obtain $\alpha = \kappa + \beta$. In Section 2.1 (see discussion below equation 5), we imposed the restriction $\alpha' = \alpha - (1-\beta)(\sigma - 1) > 0$. This condition then implies that $\kappa > \sigma(1-\beta) - 1$.

For India, we use a cross section of the Annual Survey of Industries (ASI) for the year 1997-98. We focus on 1997-98 because the ASI data for this year includes information on exports and on output quantities and values. This information is critical for our analysis because it allows us to construct product level prices (unit values). Another useful feature of the data is that it has information on whether each plant has obtained ISO 9000 certification, which can be used as a direct proxy for quality. The ASI is a survey undertaken by a government department called the Central Statistical Organization (CSO). It covers all industrial establishments (called "Factories") registered under the Factories Act employing more than 20 persons.[26] The ASI frame includes two "sectors": the census sector and the sample sector. All factories in the census sector (employing more than 100 workers or located in designated backward areas) are surveyed. Factories in the sample sector are stratified and randomly sampled. Throughout our analysis, we appropriately adjust for sampling weights (called "multiplier"). Further details about this data can be found in Sivadasan (2007).

For the US, we use data from the 1997 Census of Manufactures (CMF). The CMF data is collected by the US Census Bureau as part of the quinquennial economic census. It covers all manufacturing establishments that employs even one paid worker, and includes detailed information on inputs and outputs at the establishment level. It has been used very extensively in microeconomic research work in general (see e.g. survey by Bartelsman and Doms 1999), and also specifically to examine differences between exporters and non-exporters in pioneering work by Bernard and Jensen (1999). A detailed discussion of the Census of Manufactures data is available in LRD technical documentation manual (1992).

The novelty in this paper with regard to CMF data is the use of SIC seven-digit product-specific information on product quantity and product revenue to derive a per unit value or price (defined as product revenue divided by product quantity).[27] One drawback of our derived per unit value measure is that product quantity data is unavailable for many establishments and products. In particular, quantity information is often missing for certain products or industries where output

[26]The limit is lower (10 employees) for plants that use electric power for production. Some plants in the data report less than 10 employees, 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 remain registered even after employment levels fall below the cutoff.

[27]A recent paper that exploits the seven-digit product level information on quantity and revenue is Foster, Haltiwanger and Syverson (2008). Bernard, Jensen and Schott (2006a, 2006b) also exploit detailed product revenue information, focusing largely on 5-digit SIC level information.

units are "not meaningful" (LRD manual, 1992). However, since our model's predictions relate to comparisons across establishments (firms) *within industries*, lack of information for entire products or industries should not bias our results.[28]

Data for a large proportion (about 40%) of (largely smaller sized) plants ("AR plants") are collated by the census from administrative records. Many studies using census manufacturing data exclude these observations (e.g. Syverson 2004, Bernard, Redding and Schott, 2008). Because price data is unavailable for AR firms, our price analysis also excludes them. For the other non-price variables, since we are interested in examining differences across the size distribution, we retain the AR plants in the baseline analysis, but perform sensitivity checks to excluding AR plants.

We use manufacturing data for Chile and Colombia to examine predictions relating to non-price variables, as product level revenue and quantity (and hence price) data is unavailable in these datasets.

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 census 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 export activity is available. Further details about this dataset can be found in Liu (1991) or Roberts and Tybout (1996).

Finally, data for Colombia comes from the Colombian manufacturing census for the years 1981 to 1991. As in the Chilean case, the Colombian census covers all plants with 10 or more employees. A more detailed description of the Colombian datasets can be found in Roberts and Tybout (1996, Chapter 10).

3.2 Definition of variables and summary statistics

Testing the predictions of our theoretical model requires data on export status, revenue, potential proxies for quality, output price, average wage, and capital intensity (capital to labor ratio).[29]

Ideally, we would like to have a measure of quality that is directly consistent with λ in our model, which affects the marginal costs and fixed costs of operations. While this ideal measure is unavailable, in the Indian dataset each plant reports if it has obtained ISO 9000 certification. We

[28] In other words, our model could potentially be tested with sufficiently detailed data on a single industry or product. In any event, we undertake a robustness tests to check if results are sensitive to including information on products where price data is sparse (see in Section 4.2.3).

[29] In Section 5, as part of our robustness checks, we define and discuss number of other variables.

discuss in Section 4.3 why the ISO 9000 quality management certification could be a good proxy for quality (λ).

Export status is captured by a dummy variable defined to equal one for all establishments reporting positive value of exports. Revenue is total sales by the establishment. Labor is measured as total employment, log average wage is obtained by taking the logarithm of the ratio of total wages to total employment, for each establishment. The variable capital, in the case of Chile, is constructed using the perpetual inventory method. For India, US, and Colombia, capital is measured as reported total fixed assets.

As discussed in Section 3.1 above, the datasets for India and US contain information on the separate product lines of every establishment. This allows us to derive prices or unit values, which is critical for testing Corollary 1. Specifically, for each product line, the dataset provides information on sales value and quantity. The ratio of the two results in a unit value, which we use as a proxy for price.

The price variable is defined at the product category level, so that there are multiple price observations for each firm. Since all other data, in particular data on export value, 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 4.2).

In the case of all other non-price variables (in particular, revenue, employment, average wage and capital intensity), because the statistical unit in the Indian, Chilean and Colombian datasets is the establishment, we define and measure these variables at the establishment level. In the baseline analysis for the US, we adopt the same approach and define all non-price variables at the establishment level. However, in the US data, there are well defined ownership links that allow us to aggregate data to the firm level, and in Section 5.1, we discuss robustness of the results to defining size and other variables at the firm level.

To mitigate influence of outliers, as discussed in the data appendix, all variables are winsorized by 1% on both tails of the distribution.

Panels 1, 2, 3 and 4 of Table 1 present summary statistics for India, US, Chile and Colombia, respectively. In the case of India, all statistics are adjusted to account for sampling weights. Sampling weights are not relevant for the census data of the US, Chile and Colombia, where establishments are sampled with certainty. The nominal variables (wages and capital) for India are measured in rupees, for US in thousands of dollars, for Chile in current Chilean pesos and for

Colombia in current Colombian pesos.[30]

As noted in the data appendix, because our analysis focuses on differences between exporters and non-exporters within industries, we exclude industries with no exporters from our sample. Hence, the intensity of exporting as reflected in the number of exporters and non-exporter observations is likely to overestimate the prevalence of exporting in the full population. Subject to this caveat, in our cleaned data samples, exporting is more common in Chile, where about 22% establishment-year observations (6707/30,377) relate to exporters. It is less common in India (17.2%), in Colombia (13.4%) and least in the US (12.24%). This lower prevalence in the US may be driven by greater coverage of small firms in the US data.[31]

As noted earlier, the price data is not available for all establishments and product lines for the US. This is evident from the differences in the number of observations between price and other variables – we have 98,702 price (establishment-product) observations, while there are 389,113 total (establishment) observations for all the other key variables. The number of establishments in the price dataset is 9629, with many firms reporting multiple product lines (as documented by Bernard, Redding and Schott, 2008). Note that in the price data, the prevalence of exporting is higher than for the other variables (29.12% or 28,739 of 98702 observations); this is not surprising as larger firms who are more likely to be exporters are also more likely to have multiple product lines.[32] The product, and hence price, data availability issue is also relevant for India, but is less stark than for the US. The proportion of exporter-related observations in the Indian price data is only somewhat higher (20.59% or 5,293 of 25,709 observations).

For US data (panel 2), the unconditional overall mean price is higher for exporters, while for Indian data (panel 1), the reverse is true. Since prices for different goods are defined over different units, this unconditional mean variable may be affected by differences in units across products. A more meaningful picture of the difference in prices between non-exporters than exporters are

[30]In all our analysis using panel data from Chile and Colombia, we use industry-year fixed effects and/or allow coefficients on the industry specific control function to vary by year. Since all the nominal variables (capital intensity and wage) enter in logarithms in all regressions, our results are invariant to using an industry level deflator to normalize the nominal variables.

[31]Technically all establishments with non-zero paid employees are included in the US data, but product level information (and hence price) and export data are missing for "administrative records" establishments, which form the bulk of the small (less than 10 employees) establishments. All the other three datasets have a minimum employment cutoff (about 20 employees for India, and 10 employees for Chile and Colombia).

[32]This is partly driven by the fact that export status is available only at the establishment level, as discussed in Section 3.1 above.

presented in Section 4.2.1 where we include product specific fixed effects (and size controls).

The summary statistics for India (panel 1) show that ISO 9000 certification is much more common among exporters (17%) than non-exporters (only 2%). In all four panels, for average wage and capital intensity, the overall mean values are higher for exporters than for non-exporters.

4 Empirical analysis

Our model emphasizes the role of quality as an important factor, in addition to productivity, in determining export status. In particular, the model's key prediction (see Proposition 2) is that the expected value of quality is higher for exporters relative to non-exporters *of the same size*. This prediction contrasts with the results from the standard models in the literature (e.g. Melitz 2003) where productivity (or the single attribute that is modeled) and hence size is the sole determinant of export status. In those models, all firms above a cutoff revenue export, and conditional on revenue there are no remaining differences between exporters and non-exporters.

Because quality is not observed, directly testing Proposition 2 is difficult. But we show in Corollary 1 that the mean output price is higher for exporters relative to non-exporters, conditional on revenue. Similarly, we show that under reasonable assumptions, average wage and capital intensity are higher for exporters relative to non-exporters, also conditional on revenue (see corollaries 2 and 3). In the Indian data, we also have a reasonable proxy for quality – a dummy variable indicating whether the establishment has obtained ISO 9000 quality management certification.

In the next section, we discuss the methodology used to test the predictions of our model using data on the ISO 9000 certification dummy, output prices, capital intensity and average wage.

4.1 Estimation strategy

In equilibrium, price, quality, revenue, capital intensity, average wage, and export status are jointly determined as functions of the exogenous ability draws, φ and ξ. Proposition 2 and Corollaries 1, 2, and 3 all impose restrictions on conditional expectations derived from that joint distribution.

Defining an indicator variable for export status, D, which equals 1 if the firm exports and 0 if it does not, we can rewrite the weak versions of proposition 2 and the corollaries as

$$E\left[Y\,|_{r,D=1}\right] > E\left[Y\,|_{r,D=0}\right], \quad \forall r \tag{25}$$

where $Y = \left\{\lambda, p, \frac{VK}{L}, w^L\right\}$.

We adopt two broad approaches to test (25): a parametric approach based on a linear-regression framework and a non-parametric regression approach. First, we assume that the conditional expectations take the linear form:

$$E\left[Y\,|_{r,D}\right] = g_Y(r) + \delta_{Yx}D \tag{26}$$

where $g_Y(r)$ is a (product/industry specific) polynomial in revenue (including a constant), and δ_{Yx} is the coefficient on the export status dummy. The coefficient δ_{Yx} captures the gap between the left-hand-side and the right-hand side of (25), and hence our theory predicts it to be positive. The linearity of the conditional expectation in (26) allows us to express a realization of the dependent variable as

$$y = g_Y(r) + \delta_{Yx}D + u \tag{27}$$

where u is a random disturbance uncorrelated with the conditioning variables. In our case, the random element u captures differences in price, capital intensity or average wage for firms with different φ and ξ that have the same revenue and export status. The coefficients of (27) can then be estimated using a linear regression framework.

Since in the model the relationship between revenue and any of the dependent variables depends on parameters that can be specific to industries/products, in our empirical implementation we allow the coefficients of the polynomial $g_Y(r)$ to vary across industries/products. To flexibly capture non-linearities in the relationship between size (revenue) and the dependent variables, we specify both a parametric (a polynomial of order 3) and a semi-parametric (industry/product-specific size decile fixed effects) form for g_Y.

The coefficients in equation (27) should not be interpreted as causal effects. For example, it would be erroneous to interpret δ_{Yx} as the change in y for a firm that switched its export status holding its size constant. Such an experiment would not be possible since firms' export status is determined by the ability draws, φ and ξ, which are fixed. Even if we allowed them to change over time, those draws also determine revenue, which then would not be held constant. The correct interpretation of δ_{Yr} and δ_{Yx} should be as coefficients of a conditional expectation, which indicate the difference in the expected value of Y when we compare an exporter and a non-exporter of equal size.

The fact that we cannot give the estimated coefficients a causal interpretation does not excuse us from the need to ensure that the error term is uncorrelated with the regressors. This condition is still necessary to obtain consistent estimates of the conditional probabilities required to test the predictions of the theoretical model. To allow for arbitrary relationship between revenue and the dependent variable, we also test for (25) using a non-parametric approach, by conditioning on size using a locally weighted smoothed regression (lowess) proposed by Cleveland (1979). The lowess graph provides a non-parametric picture of $E[Y|_{r,D}]$, allowing for a much richer dependence between export status (D) and the variable of interest (Y) across different size percentiles. Fan (1992, 1992) showed that the lowess approach has advantages over other popular kernel methods and has nice sampling properties and high minimax efficiency, and this approach has found increasing favor in the literature.[33]

Another critical issue we need to address is comparability across industries. Our model and hence the predictions are essentially relevant to a single industry. Because we use data on the entire manufacturing sector to test our predictions, we need to be careful about differences across industries/products affecting our estimates. We address this concern in two ways. One, as discussed above, we allow the polynomial in revenue and the intercept term in (26) to vary by product code or across industries. Two, we standardize both the dependent and independent variables. That is, we subtract product or industry-specific means and divide by the product or industry specific standard deviations. This standardization imposes the same mean and standard deviation for all the variables across product codes and industries, and hence improves comparability across sectors. In particular, it prevents the overall results from being affected by results in particular products or industries that exhibit relatively high variance for the dependent variable.[34] At the same time,

[33]E.g. Barsky et al. (2002) use the lowess approach to estimate conditional (on earnings) expectation of wealth. We use the bandwidth of 0.8 (which is the default in the Stata procedure) in our analysis (which implies that 80% of the data are used in smoothing each point). 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 (suggested by Cleveland 1979):

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

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.

[34]As an illustration, consider measuring the relative price charged by exporters using data from two industries with equal number of firms. Suppose in industry 1, exporters price at a premium of 40% relative to non-exporters, while in the other industry exporters price at a discount of 10%. The answer we get if we used an non-standardized price variables would be an overall mean price premium of 15% for exporters. This could be misleading, as the dispersion in prices may be quite different in the two industries. In particular, if the price premium in industry 1 is low relative to the overall dispersion of prices in that industry, and if the price discount is high relative to the price dispersion in

because this standardization is a monotonic transformation of all the variables (within a product code or industry), it does not affect the nature of predictions about the coefficient on the export dummy variable. Since standardization more carefully addresses comparability concerns, we prefer and focus on specifications using the standardized variables. However, in the baseline case, we also present results using non-standardized variables.

The analysis of all the 4 key variables of interest – price, the ISO 9000 quality management dummy, average wage, and capital intensity – follows the same broad approach. Hence the description of the approach is given in most detail for price, which is the first variable we analyze.

4.2 Price results

4.2.1 Baseline price regression results

In this section, we use data for the Indian manufacturing sector for 1997-98 and the US manufacturing sector for 1997 to examine the relation between per unit price and export status. According to Corollary 1 in section 2.3, per-unit prices should be higher for exporters relative to non-exporters of similar size, reflecting the higher quality of exporters. In contrast, under the null of single-attribute models, size perfectly predicts exporting status, and conditional on revenue there are no remaining differences between exporters and non-exporters.

As discussed in section 3, price per unit is obtained by dividing value of production by quantities per product line. There are multiple product lines for most establishments. 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 and use the unit value for each product line as a distinct observation.

The results from our baseline analysis are presented in Table 2. The first two columns mainly serve as benchmark. In column 1, we include only product specific fixed effects and no controls for size (revenue) while in column 2, we include a product specific polynomial of order 2 in revenue. Columns 3 and 4 are our baseline specifications. In column 3, we include a product specific polynomial of order 3. In column 4, we include product-specific size-decile fixed effects. Panel 1 presents results for India and Panel 2 presents results for the US. In each panel, row 1 presents results using the standardized log price (and revenue) variables, while row 2 presents results using the log price variable directly (non-standardized). To allow for arbitrary correlation between error terms within

industry 2, a better overall conclusion may be that exporters do not enjoy a large price premium.

a product category, we cluster standard errors by product code.[35]

In all specifications, exporters have a positive price premium. All effects are highly statistically significant in the US data (panel 2). For the Indian data too, almost all specifications (except in row 2 of column 2) yield a statistically significant premium for exporters. The standardized regressions yield an exporter price premium ranging from about 8.3% to 13.4% of the standard deviation for the US, and 7.1% to 9.3% of the standard deviation for India.

4.2.2 Non-parametric price results

Figure 7 illustrates a locally weighted smoothed (lowess) regression of the standardized log per unit price on size, separately for domestic and export firms. In addition to allowing the exporter price premium to vary flexibly over size groups, this non-parametric regression also provides a detailed view of the relationship between firm size and price.

Overall, as documented by Kugler and Verhoogen (2008) for Colombia, prices are higher for larger firms. But conditional on size, 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). Interestingly, small firms that export have a higher price premium compared to similar sized non-exporters. The premium is high also at the top of the size distribution, and is smallest in the middle of the distribution.

4.2.3 Robustness checks of price results

In Table 3, we present results from three different robustness checks. (Results for India are presented in Panel 1 and results for the US are presented in Panel 2. Here we focus on standardized price as the dependent variable, and for comparison purposes, we present the base case results from of Table 2 in row 1 of each panel.)

First, in row 2, we redefine the export dummy as equal to one only for those firms where exports constitute at least 2% of revenue. This is done to avoid establishments that may be exporting very small quantities driven by idiosyncratic factors unrelated to our model.[36] The results here are basically the same as the benchmark case for the US, and somewhat stronger than in the benchmark

[35] We also checked for robustness to clustering at the establishment level. This yields lower standard errors, which is not surprising as the number of establishments is larger than the number of products. We prefer the more conservative approach of clustering at the product code level.

[36] In this analysis, to focus on differences between substantial exporters and non-exporters, we exclude exporters with less than 2% export share of revenue.

case (as may be expected) for India (panel 2 of Table 2).

Second, we define product categories at a broader level, so that product fixed effects are defined at a more aggregate level. For the US, we define products as belonging to the same category if they share the same 5-digit SIC code. For India, we classify all products produced by firms sharing the same 4-digit industry *and* unit code as belonging to the same broad product category. This is to allow for potential quality upgrading across narrowly defined product categories (Aw and Roberts 1986, Feenstra 1988). For example, in the Indian data, the 5-digit product code classifies ink-jet printers separately from dot matrix printers. Thus, in the base case regressions, we are examining if exporters within the ink-jet category are producing higher quality printers than domestic producers within the same category. Defining the product category more broadly allows for quality differentials between product lines; in this example, exporters may be producing higher quality ink-jet rather than lower quality dot-matrix printers. For the US, the broader classification does not change the results by much, whereas for India, results in row 3 indicate a higher relative premium for exporters when the product category is defined more broadly.

We also replicate the analysis retaining only the largest product line for each establishment, thus checking for robustness to the possibility that establishments are more likely to export their main line of products and may not export the subsidiary product lines.[37] (As discussed in section 3.2, in the data, we know only the export status for the establishment as whole, not for particular product lines. Recall that in the baseline specification, we assume that all product lines for an exporter establishment are exported.) The results in row 4 of both panels confirm that our base case results are robust to this check too.

In addition to the above we did a number of other robustness checks, the results of which are omitted for the sake of brevity. We checked and found results robust to (a) using different winsorization cutoffs (including no winsorization); (b) excluding products whose definition included the terms NEC or NES ("Not Elsewhere Classified/Specified") for India, and excluding product codes ending with 0 or 9 for the US, (c) For India, excluding products measured in "numbers" because of potential heterogeneity in the units counted (e.g. due to different pack sizes), and for the US excluding potential non-manufacturing product codes (i.e. first digit not 2 or 3). Specifically for the US, we undertook tests to ensure that results are not driven by missing observations within product codes, by examining the subset of product codes for which price data was available for all

[37]Bernard, Redding and Schott (2006) predict that multiproduct firms will export the product lines in which they are relatively more productive. These are also the product lines that earn the firm the largest revenue.

occurrences, and for which there were at least 25 observations. We also did a broader check by including only SIC 4-digit sectors that had at least 2000 price observations which also confirmed the baseline findings.

One final concern is that our results could be spurious if firms charge higher mark-ups in the export market than in the domestic market. However, the available empirical evidence shows just the opposite. Das et al. (2007) use a structural model to estimate the ratio of foreign to domestic demand elasticities in three manufacturing industries in Colombia. They find demand elasticities to be almost twice as large in the foreign market than in the domestic market in two sectors (the estimated ratio is significantly different from 1), while they find no significant difference in the remaining sector. Aw et al. (2001) use more direct evidence on foreign versus domestic mark-ups by comparing export and domestic prices charged by the same firm on the same product in the Taiwanese electronics industry in 1986 and 1991. Out of 54 product/years they investigate, they find domestic prices to be higher in 40 cases (8 significant) while in none of the remaining product/years the difference is significant.

4.3 ISO 9000 quality proxy results

An extensive literature suggests that ISO 9000 certification may be a good proxy for quality, particularly in the context of our model. First, a number of papers document that ISO 9000 certification is correlated with direct measures of product quality (e.g. Carlsson and Carlsson 1996, Brown et al. 1998, and Withers and Ebrahimpour 2001). Second, consistent with our modeling assumption that upgrading quality is costly, Guler et al. (2002) document that obtaining ISO 9000 involves a considerable monetary investment (about $125,000) and time effort (about nine months to two years). Third, consistent with our modeling of quality as a demand shifter, there is considerable evidence that ISO 9000 impacts demand (both locally and internationally), as a number of governments and private companies (particularly MNCs) require this certification from suppliers (e.g. Guler et al. 2002, Barnes 2000). There is also evidence that the certification helps improve measures of customer satisfaction (Buttle, 1997).[38] Finally, ISO 9000 certification as a proxy for quality has already been used in the international trade literature (e.g. Verhoogen,

[38] A critique of the certification process is based on some evidence that while, cross-sectionally, certified firms are have superior business performance than non-certified firms, there is not much change in performance after ISO 9000 registration (Heras, Dick and Casadesus, 2002). Thus firms with high quality may selectively choose to obtain ISO 9000 registration. However, since our objective is to use ISO 9000 as a proxy for quality, the direction of causality between quality and ISO 9000 registration is not relevant.

2008).

Results are presented in Table 4. In row 1, we present the baseline regression. In row 2, we exclude exporters that report exports of less than 2% of revenue. Since the dependent variable is a dummy, we do not use a standardized variable specification here. In all the specifications, consistent with our theory we find that exporters are much more likely to obtain ISO 9000 certification. The results are slightly weaker when we use a 2% export share cutoff to define the exporter dummy.

Thus these results confirm our earlier findings – exporters appear to have higher quality levels relative to non-exporters, conditional on size.

4.4 Wage and factor intensity results

In this section, we test corollaries 2 and 3 by examining differences between exporters and non-exporters in the log average wage rate, and capital intensity (measured as the log of the capital to labor ratio), conditional on size. Results are presented in Table 5. For each of the four countries, we examine two specifications. The first specification includes an industry-specific polynomial of order 3 in size (measured as log revenue) and industry-year fixed effects. The second specification includes industry-size decile-year fixed effects. These specifications are analogous to those reported in columns 3 and 4 of Tables 2 and 3, except that here an observation corresponds to an industry-year rather than a product code. For each dependent variable, the first row presents results using standardized variables while the second row presents results using non-standardized ones.

For the standardized wage variable, the estimated coefficient on the export dummy is positive for all countries and specifications, as predicted by corollary 2. The results in row 1 of columns 2, 4, 6, and 8 imply a 17% of standard deviation wage premium for exporters in India, 8.6% in the U.S., 15.6% in Chile and 7.6% in Colombia. For the first three countries, all specifications indicate statistically significant exporter wage premia. For Colombia, the wage premium is positive but smaller than for the other countries and not statistically significant in one of the two specifications (column 7). The results in row 2 using the non-transformed wage variable are similar.[39]

[39] We looked separately at the wages for production and non-production workers, and generally found evidence of positive wage premia for both types of workers across the four countries. Though we think the wage rate is a better measure of unobserved worker ability, we also looked at a cruder but commonly used measure of the share of non-production workers. We found the non-production share of the wage bill to be significantly higher for exporters in the US, Chile and Colombia but statistically insignificant for India. Looking at the purely physical measure of non-production worker share of employment, we found higher share for exporters in US and Colombia, but the premium was statistically insignificant for India and Chile.

Next, we examine the empirical validity of corollary 3. For India, Chile and Colombia, the results show that exporters are significantly more capital intensive than non-exporters in both specifications. The results in columns 2 indicate that exporters in India have 21.0% (of standard deviation) higher log capital to worker ratio, conditional on revenue. The premium is 25.3% for Chile and 11.4% for Colombia.

The results for the U.S. differ markedly from those of the other three countries. Contrary to the predicted effect, the estimated coefficient is negative and significant in both specifications indicating that, conditional on size, capital intensity is lower for exporters than for non-exporters. Given that this result is at odds with results previously reported in the literature using similar specifications (e.g. Bernard and Jensen 1999), we perform the same estimation using Census data for 1992 rather than 1997. We find that the the negative premium changes to an insignificant positive premium.[40] Given that, unlike the results for average wage, the capital intensity results for the U.S. are not robust across years, we are cautious about pushing strongly any particular interpretation of them and leave it for further scrutiny in future research.[41]

Overall, the evidence of this section taken as a whole supports the implications of our model for factor usage. Conditional on firm size, exporters hire more skilled workers (as reflected in the higher wage rate) and, except for the U.S. in some specifications, are more capital intensive.

5 Other robustness checks

This paper proposes an international trade model of firm heterogeneity in which firms have two heterogeneous attributes: productivity and caliber. The main predictions of the model are tested and confirmed in section 4.2, where we also check for robustness to alternative measures of price and export status. In this section we evaluate, more broadly, robustness to alternative potential explanations for our results. In section 5.1, we test for robustness against single-attribute models as the underlying explanation. In particular, since firm size and export status are correlated, we

[40] Also, when using employment rather than revenue as control for firm size, we find that the capital intensity premium is *positive* and significant for exporters, consistent with the results for the U.S. documented in Bernard and Jensen (1999), Table 1, who estimate a similar specification. While our theoretical predictions require the use of revenue as size control, the approach using employment as the size control is discussed in more detail in section 5.1.

[41] One potential explanation could be that quality upgrading requires increasing the intensity of capital in capital-scarce countries where production methods are relatively intensive in unskilled labor (e.g. need of machinery to improve cutting precision) but requires increasing the intensity of skilled labor in capital-abundant countries where production methods already use capital intensively (e.g. need of artisan "touches").

address the possibility that the evidence of exporter premia conditional on size is merely driven by measurement error in sales revenue data. In section 5.2, we test for robustness against alternative multi-attribute models.

5.1 Robustness to measurement error in sales revenue

Our empirical results show systematic differences between exporters and non-exporters *conditional on firm size*. These results contradict the predictions of single-attribute models of firm heterogeneity, which imply a monotonic relationship between firm size and the single attribute (typically productivity), and thus predict that once size is controlled for there should be no observed variation in export status. However, since firm size and export status are correlated, measurement error in the size variable (firm sales) could induce bias in the estimates of exporter premia, i.e. the coefficient on the export dummy. In that case, our results would be spurious.

We address this concern in the following four ways. First, we use employment as an alternative measure of firm size (e.g. Bernard and Jensen 1999, Kugler and Verhoogen 2008). As Kugler and Verhoogen argue, sales may be measured with error, especially in developing countries such as India, for reasons related to avoidance of excise and income taxes, which are less likely to bias measurement of employment. Since, as revenue, employment is also monotonically related to firm size in single-attribute models, employment can alternatively be used as control for size to test the predictions of those models as the null hypothesis.[42] The results (for our main price and ISO dummy variables) are presented in Table 6. As in the baseline case, there is a significant export premium across all specifications, which rejects the predictions of single-attribute models.[43]

Second, a source of error in the size measure could arise from the fact that we use *establishment* size rather than *firm* size in our analysis. This is correct so long as the heterogeneous attributes are specific to each establishment within a firm. Otherwise, our size measure could be inappropriate for multi-establishment firms. For example, a large firm that sells both domestically and internationally

[42] Our predictions indicate that we should condition for size using revenue rather than employment. Thus, even though a specification that controls for employment is appropriate to test the null of single-attribute models, it could yield biased estimates under our framework as null.

[43] Another source of measurement error could be under-invoicing of exports, which was common in controlled exchange rate regimes such as India (see e.g. Patnaik and Vasudevan, 2000). Since this error is likely to affect only measured export sales, using employment as the size proxy avoids this issue. As an alternative check, we ran the price regressions in Table 2 for the Indian data explicitly conditioning on domestic sales revenue and found the results to be robust.

may decide to focus its export operations in one plant (establishment) and domestic operations in another plant. In this case, the correct size measure would be the firm size rather than the establishment size. Using information available in the U.S. Census Longitudinal Business Database (LBD) on ownership links, we can form firm size measures for each establishment in the U.S. data (information on ownership links is unavailable in the other three datasets). The results are presented in Table 7. These are similar to the baseline results, suggesting that conclusions are not sensitive to the use of establishment versus firm size controls.[44]

Third, we exploit the panel nature of the data for Chile and Colombia to control for transitional shocks to revenue. We form four year means for each establishment (over the latest available data period – 1993-96 for Chile and 1988-91 for Colombia) for the dependent variables (average wage and capital intensity) as well as for size and export status.[45] We exclude firms that enter or exit export status during the period to avoid any transitional dynamics. The results, presented in Table 8, confirm the baseline results, except for a slight weakening of the average wage results for Chile. Thus measurement error induced by transitional fluctuations in revenue or export status does not appear to drive the baseline results.

Finally, we perform a number of robustness tests distinguishing industries according to how closely they match the quality mechanisms we stress in the theory. We discuss those tests in the next section since they simultaneously check robustness to alternative multi-attribute models.

5.2 Robustness to alternative multi-attribute models

The empirical evidence presented so far strongly rejects the predictions of single-attribute models. Thus, it suggests that models with more than one source of heterogeneity are necessary to provide a more complete characterization of firms' exporting behavior. In addition, the evidence supports the specific predictions of the multi-attribute model we propose where firms are heterogeneous in productivity and caliber. Since other multi-attribute models have been proposed in the literature, section 5.2.1 discusses the extent to which they can explain the facts we document here. More generally, since numerous models could be hypothesized as alternative explanations for our results, section 5.2.2 provides further evidence in support of our specific characterization of firms' exporting behavior. In particular, we identify industries where the economic mechanisms we emphasize are

[44]As an additional robustness check, not reported here, we perform the analysis using only single establishment firms and also found results to be robust.

[45]One interpretation of this approach is as using firm dummies as instruments to address measurement error, as discussed in Angrist and Krueger (1999).

more likely to operate and evaluate whether the predictions of our model hold more strongly in those industries than in other sectors.

5.2.1 Discussion of other multi-attribute models in the literature

Alessandria and Choi (2007) build a model with firm heterogeneity in productivity and sunk export costs. Even though sunk costs are common to all firms, their presence introduces a second source of heterogeneity: firms' export history. In this set up, less productive exporters could have the same size as more productive non-exporters if the former have paid the sunk export costs in the past – a time at which their productivity was higher. In turn, the lower productivity of exporters would imply that they charge higher prices. While this model could potentially explain our finding of an exporter price premium conditional on size, it cannot explain why, conditional on size, exporters pay higher wages and are more capital intensive.

Ruhl (2008) and Das et al. (2007) add, respectively, firm heterogeneity in sunk export costs and in sunk and fixed export costs to the previous framework. While heterogeneity in fixed or sunk export costs are natural explanations for the lack of a one-to-one correspondence between firm size and export status shown in Figure 1, they do not explain the presence of systematic exporter premia in price, average wage and capital intensity conditional on firm size. This is also the case in Nguyen (2007), who allows for heterogeneity in the appeal of firms' products both across firms in a given market and across markets for a given firm. This model also can naturally explain the facts documented in Figure 1 but it does not explain the existence of the systematic exporter premia we document.

Finally, we could think of an alternative model in which firms are heterogeneous in their productivity and in their access to financial capital. While the predictions of such a model would largely depend on assumption choices about how financial constraints affect firm size and export status, it is not *a priori* obvious that such a model would be able to replicate our facts.

5.2.2 Results by industry characteristics

More generally, numerous alternative dimensions of heterogeneity other than "productivity" and "caliber" could introduce a wedge between firm size and export status. In this section, we present a body of evidence that, as a whole, strongly supports the empirical relevance of the specific characterization of firms' exporting behavior that we propose.

Degree of product differentiation Since our model intends to characterize determinants of export performance in differentiated-good industries, its assumptions are not necessarily appropriate for industries that produce homogeneous goods. First, as suggested in section 2.3, minimum quality requirements for export might exist to solve informational problems that are prevalent in the former industries but not in the latter ones. In particular, since differentiated goods tend to be more complex, quality might be difficult to observe or contract upon. In contrast, homogeneous goods tend to be more standardized, making the informational problem-solving role of quality certification unnecessary. Even if minimum export quality requirements exist for homogeneous goods, the predictions of our model might still not apply. On the supply side, our assumption of an underlying heterogeneous ability to produce quality might not be appropriate for homogeneous-good industries where the cost of upgrading the quality of a product is often exclusively determined by the cost of upgrading the quality of intermediate inputs (e.g. packaged tea in India). On the demand side, the assumptions of product differentiation and consumers' love of variety do not naturally apply to homogeneous-good industries. As a result of the mismatch between the theoretical assumptions and the characteristics of homogeneous products, our predictions about how prices differ between exporters and non-exporters of the same size need not hold for those products.

As a further test that the mechanisms we describe in the paper are indeed those driving our empirical results, we test Proposition 2 alternatively using differentiated and homogeneous goods. To implement the test, we use Rauch's (1999) widely used classification of 4-digit SITC industries into homogeneous, reference-priced, and differentiated goods (liberal version). Merging the first two categories of goods, we map product categories in the Indian and U.S. datasets into a "homogeneous" group and a "differentiated" group. For the Indian data, we manually form a concordance between the SITC Rev.2 product classification and the Indian ASI 5-digit product codes. Since the Indian 5-digit product codes are finer than the SITC codes, each 5-digit Indian product code is linked to a unique SITC code. For the US, we use an SITC-SIC concordance obtained from the US Census Bureau's "U.S. Imports of Merchandise" data CD. Since the SITC classification is more detailed than the SIC 4-digit classification, multiple SITC codes map into the same SIC codes. For each SIC code, we form a product differentiation measure defined as the fraction of SITC codes within the SIC code that are differentiated.[46] Thus for India, the measure is a product

[46]This concordance from SITC to SIC is based on a US census cross-walk that matches trade classification codes to the SIC code. Also, in order to preserve sample size (and hence reduce confidentiality concerns), for SIC codes that do not directly match up to SITC codes, we impute data based on the score for the next highest level of aggregation.

differentiation index is dummy variable (that equals one if the good is classified as differentiated) and for the US the index is a continuous measure of the fraction of goods within the SIC code that is classified as differentiated.

The results from interacting the Rauch product differentiation measures with the export dummy are presented in Table 9. Consistent with our previous discussion, the exporter price premium is higher for differentiated goods in both countries. In India, while the premium is large and statistically significant for differentiated products (as evidenced by the magnitude and statistical significance of the interaction term), the premium is small and not significant for homogeneous products. For the US, even though there is a price premium for homogeneous-good exporters, the premium for exporters of differentiated goods is significantly higher.

Destination market characteristics As discussed in Section 2.3, export quality requirements could be related to the income per capita and distance of destination markets. In this case, we would expect firms exporting to rich and/or distant countries to have a higher quality, and hence price premium, relative to firms exporting to poor and/or proximate countries. In this section, we exploit variation in per capita income and distance across destination markets to further check that the mechanisms we highlight drive the results rather than other mechanisms unrelated to quality.

Unfortunately, our data sets do not provide information on firms' exports by destination country. Instead, we use export destinations at the industry level as a coarser measure. Specifically, we use the concordances from product and industry categories in the Indian and U.S. datasets, respectively, to 4-digit SITC categories described earlier to construct trade-weighted means of destination GDP per capita and destination distance for each Indian and US product categories.[47] This measure is then interacted with the export dummy to test whether the exporter price premium is higher for products which are, on average, sent to richer or to more distant countries.

Table 10 displays the results when we alternatively include each of these interaction terms. In the case of India, the coefficients on both interactions are positive and significant, indicating that the exporter price premium is higher for products sent to richer and to more distant countries. These

That is, for any unmatched 4-digit SIC code, we impute the fraction of differentiated products as equal to the fraction of differentiated products in the the 3-digit SIC classification that the 4-digit code belongs to.

[47]We downloaded the bilateral trade data from the UC Davis Center for International Data website (http://www.internationaldata.org/). GDP per capita data was obtained from the World Bank's World Development Indicators CD ROM. Bilateral distance data was downloaded from the CEPII website http://www.cepii.fr/anglaisgraph/bdd/distances.htm.

results provide strong support for the theory. We note, however, that the correlation between the destination average per capita GDP and the destination average distance variables is 0.75. Thus, we cannot identify their independent effects with precision.[48]

For the U.S., when we include the interaction term for GDP per capita the estimated coefficient is statistically significant – at the 10% level in one of the two specifications. The regressions including the interaction term for distance the coefficient is not significantly different from zero (the correlation between the weighted destination GDP per capita and distance variables is 0.13).

We wish to note the following about these results. First, the finding of a positive coefficient on the GDP interaction is consistent with the notion that income per capita influences the relative stringency of export quality requirement across destination markets. Second, the results for the U.S. are weaker than for India. One possible explanation is that the concordance was done at a more aggregate level in the U.S. (4-digit SIC to 4-digit SITC) compared to India (5-digit product code to 4-digit SITC), which increases the extent of measurement error in the weighted destination GDP and destination distance measures. Third, the U.S. is among the countries with the highest income per capita in the world, which would suggest that quality requirements may not explain the higher prices charged by exporters over those charged by domestic firms. However, a substantial fraction of U.S. exports go to the European Union, where adoption of ISO 9000 quality requirements was initiated and spread much earlier during the 1990s (see Guler et al. 2002).

6 Conclusion

In this paper, we present a model of industry equilibrium with heterogeneous firms where firms differ on two dimensions: productivity (which reduces the marginal costs of the firm), and caliber (which endows the firm with a cost advantage in producing higher quality of output). Higher quality shifts out the demand for the product, or equivalently enables the firm to charge higher prices. We propose that quality plays an important role in determining the export status of a firm. In particular, we propose that firms need to possess a minimum quality threshold in order to export, independent of their productivity level.

[48] When both interaction terms are included simultaneously, the magnitude and statistical significance of their coefficients drop. The reduction in magnitude and increase in standard error is small for the GDP interaction, which is significant in one specification at 10% and just below significance in the second specification. The coefficient on the distance interaction drops by more than 60% and is estimated very noisily. Thus, it appears that the GDP effect is statistically more robust, and may explain part of the distance interaction effect.

Our model leads to a number of interesting implications, including the following: (i) Size is not the sole determinant of export status; if productivity is high but caliber is low, a firm may be large but restrict itself to the domestic market. Similarly a high caliber but low productivity firm may enter the export market though its size is small. (ii) The price charged by exporting firms is higher than that charged by non-exporting firms, *conditional on size*. (iii) Under the assumption that producing higher quality requires workers of greater ability, average wage rate would be higher for exporters relative to non-exporters, *conditional on size*. (iv) capital intensity (defined as the ratio of capital to labor) is higher for exporters relative to non-exporters, conditional on size.

We test these predictions using establishment-level data from India, the U.S., Chile and Colombia, and find strong support for the predictions of the model. Because we document evidence for exporter price, wage and capital intensity premia flexibly *conditioning on size*, the documented effects contrast with what would be predicted by single-attribute models (e.g. Melitz 2003, Baldwin and Harrigan 2007, Johnson 2008, and Kugler and Verhoogen 2008), as these models do not predict differences between exporters and non-exporters, *conditional on size*. We argue that, relative to other multi-attribute models (e.g. Alessandria and Choi (2007), Das et al. (2008), Ruhl (2008), and Nguyen (2008)) our model provides the simplest explanation for the set of empirical finings documented here. Consistent with some of the possible motivations for the minimum quality requirement, we find evidence that the exporter price premium is correlated with the degree of differentiation of products, the per capita income levels of destinations, and the distance to destinations.

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Appendix 1: Existence and uniqueness of equilibrium in the constrained environment

To save notation, rename $\varphi = \widetilde{\varphi}/c$ and $\xi = \widetilde{\xi}/f$ so that $\widetilde{\varphi}$ and $\widetilde{\xi}$ now denote the original productivity and caliber draws. Hence, φ and ξ can be interpreted as "cost-adjusted productivity and caliber", a combination of technology and input cost.

Ex-ante expected profits are given by

$$\overline{\Pi}(P, P^*) = \int_0^{\overline{\varphi}} \int_0^{\bar{\xi}} \Pi\left(\varphi, \xi, P, P^*\right) v\left(\varphi, \xi\right) d\xi d\varphi, \qquad P > 0, P^* > 0$$

where

$$\Pi\left(\varphi, \xi, P, P^*\right) = \begin{cases} 0 & \text{if } (\varphi,\xi) \in r(I) = \left\{(\varphi,\xi) : \xi \leq \underline{\xi}(\varphi)\right\} \\ \Pi_d(\varphi,\xi,P) & \text{if } (\varphi,\xi) \in r(II) = \left\{(\varphi,\xi) : \underline{\xi}(\varphi) < \xi \leq \underline{\xi}_u(\varphi)\right\} \text{ or} \\ & (\varphi,\xi) \in r(III) = \left\{(\varphi,\xi) : \varphi > \varphi_{\underline{\lambda}} \text{ and } \underline{\xi}_u(\varphi) < \xi \leq \underline{\xi}_x(\varphi)\right\} \\ \Pi_c\left(\varphi,\xi,P,P^*\right) & \text{if } (\varphi,\xi) \in r(IV) = \left\{(\varphi,\xi) : \varphi > \varphi_{\underline{\lambda}} \text{ and } \underline{\xi}_x(\varphi) < \xi \leq \underline{\xi}_\lambda(\varphi)\right\} \\ \Pi_u\left(\varphi,\xi,P,P^*\right) & \text{if } (\varphi,\xi) \in r(V.a) = \left\{(\varphi,\xi) : \varphi \leq \varphi_{\underline{\lambda}} \text{ and } \underline{\xi}_u(\varphi) < \xi\right\} \text{ or} \\ & (\varphi,\xi) \in r(V.b) = \left\{(\varphi,\xi) : \varphi > \varphi_{\underline{\lambda}} \text{ and } \underline{\xi}_\lambda(\varphi) < \xi\right\}. \end{cases}$$

At the limits between regions, firms are indifferent among the different choices implied by the limiting regions. Thus, the function $\Pi\left(\varphi, \xi, P, P^*\right)$ does not jump. Hence, it is continuous in (φ, ξ), even though not differentiable at the limits of integration – of measure zero in R^2.

Expected profits can be written as:

$$\begin{aligned} \overline{\Pi}(P, P^*) &= \int_0^{\overline{\varphi}} \int_0^{\bar{\xi}} \Pi\left(\varphi, \xi, P, P^*\right) v\left(\varphi, \xi\right) d\xi d\varphi \\ &= \int_0^{\overline{\varphi}} \int_{\underline{\xi}(\varphi,P,P^*)}^{\underline{\xi}_u(\varphi,P,P^*)} \Pi_d\left(\varphi,\xi,P,P^*\right) v\left(\varphi,\xi\right) d\xi d\varphi + \int_{\varphi_{\underline{\lambda}}(P,P^*)}^{\overline{\varphi}} \int_{\underline{\xi}_u(\varphi,P,P^*)}^{\underline{\xi}_x(\varphi,P,P^*)} \Pi_d\left(\varphi,\xi,P,P^*\right) v\left(\varphi,\xi\right) d\xi d\varphi \\ &+ \int_{\varphi_{\underline{\lambda}}(P,P^*)}^{\overline{\varphi}} \int_{\underline{\xi}_x(\varphi,P,P^*)}^{\underline{\xi}_\lambda(\varphi,P,P^*)} \Pi_c\left(\varphi,\xi,P,P^*\right) v\left(\varphi,\xi\right) d\xi d\varphi \\ &+ \int_{\varphi_{\underline{\lambda}}(P,P^*)}^{\overline{\varphi}} \int_{\underline{\xi}_\lambda(\varphi,P,P^*)}^{\bar{\xi}} \Pi_u\left(\varphi,\xi,P,P^*\right) v\left(\varphi,\xi\right) d\xi d\varphi + \int_0^{\varphi_{\underline{\lambda}}(P,P^*)} \int_{\underline{\xi}_u(\varphi,P,P^*)}^{\bar{\xi}} \Pi_u\left(\varphi,\xi,P,P^*\right) v\left(\varphi,\xi\right) d\xi d\varphi \end{aligned} \tag{28}$$

where Π_d, Π_u, and Π_c are respectively given by equations (8), (16), and (21). The functions Π_d, Π_u, and Π_c are continuous and differentiable in P and P^*, as are also the limits of integration. Therefore, the continuity and differentiability of the function $\overline{\Pi}(P, P^*)$ in P and P^* follows directly.

Since $\Pi\left(\varphi, \xi, P, P^*\right)$ is continuous in (φ, ξ), by application of Leibniz rule we can find the derivatives of $\overline{\Pi}(P, P^*)$ with respect to P and P^*. These derivatives result in expressions analogous to

(28) except that they integrate over derivatives instead of function values (note that the derivatives of the limits of integration cancel out). Since $\forall(P, P^*, \varphi, \xi) : \frac{\partial \Pi_i}{\partial P} < 0$, $i = d, u, c$, $\frac{\partial \Pi_i}{\partial P^*} < 0$, $i = u, c$, and $\frac{\partial \Pi_d(\varphi,\xi,P,P^*)}{\partial P^*} = 0$, we can easily establish that $\forall(P, P^*) : \frac{\partial \overline{\Pi}(P,P^*)}{\partial P} < 0$ and $\frac{\partial \overline{\Pi}(P,P^*)}{\partial P^*} < 0$. Analogously, we can establish that in the foreign country, $\forall(P, P^*) : \frac{\partial \overline{\Pi}^*(P,P^*)}{\partial P} < 0$ and $\frac{\partial \overline{\Pi}^*(P,P^*)}{\partial P^*} < 0$.

Free-entry in each country implies the following system of equations:

$$\overline{\Pi}(P, P^*) = f_e \tag{29}$$

$$\overline{\Pi}^*(P, P^*) = f_e^* \tag{30}$$

We want to show that an equilibrium pair (P, P^*) exists and is unique. First, we make the following assumption:

Assumption 1:

$$\lim_{P\to\infty} \overline{\Pi}(P, P^*) < \lim_{P\to\infty} \overline{\Pi}^*(P, P^*)$$

$$\lim_{P^*\to\infty} \overline{\Pi}(P, P^*) > \lim_{P^*\to\infty} \overline{\Pi}^*(P, P^*)$$

The two inequalities are analogous. When $P \to \infty$ there are no profits to be made in the Home market so firms only operate in the Foreign market. Then, the first inequality simply states that Foreign firms' expected profits in the Foreign market – for any P^* – are higher than Home firms' expected profits in that market. Analogously, the second inequality states that Home firms' expected profits in the Home market are higher than Foreign firms' expected profits there.

Proposition 3. *: Under Assumption 1, there exists a unique pair (P, P^*) that solves the system of equations (29) and (30).*

Since $\overline{\Pi}(P, P^*)$ is strictly decreasing in P^*, for any given P the value of P^* that solves equation (29) is unique and implicitly defines a function $P^* = {P^*}^H(P)$. Similarly, since $\overline{\Pi}(P, P^*)$ is strictly decreasing in P, we can obtain the inverse function $P = P^H(P^*)$. Using the Implicit Function Theorem and previous results, we establish that this function is downward sloping: $\frac{dP^*}{dP}\big|_H = -\frac{\partial \overline{\Pi}(P,P^*)/\partial P}{\partial \overline{\Pi}(P,P^*)/\partial P^*} < 0$. Analogously, equation (30) defines $P^* = {P^*}^F(P)$ and $P = P^F(P^*)$ with slope $\frac{dP^*}{dP}\big|_F = -\frac{\partial \overline{\Pi}^*(P,P^*)/\partial P}{\partial \overline{\Pi}^*(P,P^*)/\partial P^*} < 0$.

The existence proof is represented in Figure A1. Assumption 1 implies that $f_e = \lim_{P\to\infty} \overline{\Pi}\left(P, {P^*}^H(P)\right) < \lim_{P\to\infty} \overline{\Pi}^*\left(P, {P^*}^H(P)\right)$. Since $\overline{\Pi}^*(P, P^*)$ is decreasing in P^*, this inequality also implies that

$$\lim_{P\to\infty} {P^*}^H(P) < \lim_{P\to\infty} {P^*}^F(P). \tag{31}$$

Analogously, assumption 2 implies that $f_e^* = \lim_{P^* \to \infty} \overline{\Pi}^* \left(P^F(P^*), P^*\right) < \lim_{P^* \to \infty} \overline{\Pi} \left(P^F(P^*), P^*\right)$. Together with the fact that $\overline{\Pi}(P, P^*)$ is decreasing in P, this inequality implies that

$$\lim_{P^* \to \infty} P^F(P^*) < \lim_{P^* \to \infty} P^H(P^*). \tag{32}$$

Since both ${P^*}^H(P)$ and ${P^*}^F(P)$ are decreasing, (31) and (32) imply that these two curves must cross at least once. Thus, an equilibrium exists.

To show uniqueness we only need to demonstrate that the two curves satisfy the *single crossing* property: $\left| \left. \frac{dP^*}{dP} \right|_H \right| > \left| \left. \frac{dP^*}{dP} \right|_F \right|$. These derivatives are given by the following expressions:

$$\left| \left. \frac{dP^*}{dP} \right|_H \right| = \frac{A + \frac{E}{P^2} B}{\tau^{-\sigma} \frac{E^*}{{P^*}^2} B}, \qquad \left| \left. \frac{dP^*}{dP} \right|_F \right| = \frac{\tau^{-\sigma} \frac{E}{P^2} D}{C + \frac{E^*}{{P^*}^2} D}$$

where

$$A = J \tfrac{\alpha}{\alpha'} \left(\tfrac{E}{P}\right)^{\frac{\alpha}{\alpha'}} P^{-1} \left[\int_0^{\overline{\varphi}} \int_{\underline{\xi}(\varphi,P,P^*)}^{\underline{\xi}_u(\varphi,P,P^*)} \eta(\varphi,\xi)\, v(\varphi,\xi)\, d\xi d\varphi + \int_{\varphi_{\underline{\lambda}}(P,P^*)}^{\overline{\varphi}} \int_{\underline{\xi}_u(\varphi,P,P^*)}^{\underline{\xi}_x(\varphi,P,P^*)} \eta(\varphi,\xi)\, v(\varphi,\xi)\, d\xi d\varphi \right]$$

$$B = \tfrac{1}{\sigma} \left(\tfrac{\sigma-1}{\sigma}\right)^{\sigma-1} \underline{\lambda}^{\alpha-\alpha'} \int_{\varphi_{\underline{\lambda}}(P,P^*)}^{\overline{\varphi}} \int_{\underline{\xi}_x(\varphi,P,P^*)}^{\underline{\xi}_\lambda(\varphi,P,P^*)} \varphi^{\sigma-1} v(\varphi,\xi)\, d\xi d\varphi$$
$$+ J \tfrac{\alpha}{\alpha'} W^{\frac{\alpha-\alpha'}{\alpha'}} \left[\int_{\varphi_{\underline{\lambda}}(P,P^*)}^{\overline{\varphi}} \int_{\underline{\xi}_\lambda(\varphi,P,P^*)}^{\overline{\xi}} \eta(\varphi,\xi)\, v(\varphi,\xi)\, d\xi d\varphi + \int_0^{\varphi_{\underline{\lambda}}(P,P^*)} \int_{\underline{\xi}_u(\varphi,P,P^*)}^{\overline{\xi}} \eta(\varphi,\xi)\, v(\varphi,\xi)\, d\xi d\varphi \right]$$

$$C = J \tfrac{\alpha}{\alpha'} \left(\tfrac{E^*}{P^*}\right)^{\frac{\alpha}{\alpha'}} {P^*}^{-1} \left[\int_0^{\overline{\varphi}} \int_{\underline{\xi}^*(\varphi,P,P^*)}^{\underline{\xi}_u^*(\varphi,P,P^*)} \eta(\varphi,\xi)\, v^*(\varphi,\xi)\, d\xi d\varphi + \int_{\varphi_{\underline{\lambda}}(P,P^*)}^{\overline{\varphi}} \int_{\underline{\xi}_u^*(\varphi,P,P^*)}^{\underline{\xi}_x^*(\varphi,P,P^*)} \eta(\varphi,\xi)\, v^*(\varphi,\xi)\, d\xi d\varphi \right]$$

$$D = \tfrac{1}{\sigma} \left(\tfrac{\sigma-1}{\sigma}\right)^{\sigma-1} \underline{\lambda}^{*\alpha-\alpha'} \int_{\varphi_{\underline{\lambda}}(P,P^*)}^{\overline{\varphi}} \int_{\underline{\xi}_x^*(\varphi,P,P^*)}^{\underline{\xi}_\lambda^*(\varphi,P,P^*)} \varphi^{\sigma-1} v^*(\varphi,\xi)\, d\xi d\varphi$$
$$+ J \tfrac{\alpha}{\alpha'} {W^*}^{\frac{\alpha-\alpha'}{\alpha'}} \left[\int_{\varphi_{\underline{\lambda}}(P,P^*)}^{\overline{\varphi}} \int_{\underline{\xi}_\lambda^*(\varphi,P,P^*)}^{\overline{\xi}} \eta(\varphi,\xi)\, v^*(\varphi,\xi)\, d\xi d\varphi + \int_0^{\varphi_{\underline{\lambda}}(P,P^*)} \int_{\underline{\xi}_u^*(\varphi,P,P^*)}^{\overline{\xi}} \eta(\varphi,\xi)\, v^*(\varphi,\xi)\, d\xi d\varphi \right]$$

Since $A > 0$, $B > 0$, $C > 0$, $D > 0$, it is easy to show with simple algebra that the single property holds $\forall (P, P^*)$. Thus, there is a unique equilibrium. *QED*

Appendix 2: Proof of Proposition 2

Consider an exporter and a domestic firms located on the same iso-revenue curve. Then $r_x(\lambda_x(\varphi_x, \xi_x)) = r_d(\lambda_d(\varphi_d, \xi_d))$. Since the exporter has chosen to export, the benefits of participating both in the domestic and in the foreign markets must outweigh the benefits of participating only in the domestic market:

$$\pi_x(\lambda_x(\varphi_x, \xi_x)) \geq \pi_d(\lambda_d(\varphi_x, \xi_x)). \tag{33}$$

In (33), $\lambda_d(\varphi_x, \xi_x)$ indicates the quality level that the exporter would have chosen had she decided not to export. The optimality of $\lambda_d(\varphi_x, \xi_x)$, conditional on not exporting, implies that any other quality level, in particular $\lambda_x(\varphi_x, \xi_x)$, would have yielded lower profits. Therefore:

$$\pi_d(\lambda_d(\varphi_x, \xi_x)) \geq \pi_d(\lambda_x(\varphi_x, \xi_x)). \tag{34}$$

Combining inequalities (33) and (34), we obtain:

$$\pi_x(\lambda_x(\varphi_x, \xi_x)) - \pi_d(\lambda_x(\varphi_x, \xi_x)) \geq 0, \tag{35}$$

which can be expressed as:

$$\frac{1}{\sigma}(r_x(\lambda_x(\varphi_x, \xi_x)) - r_d(\lambda_x(\varphi_x, \xi_x))) - f_x \geq 0.$$

Since $r_x(\lambda_x(\varphi_x, \xi_x)) = r_d(\lambda_d(\varphi_d, \xi_d))$ on the same iso-revenue curve, this expression can be written as

$$-\frac{1}{\sigma}(r_d(\lambda_x(\varphi_x, \xi_x)) - r_d(\lambda_d(\varphi_d, \xi_d))) - f_x \geq 0.$$

Using $r_d = p^{1-\sigma}\lambda^{\sigma-1}\frac{E}{P}$ and the pricing equation (**??**), we obtain

$$-\frac{1}{\sigma}(\frac{\sigma}{\sigma-1}\frac{c}{\varphi})^{1-\sigma}\frac{E}{P}\left[(\lambda_x(\varphi_x, \xi_x))^{\alpha-\alpha'} - (\lambda_d(\varphi_d, \xi_d))^{\alpha-\alpha'}\right] - f_x \geq 0. \tag{36}$$

In the case of a non-exporter, the optimality of his choice analogously implies that

$$\pi_x(\lambda_d(\varphi_d, \xi_d)) - \pi_d(\lambda_d(\varphi_d, \xi_d)) < 0.$$

Following similar steps as we did for the exporter, we obtain the following inequality:

$$\frac{1}{\sigma}(\frac{\sigma}{\sigma-1}\frac{c}{\varphi})^{1-\sigma}W\left[(\lambda_d(\varphi_d, \xi_d))^{\alpha-\alpha'} - (\lambda_x(\varphi_x, \xi_x))^{\alpha-\alpha'}\right] - f_x < 0 \tag{37}$$

Finally, multiplying (37) by -1 and adding it to (36), we obtain:

$$\frac{1}{\sigma}(\frac{\sigma}{\sigma-1}\frac{c}{\varphi})^{1-\sigma}\left[(\lambda_x(\varphi_x, \xi_x))^{\alpha-\alpha'} - (\lambda_d(\varphi_d, \xi_d))^{\alpha-\alpha'}\right](W - \frac{E}{P}) > 0.$$

Since $W > \frac{E}{P}$ and $\alpha - \alpha' > 0$, this inequality implies that $\lambda_x(\varphi_x, \xi_x) > \lambda_d(\varphi_d, \xi_d)$.

QED

Appendix 3: Proof of Corollary 3

To demonstrate Corollary 3, we first substitute the pricing equation for capital goods, $p_{hv} = \sum_{t=0}^{v} \frac{w_{ht}^K}{\rho_t}$, into the definition of VK to obtain

$$VK = \sum_{h=1}^{H} \sum_{v=1}^{V} \sum_{t=0}^{v} \frac{w_{ht}^K K_{hv}}{\rho_t}. \tag{38}$$

We now make two assumptions. First, we assume that the relative prices of different types of capital do not change over time:

$$\forall h,\ w_{ht}^K = \upsilon_t w_h^K$$

Then, we assume that, although firms differ in the composition of their capital across types of capital goods, they do not differ in the composition of their capital across vintages within types, i.e.,

$$\forall h,\ K_{hv} = a_v K_h, \quad K_h = \sum_{v=1}^{V} K_{hv}$$

Substituting these two assumptions into equation (38), we obtain

$$VK = \sum_{h=1}^{H} \sum_{v=1}^{V} \sum_{t=0}^{v} \frac{\upsilon_t w_h^K a_v K_h}{\rho_t} = \gamma \sum_{h=1}^{H} w_h^K K_h = \gamma w^K K$$

where $\gamma = \sum_{v=1}^{V} \sum_{t=0}^{v} \frac{\upsilon_t a_v}{\rho_t}$.

Variable costs are characterized by a Cobb-Douglas production function. Thus, cost shares are constant and $\frac{w^K K}{\alpha_K} = \frac{w^L L}{\alpha_L}$, which implies that

$$\frac{VK}{L} = \gamma \frac{w^K K}{L} = \gamma \frac{\alpha_K}{\alpha_L} w^L = \gamma \frac{\alpha_K}{\alpha_L} \underline{w}^L \lambda^{b_L}. \tag{39}$$

Since fixed costs are also characterized by a Cobb-Douglas production function with identical coefficients, equation (39) also applies to those costs. Then, equation (39) also characterizes the capital intensity of the plant, i.e. including labor and capital associated with fixed and variable costs.

It is easy to check that $\frac{d\left(\frac{VK}{L}\right)}{d\lambda} > 0$ if $b_L > 0$. This result, combined with Proposition 2, immediately implies Corollary 3. *QED*

Data Appendix

Indian Manufacturing Survey Data (ASI 1997-98)

In the Indian data, each establishment is classified under a 4-digit National Industrial Classification 1987 revision (NIC) code. This is a narrower classification than the ISIC 4-digit code; there are about 520 distinct 4-digit NIC codes. Because all the variables except price are defined uniquely at the establishment level, our analysis of all variables except price uses 4-digit NIC fixed effects and other controls. As part of cleaning up the data, we drop observations that having missing data on our size proxies (revenue and employment) and key dependent variables (capital intensity and average wage rates). Also, because we use industry-specific revenue (or employment) polynomial of order 3 (i.e. 3rd order revenue polynomials where the coefficients are allowed to vary by industry) in some of our specifications, we exclude industries with less than 5 observations from our sample as well as industries with no exporters. Further, to avoid the influence of outliers, we winsorize all variables by 1 % on both tails of the distribution (within each industry). After cleaning the data (dropping observations with missing and industries with less than 5 observations), we are left with about 320 distinct 4-digit NIC industries.

The ASI survey data for 1997-98 includes information on the value of shipments as well as quantity for different product lines produced by each establishment. The products are classified under a 5 digit product code, which provides a very detailed breakdown and description of the individual product line. Two of the products codes (99920 and 99930) correspond to reporting of subtotals of basic and non-basic items respectively, and hence we exclude them from our sample. Further, there are a number of observations in an unclassified product code (99999) which also we drop from our sample.

Different products are measured using different units. There are about 25 distinct unit codes reported in the raw data. One of the unit codes (999) correspond to products with no specified units of measurement. In order to ensure comparability of price, we drop all observations where the product is measured in unspecified units. As we did for the other establishment-level capital intensity and average wage variables, for the price analysis also we drop observations with missing data on price and size (revenue or employment) controls. Again, to ensure identification of the product specific cubic size control function, we exclude from our sample product codes with less than 5 observations, as well as product codes for which there are no exporters. After cleaning of the data, we are left with about 25,709 observations covering about 993 distinct product codes. The price variable is also winsorized by 1% on both tails of the distribution.

As discussed in the text, different establishments are sampled with different sampling probabilities reflected in the multiplier (which provides the inverse of the sampling weight). All our analysis adjusts appropriately for these sampling probabilities.

US Census of Manufactures Survey Data (CMF 1997)

The cleaning and analysis of the US data followed the same procedures used for the Indian data discussed above.

Similar to the case of the Indian data, each establishment in the US CMF 1997 is classified under a 4-digit Standard Industrial Classification 1987 revision (SIC87) code. Overall there are about 450 distinct 4-digit SIC87 codes. Because all the variables except price are defined uniquely at the establishment level, our analysis of all variables except price uses 4-digit SIC fixed effects and other controls. As part of cleaning up the data, we drop observations that having missing data on our size proxies (revenue and employment) and key dependent variables (capital intensity and average wage rates). Also, because we use industry-specific revenue (or employment) polynomial of order 3 (i.e. 3rd order revenue polynomials where the coefficients are allowed to vary by industry) in some of our specifications, we exclude industries with less than 5 observations from our sample as well as industries with no exporters. Further, to avoid the influence of outliers, we winsorize all variables by 1 % on both tails of the distribution (within each industry). After cleaning the data (dropping observations with missing and industries with less than 5 observations), we are left with about 320 distinct 4-digit NIC industries.

The CMF 1997 has separate files that cover information on the value of shipments as well as quantity for different product lines produced by each establishment. The products are classified under a 7 digit SIC based product code, which provides a very detailed breakdown and description of the individual product line.

As we did for the other establishment-level capital intensity and average wage variables, for the price analysis also we drop observations with missing data on price and size (revenue or employment) controls. Again, to ensure identification of the product specific cubic size control function, we exclude from our sample product codes with less than 5 observations, as well as product codes for which there are no exporters. After cleaning of the data, we are left with about 98,702 observations covering about 2069 distinct product codes. The price variable is also winsorized by 1% on both tails of the distribution. In our cleaned data sample with price information, a small fraction of product codes start with digits other than 2 or 3, implying that these are not manufacturing sector products. We checked robustness to excluding such non-manufacturing products. Similarly, a small fraction of products ended with 0 or 9, indicating a broad or residual classification; we checked and found results robust to omitting these products as well.

One drawback of the product data is that its coverage is limited. In our cleaned up data set, there is detailed product-level information available from 33,995 establishments, whereas we have information on other variables such as capital intensity and average wages for 389,113 establishments. A big part of the difference in number of establishments is accounted for by the fact that data are not available for a large number of "administrative records" establishments for which the US Census collates data from administrative records rather than from direct surveys.

Unlike the Indian ASI data, in the US CMF data all establishments are included in the survey, so no adjustments for sampling probability is required.

Chilean and Colombian Manufacturing Survey Data

The cleaning of these datasets was more straightforward as they do not have data on product lines (hence issues related to undefined units and product codes do not arise here). As we did for the Indian data, we excluded observations for which data is missing for the average wage and capital intensity variables, as well as size (revenue or employment) controls. To ensure identification of the industry specific cubic size control function, we exclude from our sample industries with less than 5 observations. Also, industries with no exporters were excluded.

Both Chilean and Colombian data are classified using the 4-digit (ISIC) industry classification that is more broadly defined than the Indian NIC 4-digit classification. After data cleaning, there are about 83 4-digit industries in Chile and 92 4-digit industries in Colombia.

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

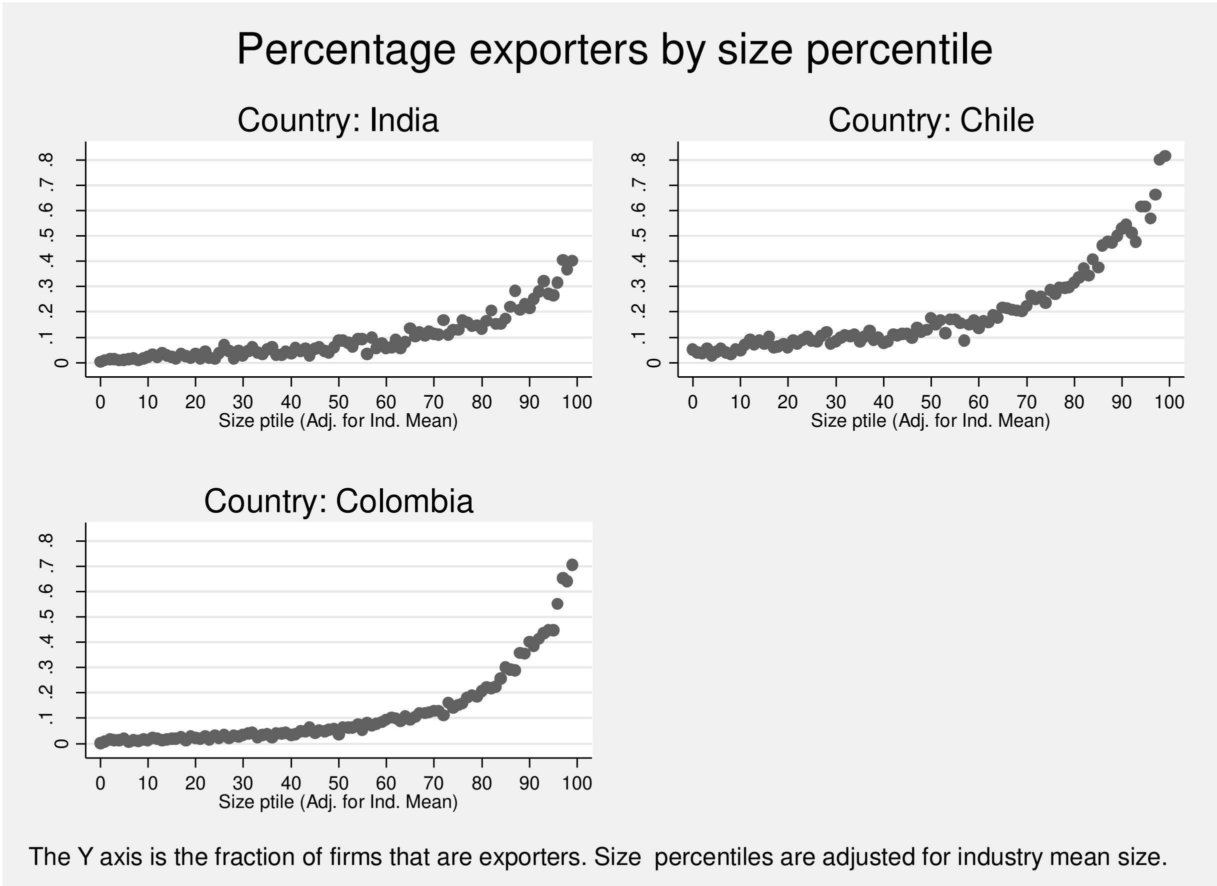
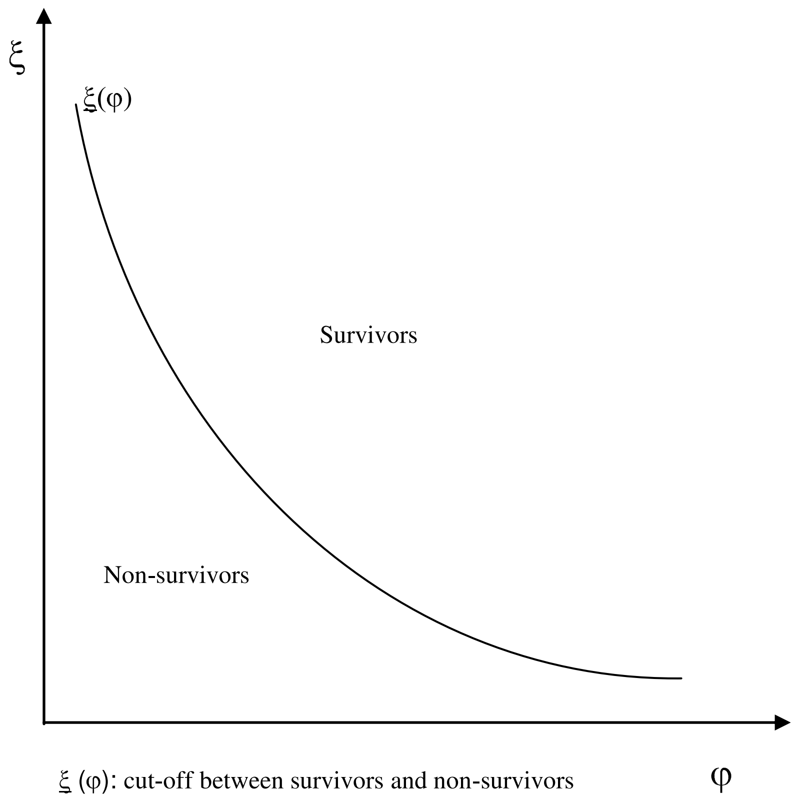
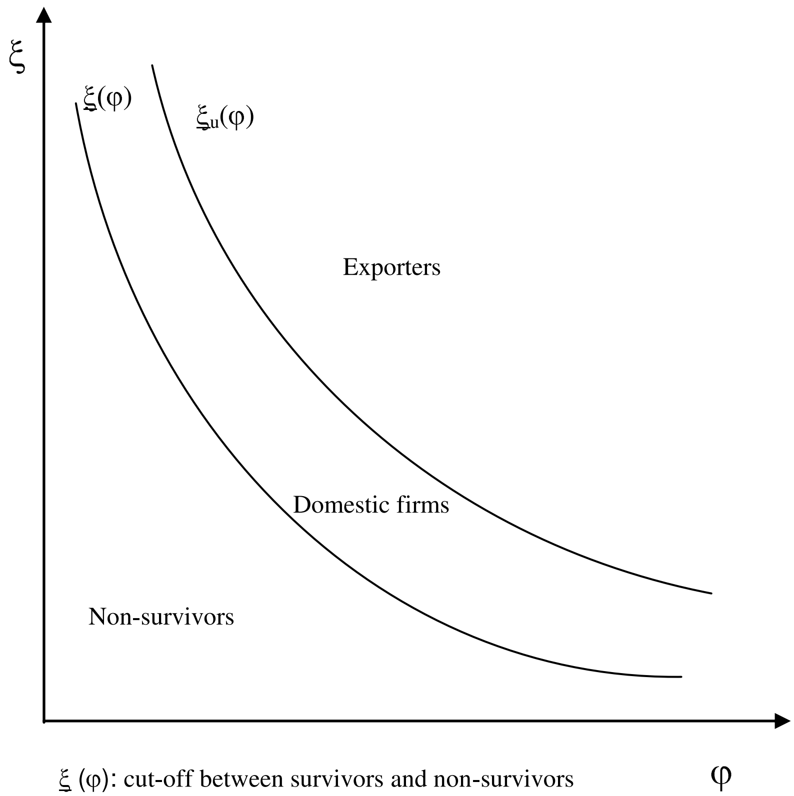


Figure 2: Equilibrium in the closed economy



ξ (φ): cut-off between survivors and non-survivors

Figure 3: Unconstrained export quality equilibrium



ξ (φ): cut-off between survivors and non-survivors

ξ_u(φ): export cut-off in the unconstrained regime

Figure 4: Fraction of exporters as a function of revenue in the unconstrained export quality equilibrium

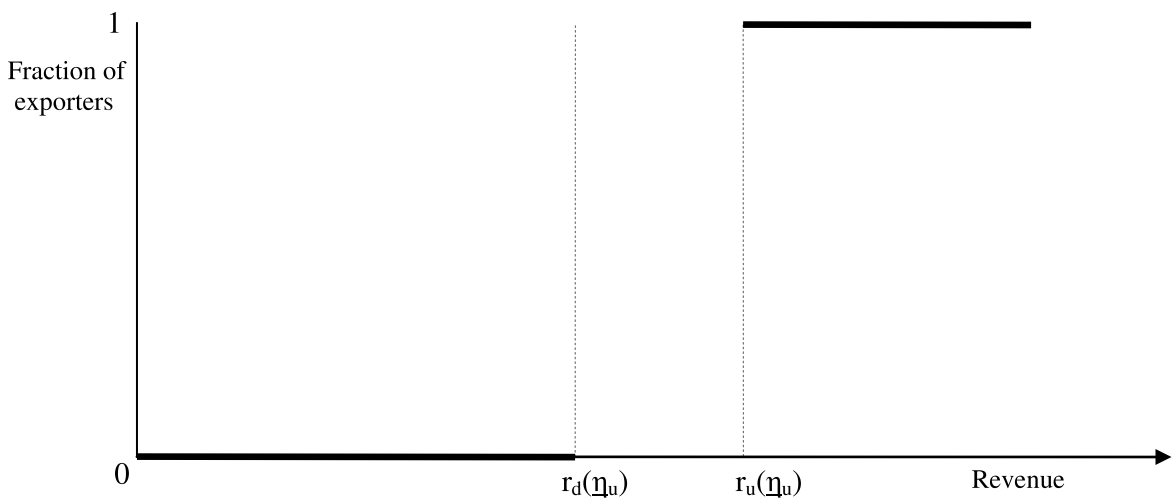
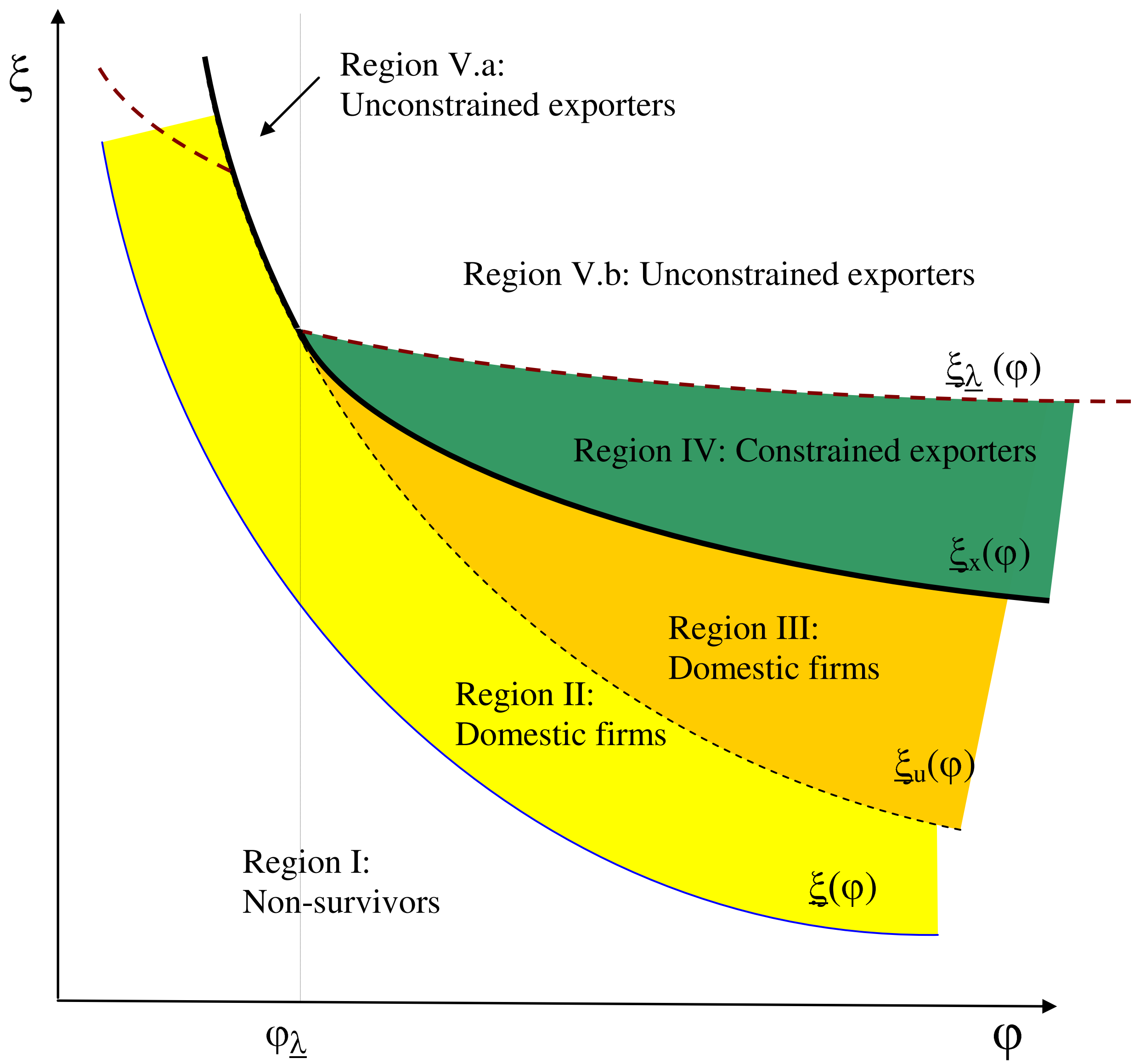


Figure 5: Constrained export quality equilibrium



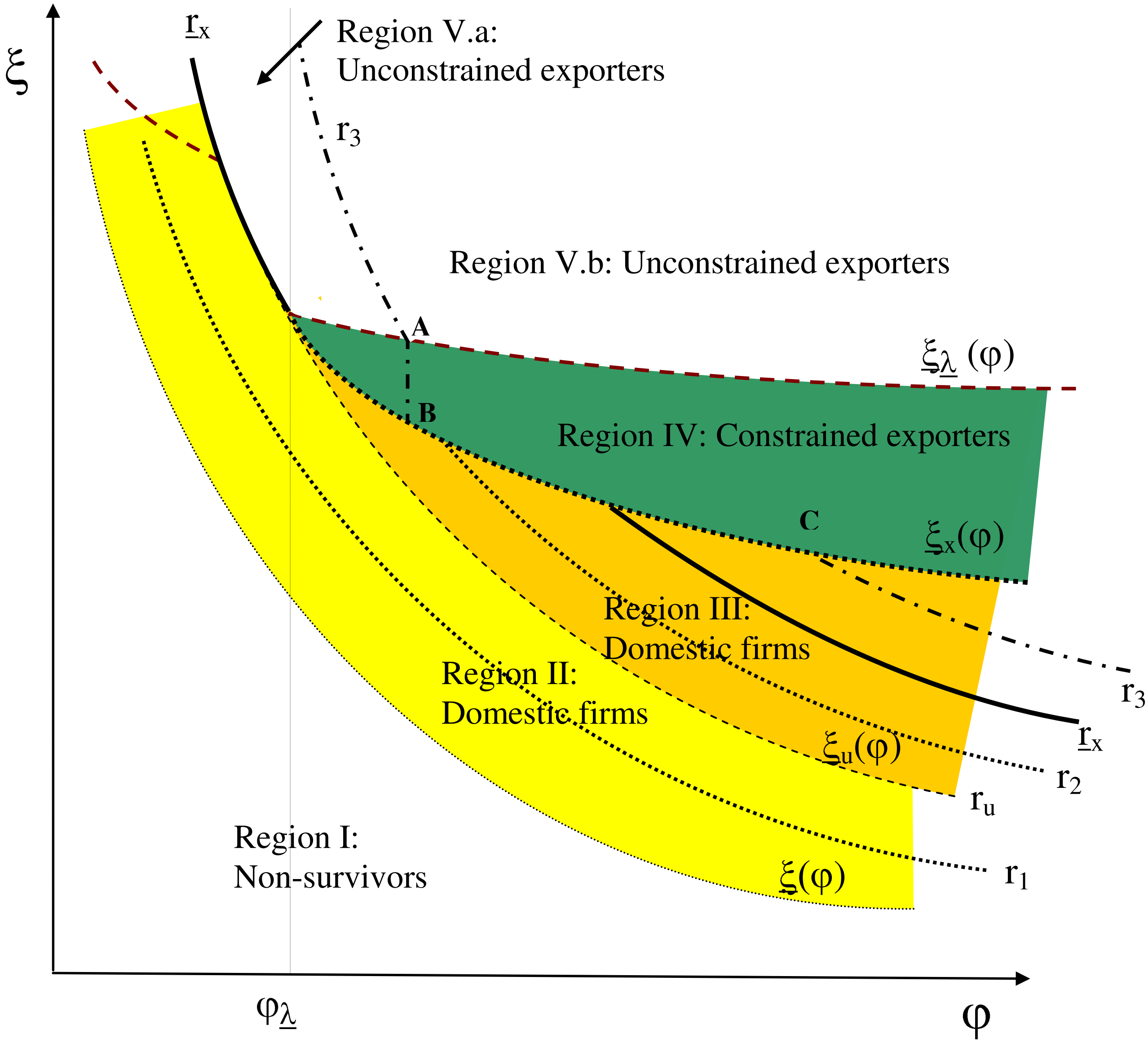
$\underline{\xi}(\varphi)$: cut-off between survivors and non-survivors

$\underline{\xi}_u(\varphi)$: export cut-off in the unconstrained regime

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

$\underline{\xi}_x(\varphi)$: export cut-off in the constrained regime

Figure 6: Iso-revenue and iso-quality curves in the constrained export quality equilibrium



$\underline{\xi}(\varphi)$: cut-off between survivors and non-survivors

$\underline{\xi}_u(\varphi)$: export cut-off in the <u>unconstrained</u> regime

$\underline{\xi}_{\underline{\lambda}}(\varphi)$: isoquality curve for threshold quality $\underline{\lambda}$

$\underline{\xi}_x(\varphi)$: export cut-off in the <u>constrained</u> regime

Figure 7: Lowess regression: Log price

The graph presents a locally weighted smoothed (lowess) regression of standardized (i.e. demeaned by the product specific mean and divided by the product specific standard deviation) log per unit price on standardized revenue groups. The weighting function used is Cleveland's (1979) tricube weighting function and the bandwidth used is 0.80.

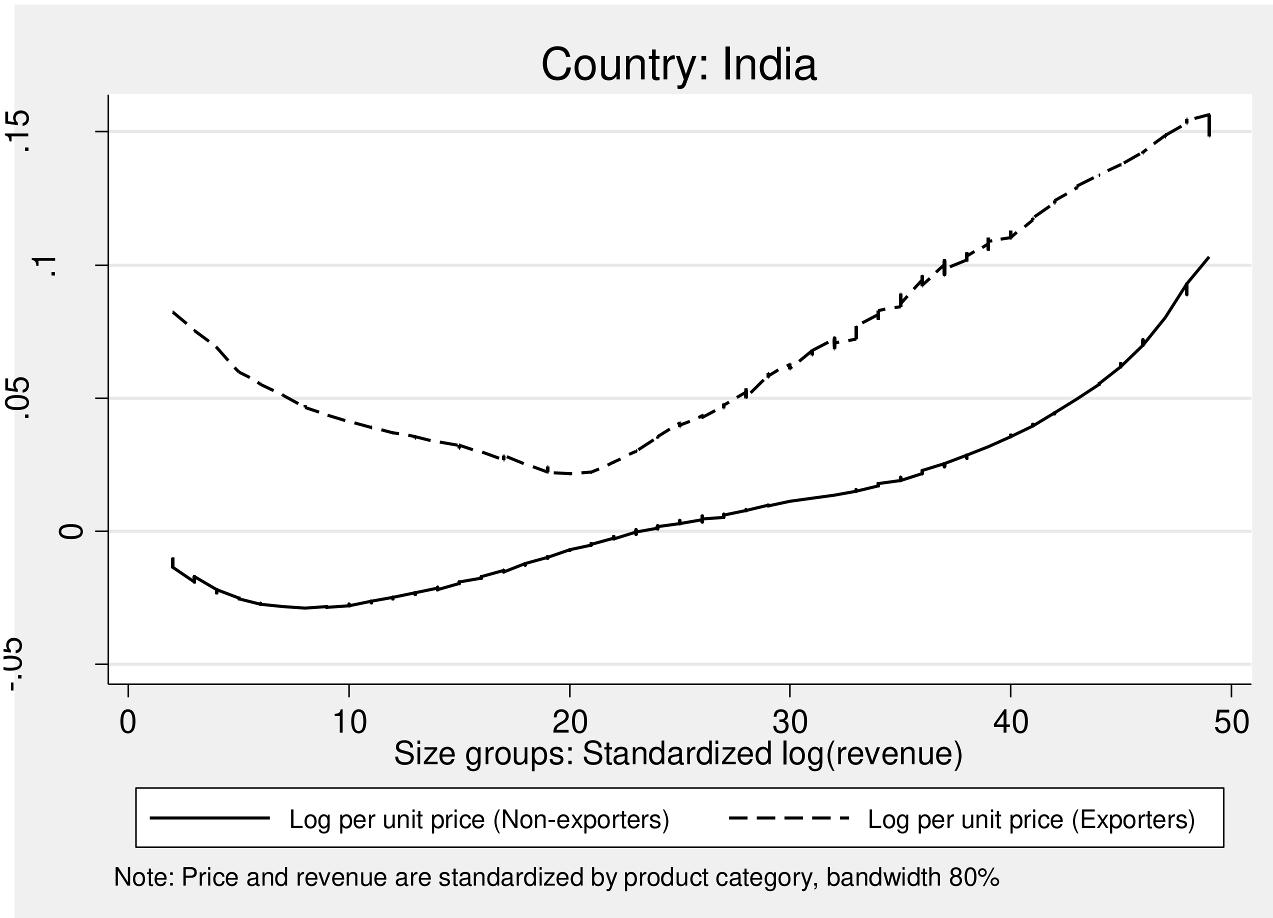


Figure A.1: Existence of equilibrium

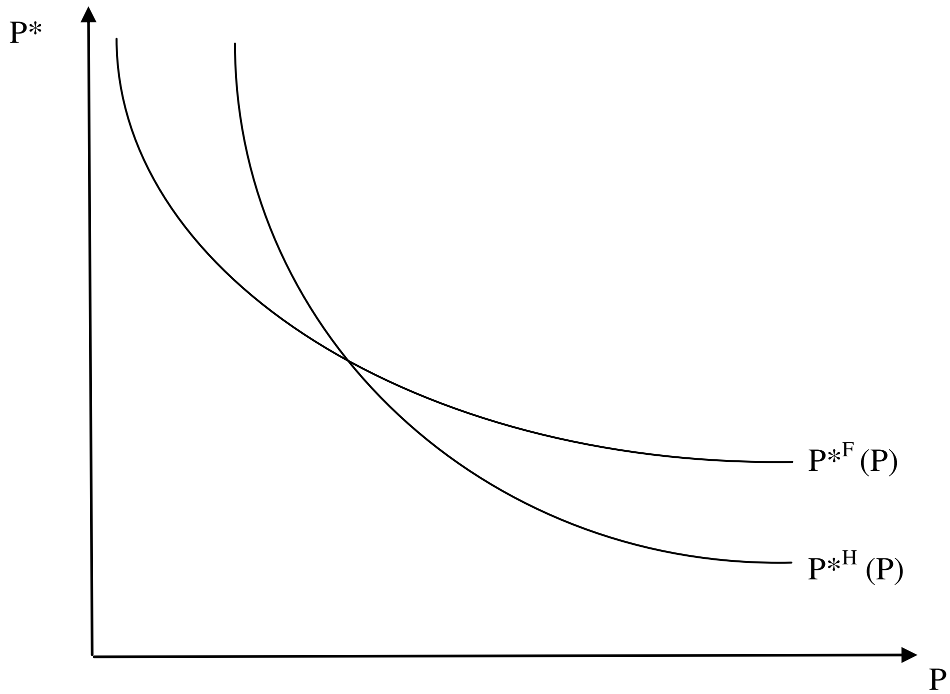


Table 1: Summary statistics

The reported means and standard deviations are adjusted for sampling weights. The nominal variables (wages and capital) for India are measured in rupees, for US in thousands of dollars, for Chile in current Chilean pesos, and for Colombia in current Colombian pesos. All variables (except the ISO 9000 dummy) are winsorized by 1% on both tails of the distribution.

	ALL ESTABLISHMENTS			NON-EXPORTERS			EXPORTERS		
Description	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**
Panel 1: India (1998)									
Log per unit price	25,709	8.02	2.62	20,416	8.08	2.57	5,293	7.64	2.87
Log(average wage rate)	21,143	10.10	0.66	17,509	10.04	0.64	3,634	10.56	0.64
Capital intensity [Log (capital/labor)]	21,143	10.72	1.87	17,509	10.58	1.87	3,634	11.73	1.54
ISO 9000 dummy	24,064	0.04	0.19	20,338	0.02	0.14	3,726	0.17	0.38
Panel 2: USA (1997)									
Log per unit price	98,702	-0.55	1.92	69,963	-0.66	1.86	28,739	-0.29	2.04
Log(average wage rate)	389,113	3.10	0.57	341,502	3.05	0.58	47,611	3.45	0.39
Capital intensity [Log (capital/labor)]	389,113	3.31	1.06	341,502	3.27	1.03	47,611	3.57	1.25
Panel 3: Chile (1991-96)									
Log(average wage rate)	30,377	7.30	0.71	23,670	7.18	0.67	6,707	7.73	0.67
Capital intensity [Log (capital/labor)]	30,377	4.84	1.37	23,670	4.60	1.27	6,707	5.69	1.39
Panel 4: Colombia (1981-91)									
Log(average wage rate)	67,982	6.12	0.87	58,878	6.04	0.84	9,104	6.61	0.90
Capital intensity [Log (capital/labor)]	67,982	5.64	1.50	58,878	5.53	1.48	9,104	6.37	1.44

Table 2: Log price: Baseline results

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 log price variable is defined as the log of the ratio of product revenue to quantity. The log price (standardized) variable is log price demeaned by the product specific mean and divided by the product specific standard deviation. The first column reports results from regressions that include product code fixed effects only. The second column includes product code fixed effects and a product specific polynomial of order two in log revenue. The third column includes product code fixed effects and a product specific polynomial of order three in log revenue. The fourth column includes product-size decile dummies. Standard errors are clustered at product level; * significant at 10%; ** significant at 5%, *** significant at 1%.

	(1)	(2)	(3)	(4)
Panel 1: India (1997-98)				
Dependent variable: Log price (standardized)	0.0888***	0.0711**	0.0858**	0.0930**
	[0.033]	[0.035]	[0.036]	[0.044]
Dependent variable: Log price	0.0488*	0.0336	0.0523**	0.0557**
	[0.027]	[0.028]	[0.027]	[0.023]
Number of observations	25,136	25,136	25,136	25,136
Number of plants	9,629	9,629	9,629	9,629
Number of products	986	986	986	986
Panel 2: USA (1997)				
Dependent variable: Log price (standardized)	0.083***	0.116***	0.118***	0.134***
	[0.012]	[0.012]	[0.012]	[0.015]
Dependent variable: Log price	0.032***	0.050***	0.050***	0.061***
	[0.007]	[0.008]	[0.008]	[0.010]
Number of observations	98,702	98,702	98,702	98,702
Number of plants	33,995	33,995	33,995	33,995
Number of products	2,069	2,069	2,069	2,069
Product fixed effects	Yes	Yes	Yes	No
Product specific revenue polynomial (order 2)	No	Yes	No	No
Product specific revenue polynomial (order 3)	No	No	Yes	No
Product-size decile fixed effects	No	No	No	Yes

Table 3: Log price: Robustness checks

The dependent variable is standardized log per unit price, i.e. demeaned by the product specific mean and divided by the product specific standard deviation. Except for row 2, all reported figures are coefficients on an exporter dummy which equals one for exporting establishments and is zero for non-exporters. In row 2, reported figures are coefficients on an exporter dummy which equals one for establishments exporting more than 2% of their sales and is zero for non-exporters. The first column reports results from regressions that include product code fixed effects only. The second column includes product code fixed effects and a product specific polynomial of order two in size, defined as log revenue in row 1, 3 and 4 and as log employment in row 2. The third column includes product code fixed effects and a product specific polynomial of order three in size. The fourth column includes product-size decile dummies. Standard errors clustered at product level; * significant at 10%; ** significant at 5%, *** significant at 1%.

	(1)	(2)	(3)	(4)
Panel 1: India (1997-98)				
Base case: Coefficient on exporter dummy from Panel 2 of Table 2	0.0888***	0.0711**	0.0858**	0.0930**
	[0.033]	[0.035]	[0.036]	[0.044]
Coefficient on dummy for export share >2%	0.115***	0.0807**	0.0999**	0.114**
	[0.036]	[0.039]	[0.040]	[0.048]
Coefficient on exporter dummy, broader product definition	0.159***	0.102***	0.103***	0.124***
	[0.033]	[0.036]	[0.037]	[0.041]
Coefficient on exporter dummy, main product line only	0.159***	0.101**	0.124**	0.127**
	[0.043]	[0.047]	[0.050]	[0.056]
Panel 2: USA (1997)				
Base case: Coefficient on exporter dummy from Panel 1 of Table 2	0.083***	0.116***	0.118***	0.134***
	[0.012]	[0.012]	[0.012]	[0.015]
Coefficient on dummy for export share >2%	0.080***	0.106***	0.110***	0.130***
	[0.014]	[0.014]	[0.014]	[0.017]
Coefficient on exporter dummy, broader product definition	0.083***	0.115***	0.115***	0.134***
	[0.012]	[0.012]	[0.012]	[0.015]
Coefficient on exporter dummy, main product line only	0.108***	0.120***	0.117***	0.138***
	[0.018]	[0.018]	[0.018]	[0.025]
Product fixed effects	Yes	Yes	Yes	No
Product specific size polynomial (order 2)	No	Yes	No	No
Product specific size polynomial (order 3)	No	No	Yes	No
Product-size decile fixed effects	No	No	No	Yes

Table 4: Quality proxy – ISO 9000 certification dummy (India 1997-98)

The dependent variable is a dummy variable equal to 1 if the establishment has obtained ISO 9000 quality certification. All reported figures are coefficients on an exporter dummy. In rows 1 and 2 size is defined as log revenue and in row 3 as log employment. Standard errors are clustered at industry level; * significant at 10%; ** significant at 5%, *** significant at 1%.

Dependent variable	**(1)**	**(2)**	**(3)**	**(4)**
Coefficient on exporter dummy	0.146***	0.0804***	0.0787***	0.0878***
	[0.016]	[0.013]	[0.013]	[0.014]
Coefficient on dummy for export share >2%	0.130***	0.0741***	0.0727***	0.0802***
	[0.017]	[0.014]	[0.014]	[0.015]
Number observations/plants	24,064	24,064	24,064	24,064
Industry fixed effects	Yes	Yes	Yes	No
Industry specific size polynomial (order 2)	No	Yes	No	No
Industry specific size polynomial (order 3)	No	No	Yes	No
Industry-size decile fixed effects	No	No	No	Yes

Table 5: Wage and factory intensity results

Average wage is the ratio of total wage bill to number of employees. Capital intensity defined as log of the capital to labor ratio. All reported figures are coefficients on an exporter dummy which equals one for exporting establishments and is zero for non-exporters. The industry definition is 4-digit NIC for India and 4-digit ISIC for Chile and Colombia. Standard errors are clustered at industry level; * significant at 10%; ** significant at 5%, *** significant at 1%.

	India		**USA**		**Chile**		**Colombia**	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Dependent variable								
Standardized log average wage	0.164***	0.170***	0.086***	0.086***	0.105***	0.156***	0.0282	0.0759**
	[0.029]	[0.034]	[0.010]	[0.010]	[0.035]	[0.039]	[0.039]	[0.037]
Log average wage	0.0889***	0.0923***	0.040***	0.040***	0.0486**	0.0740***	0.0175	0.0356**
	[0.016]	[0.018]	[0.005]	[0.005]	[0.019]	[0.020]	[0.015]	[0.015]
Standardized capital intensity	0.176***	0.210***	-0.253***	-0.233***	0.212***	0.253***	0.0989**	0.114**
	[0.034]	[0.036]	[0.016]	[0.016]	[0.045]	[0.052]	[0.042]	[0.049]
Capital intensity	0.269***	0.319***	-0.221***	-0.205***	0.268***	0.309***	0.112**	0.126**
	[0.049]	[0.053]	[0.015]	[0.015]	[0.056]	[0.064]	[0.048]	[0.055]
Number of observations/plants	21,143	21,143	389,113	389,113	30,377	30,377	67,982	67,982
Industry-year fixed effects	Yes	No	Yes	No	Yes	No	Yes	No
Industry-year specific revenue polynomial (order 3)	Yes	No	Yes	No	Yes	No	Yes	No
Industry-year-size decile fixed effects	No	Yes	No	Yes	No	Yes	No	Yes

Table 6: Robustness to using log employment as proxy for underlying factor

All reported figures are coefficients on an exporter dummy which equals one for exporting establishments and is zero for non-exporters. The first column reports results from regressions that include product code fixed effects only. The second column includes product code fixed effects and a product specific polynomial of order two in size, defined as log revenue in row 1, 3 and 4 and as log employment in row 2 . The third column includes product code fixed effects and a product specific polynomial of order three in size. The fourth column includes product-size decile dummies. Standard errors are clustered at product level; * significant at 10%; ** significant at 5%, *** significant at 1%.

	(1)	(2)	(3)	(4)
Log price (standardized)				
India	0.0890***	0.0767**	0.0860**	0.128***
	[0.032]	[0.033]	[0.034]	[0.037]
USA	0.083***	0.117***	0.119***	0.118***
	[0.012]	[0.013]	[0.013]	[0.016]
ISO 9000 certification dummy	0.146***	0.102***	0.101***	0.109***
	[0.016]	[0.014]	[0.014]	[0.016]
Product fixed effects	Yes	Yes	Yes	No
Product specific size polynomial (order 2)	No	Yes	No	No
Product specific size polynomial (order 3)	No	No	Yes	No
Product-size decile fixed effects	No	No	No	Yes

Table 7: Robustness to conditioning on firm sales: USA (1997)

All reported figures are coefficients on an exporter dummy which equals one for exporting establishments and is zero for non-exporters. The first column includes product code fixed effects and a product specific polynomial of order 3 in firm size. The fourth column includes product-firm size decile dummies. Standard errors are clustered at product level; * significant at 10%; ** significant at 5%, *** significant at 1%.

	(1)	**(2)**
Log price (standardized)	0.119***	0.133***
	[0.013]	[0.016]
Log average wage (standardized)	0.117***	0.130***
	[0.009]	[0.010]
Capital intensity (standardized)	-0.224***	-0.183***
	[0.016]	[0.015]
Product fixed effects	Yes	No
Product specific size polynomial (order 3)	Yes	No
Product-size decile fixed effects	No	Yes

Table 8: Robustness to using four-year means of variables

All reported figures are coefficients on an exporter dummy which equals one for exporting establishments and is zero for non-exporters. The first and third columns include product code fixed effects and a product specific polynomial of order two in establishment size. The second and fourth columns include product- size decile dummies. All variables are the 4 year mean values by establishment. Establishments that switched exporter status during the 4 year period are excluded. Standard errors are clustered at product level; * significant at 10%; ** significant at 5%, *** significant at 1%.

	Chile (1993-1996 mean)		**Colombia (1988-1991 mean)**	
	(1)	**(2)**	**(3)**	**(4)**
Dependent variable: Standardized average wage	0.0653	0.0996*	0.0193	0.0975
	[0.048]	[0.054]	[0.087]	[0.096]
Dependent variable: Standardized capital intensity	0.266***	0.301***	0.213***	0.237***
	[0.056]	[0.074]	[0.058]	[0.056]
Industry-year fixed effects	Yes	Yes	Yes	No
Industry-year specific revenue polynomial (order 2)	No	Yes	No	No
Industry-year specific revenue polynomial (order 3)	No	No	Yes	No
Industry-year-size decile fixed effects	No	No	No	Yes

Table 9: Log price: Product differentiation interaction results

The dependent variable is log per unit price (standardized). The log price (standardized) variable is log price demeaned by the product specific mean and divided by the product specific standard deviation. In columns 1 and 2, the product differentiation index is a dummy variable that equals one if the product code matches (as per our concordance) to an SITC code that is classified as differentiated as per the Rauch (1999) classification. In columns 3 and 4, the product differentiation index is the share of SITC codes within each SIC code that are "differentiated" as the pre the Rauch (1999) classification. Columns (1) and (3) include product code fixed effects and a product specific polynomial of order three in log revenue. Columns (2) and (4) include product-size decile dummies. Standard errors are clustered at product level; * significant at 10%; ** significant at 5%, *** significant at 1%.

	India (1997-98)		**USA (1997)**	
	(1)	**(2)**	**(3)**	**(4)**
Export dummy	0.0292	0.0417	0.092***	0.092***
	[0.041]	[0.049]	[0.016]	[0.019]
Export dummy * product differentiation index	0.211***	0.201**	0.049*	0.076**
	[20.6]	[21.7]	[0.027]	[0.032]
Product fixed effects	Yes	No	Yes	No
Product specific revenue polynomial (order 3)	Yes	No	Yes	No
Product-size decile fixed effects	No	Yes	No	Yes

Table 10: Log price: Destination characteristics interaction results

The dependent variable is log per unit price (standardized). All reported figures are coefficients on an exporter dummy which equals one for exporting establishments and is zero for non-exporters. The log price (standardized) variable is log price demeaned by the product specific mean and divided by the product specific standard deviation. Columns (1) and (3) include product code fixed effects and a product specific polynomial of order three in log revenue. Columns (2) and (4) include product-size decile dummies. "Destination GDP per capita" is the export value weighted average GDP per capita of the destinations to which the product is exported, scaled to US $ million per person. "Destination distance" is the export value weighted average distance to the destinations to which the product is exported, scaled to million kilometers. Standard errors are clustered at product level; * significant at 10%; ** significant at 5%, *** significant at 1%.

	India (1997-98)		USA (1997)	
	(1)	(2)	(3)	(4)
Export dummy	-0.221*	-0.149	0.050	0.039
	[0.12]	[0.11]	[0.046]	[0.051]
Export dummy X Destination GDP per capita	17.88***	14.55**	4.172	5.774*
	[6.27]	[6.32]	[2.949]	[3.219]
Export dummy	-0.253	-0.208	0.141***	0.092
	[0.16]	[0.15]	[0.050]	[0.056]
Export dummy X Destination distance	45.88**	43.10**	-3.581	6.429
	[20.6]	[21.7]	[8.038]	[9.075]
Product fixed effects	Yes	No	Yes	No
Product specific revenue polynomial (order 2)	No	No	No	No
Product specific revenue polynomial (order 3)	Yes	No	Yes	No
Product-size decile fixed effects	No	Yes	No	Yes